# MEASURING THE EFFECTS OF THE LIGHT RAIL TRANSIT (LRT) SYSTEM ON HOUSE PRICES IN THE KLANG VALLEY, MALAYSIA

by

MOHD FARIS DZIAUDDIN

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Mohd Faris Dziauddin

School of Geography, Politics and Sociology

Faculty of Humanities and Social Sciences

University of Newcastle, Newcastle upon Tyne

NE1 7RU, United Kingdom

# Table of Contents

## Chapter 3

## The Effects of Transportation Investments on Property Values: Rail Transit Systems



## Chapter 4

## Towards Estimating Total Economic Value of the LRT System

## Chapter 5

## The Dynamics of Housing Attributes-House Prices Relationship and Hedonic Modelling

## Chapter 6

## Measuring the Effects of the Kelana Jaya Line LRT System on House Prices: Research Methodology



## Chapter 7

## The Development of Database and GIS Analysis

## Chapter 8

## The Effects of the Light Rail Transit on House Prices in the Klang Valley: Global and Local Models

## Chapter 9

## Conclusions and Discussion

# List of Figures

# List of Tables

# List of Abbreviations

## Focus Variables

| | |
|---|---|
| STRDIST | Straight-line-distance |
| STRSTN1 | Location within 500m |
| STRSTN2 | Location within 501-1,000m |
| STRSTN3 | Location within 1,001-1,500m |
| STRSTN4 | Location within 1,501-2,000m |
| NETDIST | Network-distance |
| NETSTN1 | Location within 500m |
| NETSTN2 | Location within 501-1,000m |
| NETSTN3 | Location within 1,001-1,500m |
| NETSTN4 | Location within 1,501-2,000m |
| NETSTN5 | Location beyond 2,001m |
| TIMESAVINGS | Travel time savings to CBD |

## Structural Variables

| | |
|---|---|
| FLRAREA | Floor area |
| BED | Number of bedrooms |
| BATH | Number of bathrooms |
| TYPTRRD | Terraced house |
| TYPCLTR | Cluster House |
| TYPSEMID | Semi-detached house |
| TYPDETCH | Detached house |
| TYPFLAT | Flat |
| TYPAPT | Apartment |
| TYPCONDO | Condominium |
| PARKING | Car parking |
| GARDEN | Garden |
| SWMPOOL | Swimming pool |
| SAUNA | Sauna |
| CAFÉ | Cafeteria |
| GYM | Gymnasium |
| SPORTF | Sport facilities |
| LAUNDRY | Launderette |
| SECURE | Security |
| MSHOP | Mini shop |
| LANDSCAPE | Landscaping |

## Locational Variables

| | |
|---|---|
| CBD | Accessibility to CBD |
| MJRROAD | Proximity to major roads |
| HIGHWAY | Proximity to highways |
| PRIMARYSCH | Proximity to primary schools |
| SECONDARYSCH | Proximity to secondary schools |
| UNIVERSITY | Proximity to college/university |
| HOSPITALS | Proximity to hospitals |
| INSTITUTE | Proximity to institutional centres |
| COMMERCIAL | Proximity to commercial areas |
| WORSHIP | Proximity to religious centres |
| GREEN | Proximity to green areas |
| PARK | Proximity to parks |
| INDUSTRY | Proximity to industrial areas |
| FOREST | Proximity to forest |
| CEMETERY | Proximity to cemeteries |

## Socio-Economic and Social Variables

| | |
|---|---|
| ELDERLY | Proportion of elderly (age 55-64) |
| YOUNG | Proportion of young adults (age 26-34) |
| PROF | Proportion of professionals |
| EMPLOY | Rate of employment |
| MALAY | Proportion of Malays |
| CHI | Proportion of Chinese |
| IND | Proportion of Indians |

## Other Abbreviations

| | |
|---|---|
| AIC | Akaike Information Criterion |
| ANCOVA | Analysis of Covariance |
| ANOVA | Analysis of Variance |
| BART | Bay Area Rapid Transit |
| BWK | Belsley-Kuh-Welsch |
| CBD | Central Business District |
| CO | Carbon Monoxide |
| CURDS | Centre for Urban and Regional Development Studies |
| CV | Cross-Validation |
| DALY | Disability-Adjusted Life-Years |
| DRB | Diversified Resources Bhd |
| DVPS | Department of Valuation and Property Services |
| ERL | Express Rail Link |
| EU | European Union |

| | |
|---|---|
| FTA | Freight Transport Association |
| GDP | Gross Domestic Product |
| GIS | Geographic Information Systems |
| GWR | Geographically Weighted Regression |
| HPM | Hedonic Price Model |
| JICA | Japan International Cooperation Agency |
| JLE | Jubilee Line Extension |
| KLIA | Kuala Lumpur International Airport |
| KVPC | Klang Valley Planning Council |
| KVPS | Klang Valley Planning Secretariat |
| KVWC | Klang Valley Working Committee |
| LRT | Light Rail Transit |
| LVC | Land Value Capture |
| MARTA | Metropolitan Atlanta Rapid Transit Authority |
| MAX | Metropolitan Area Express |
| MSC | Multimedia Super Corridor |
| MTS | Metropolitan Transit System |
| MYR | Malaysia Ringgits |
| NDP | National Development Policy |
| NEP | New Economic Policy |
| NIMBY | Not-In-My-Back Yard |
| OLS | Ordinary Least Squares |
| PATCO | Port Authority Transit Corporation |
| RAPIDKL | Rangkaian Pengangkutan Integrasi Deras Sdn Bhd |
| SDTI | San Diego Trolley Incorporation |
| SPSS | Statistical Package for the Social Sciences |
| SUV | Single-occupant Utility Vehicle |
| TEV | Total Economic Value |
| TIF | Tax Increment Financing |
| UCGIA | University Consortium for Geographic Information Systems |
| UMTA | Urban Mass Transit Association |
| VIF | Varian Inflation Factors |
| VOC | Volatile Organic Compound |
| VTA | Valley Transportation Authority |
| WHO | World Health Organisation |
| WTP | Willingness To Pay |

# Abstract

This research attempts to estimate the increased value of land in the form of house prices as a result of improved accessibility owing to the construction of Light Rail Transit (LRT) systems. Kelana Jaya Line LRT system is chosen as the case study in this research. Hedonic house price modelling and Geographically Weighted Regression (GWR) are employed to measure the effects of the LRT system on house prices in the Klang Valley, Malaysia (2004 and 2005 transactions). Selling price, structural attributes, land use and socio-economic attributes were collected from the Department of Valuation and Services of Malaysia database, selected maps and reports. Fifty-five factors that are likely to influence house price were identified and used to measure the overall effects of the LRT system on house prices. However, only significant variables were included in the final deliberation and these were identified by using correlation analysis and step-wise procedures.

The outcome of this study shows a positive relationship between the existence of the LRT system and house prices. In short, people are willing to pay a higher price in order to live within close proximity to a rail transit station. The hedonic house price model suggests – for houses that are located within two-kilometre radius – prices decrease as the distance increases from the LRT station; for both straight-line-distance and network-distance. However, since hedonic house price models are global, the results produced by the model are applied equally for the entire area, and therefore may hide important local differences in the determinants of house prices. Spatial processes are instead seen to be heterogeneous in which the measurement of a relationship depends in part on where the measurement is taken. The generalisation of the effects of the LRT system on house prices is found to be consistent when it is examined further by employing a GWR model, which reveals that house prices decrease only for majority of houses located in the Petaling Jaya area and high-rise units located in Bangsar and Kerinchi. Yet, the majority of houses located in Wangsa Maju-Maluri area are found to be not affected by the existence of the LRT system. The GWR results indicate a statistical significant improvement over the global model for both straight-line-distance and network-distance models even after taking into account the extra degrees of freedom. The highest significant positive price premiums are found in houses that are located

within 1,001-1,500 metres of straight-line-distance and 501-1,000 metres of network-distance.

The findings summarised in the thesis have important implications for policy implementation. Firstly, the research findings provide justification for potential implementation of a Land Value Capture (LVC) policy; a policy that can be implemented in order to provide a funding mechanism for the new transport infrastructure. This is due to the fact that the construction of rail transit systems should not be viewed as a subsidised service for the poor but as an investment that returns a profit through increased land values. Strategies in a LVC policy that may be implemented include property and sales taxes, real-estate lease and sales revenues, fare-box revenues, fees on everything from parking to business licenses, join development, tax increment financing, special assessment districts, equity participation and public-private partnership. This approach has become a common practice in some more developed countries such as in the United Kingdom (UK) and United States (US). Finally, having a method to measure the land value premium due to the improvement in transportation service can facilitate alternative options or scenarios to be assessed. For example, different transport schemes for the same route may give rise to different land value capture potential, which may, in turn, help determine which transport scheme to pursue.

This study therefore contributes to the growing literature on the positive relationship between the existence of the LRT system and house price by providing more accurate, robust and reliable empirical evidence as shown in the approach and the outcome of this research. In particular, it has produced meaningful results by addressing the nature of spatial process; *spatial heterogeneity.*

# CHAPTER 1

## Introduction

### 1.1 Preliminary

This chapter outlines the basis of the thesis starting with the research background leading to the statement of the research issue. This is followed by a discussion of the aims and objectives of the research. This chapter ends with the thesis structure.

### 1.2 Research Background

It has been established that public transportation is an extremely important means of travel, particularly in larger and denser metropolitan areas. In most cities in Europe, North America and Japan public transportation systems play a significant role in allowing their residents to travel from work and other activities such as shopping, visiting relatives and friends, accessing schools and colleges, healthcare, entertainment and recreation. Ensuring high levels of accessibility to all of these activities and amenities is indispensable for health, quality of life and social inclusion. One of the important achievements over the past 100 years has been the construction of rail transit systems which is considered to be a vital part of public transportation. The construction of rail transit systems began in the United Kingdom (UK) as early as the nineteenth century and in North America (the United States and Canada) in the mid-twentieth century. Since the early 1990s, several cities in developing countries have begun constructing their own rail transit systems.

Rail transit systems, namely heavy and light transit systems are 'public good'[1] and has been seen as serving a number of purposes and producing a number of public benefits. These public benefits can be categorised into two; direct and indirect benefits. The direct benefits of rail transit systems are defined in terms of accessibility improvement impacts (Banister and Berechman, 2000). This is due to the fact that the original function of rail transit system investment is simply to improve the accessibility of city centres for those living in residential areas. For example, Baum-Snow and Kahn (2005) found the existence of rail transit systems in various cities such as Atlanta, Boston, Chicago, San Francisco and Washington to have reduced average commute travel times to the city centres. This is evidently true for those residents who live in surrounding areas of rail transit stations. For instance, 50,000 commuting hours saved per-work-day has been estimated for Washington, and a similar reduction is also found for Atlanta and Chicago. These benefits are due in part to the separation of rail transit systems from motor vehicle congestion. However, rail transit systems have other indirect benefits which address more modern concerns such as congestion relief, reduction in per capita road-traffic accidents, energy savings, environmental advantages, improved personal mobility for disadvantaged groups and transit-oriented development (Banister and Banister, 1995; Knowles, 1996; Pucher, 2004; Litman 2003, 2004a, 2004b, 2007). Rail transit systems can also produce negative externalities such as traffic congestion, noise pollution effects, safety and visual clutter effects for residents who reside too close to a railway station and line, hence, may negatively affect property values (see, for example, Al-Mosaind et al., 1993).

[1] A 'public good' in economic terms is a good that is non-excludable and non-rival in consumption (Willis et al., 2005).

However, the potential negative locational externalities for properties located too close to rail transit line or along the route are not within the scope of this study. The justification for this omission will be given in Chapter six.

The twentieth century witnessed a dramatic increase in private vehicle ownership such as cars and trucks. Due to this dramatic increase, most countries have struggled with traffic and parking congestion problems especially in city centres. Traffic congestion leads to negative effects such as increased travel time for motorists and their passengers, increased levels of pollution (noise and air) and increased tardiness, stress, frustration and to potentially cause road-traffic accidents. In addition, increasing time spent in congested traffic results in exposure to air pollution. However, traffic congestion could be reduced through the improvement of public transportation such as by constructing rail transit systems. This is because rail transit systems can provide the quickest means of transport in the most congested travel corridors, convenient and be able to carry up large number of passengers.

For instance, a heavy rail transit can generally carry up to 36,000 passengers per hour in one direction. In London, between 2005 and 2006, underground systems carried 971 million passengers, an average of 2.65 million per day (London Underground Report, 2006). Most rail transit systems have reduced car-driving and benefiting not only transit passengers but also car occupants on the less congested roadways. Litman (2004a) suggests that reducing vehicles on the roads by only a few percentage points can significantly reduce congestion levels, mainly for daily commuting and freight movement. Arguably, this positive effect can only be achieved if rail transit systems can draw people out of their cars. Baum-Snow and Kahn (2005) and Stopher (2004) advocated that there is little evidence to support the reduction in traffic congestion levels after the construction of rail transit systems in many major US cities. Contrary to this, Litman (2006) argued that there is ample evidence to support the reduction in traffic congestion levels, in particular for those cities that are served by high quality of rail transit systems. Garrett and Castelazo (2004) arrived at a similar conclusion where they concluded that traffic congestion levels declined in several US cities after the light rail transit system was constructed. Similarly, Litman (2004a) carried out a study focusing on the evaluation of rail transit systems benefits in the US and finding that per capita traffic congestion delay is significantly lower in cities with high quality of rail transit systems compared to the cities with little or those that are not served by the systems. As Litman summarised the cities with high quality of rail transit systems have 400 per cent per capita transit ridership (589 versus 118 annual passenger-miles), 21 per cent lower per capita motor vehicle mileage (1,958 fewer annual miles), 887 per cent higher transit commute mode split (13.4 per cent versus 2.7 per cent), 36 per cent lower per capita traffic fatalities (7.5 versus 11.7 annual deaths per 100,000 populations), 14 per cent lower per capita consumer transportation expenditures ($448 average annual savings), 19 per cent smaller portion of household budgets devoted to transportation (12.0 per cent versus 14.9 per cent), 33 per cent lower transit operating costs per passenger-mile (42¢ versus 63¢) and 58 per cent higher transit service cost recovery (38 per cent versus 24 per cent). In addition, a study conducted by Winston and Langer (2006) indicates that traffic congestion costs decline in a city as rail transit mileage expands. In the UK, Knowles (1996) found the existence of light rail transit in Manchester has indeed reduced traffic congestion to and from CBD. As reported by Knowles, between September 1993 and August 1994 the number of passengers who travelled by rail transit was about 12.1 million, and most of these passengers were former car users. The reduction in traffic congestion can result in reducing the rate of road-traffic accidents as fewer car trips made.

In many countries road-traffic accidents continue to be the largest cause of deaths, people disabilities and vehicle damages, imposing many billions of pounds in economic losses annually (Litman, 2004b). In developing countries for instance, road-traffic accidents have cost 1-2 per cent of their gross domestic product (GDP) each year (Woodcock et al., 2007). Moreover, most of the road-traffic accidents victims are often young adults whose families rely on their earnings. The World Health Organisation (WHO) World Report on Road Traffic Injury Prevention as cited by Woodcock et al. (2007) estimated that 1.2 million people were killed and fifty million people were injured in road-traffic accidents in 2002. These figures continue to rise with the increasing number of vehicles on the roads. In the European Union (EU) for instance, 34 per cent of children deaths are caused by road-traffic accidents. WHO reported that road-traffic accidents was listed as the ninth overall cause of death in 1990 and most likely become the sixth by 2020 in developing countries (WHO, 2002a). The phenomenon of road-traffic accidents could be reduced by constructing rail transit systems as the systems are much safer than cars. Litman (2004a) advocated that rail transit systems have significantly lowered per capita traffic death rates. For instance, an average number of fatalities caused by rail transit systems are 7.5 per 100,000 populations. In addition, areas served by good quality of rail transit systems are found to have much lower per capita traffic fatality rates among young adults and the elderly residents. This is the outcome from delaying young adult vehicle ownership and reducing vehicle use by the elderly residents (Litman, 2004b).

Another issue that needs to be addressed is energy use. According to Banister and Banister (1995) there are two reasons as to why this issue is important and therefore need to be focused on. Firstly, energy use is primarily a non-renewable resource and, secondly its contribution to environmental pollution that negatively leads to global warming. For instance, in 1996 transport was responsible for over 25 per cent of world primary energy use (Banister and Berechman, 2000) and road transport such as private vehicles contributes significantly to the emission of carbon monoxide, hydrocarbons, nitrogen oxides and carbon dioxide (Banister and Banister, 1995) (see Table 1.1). Air pollution from road transport is also responsible for major health hazards. The Global Burden of Disease Study cited by Woodcock et al. (2007) estimated that lead exposure mainly from road transport was responsible for 12.9 million disability-adjusted life-years (DALYs) through diseases such as ischemic heart disease, diabetes, colon cancer, stroke and breast cancer. Moreover, a study conducted in France, Austria and Switzerland revealed that emissions from road transport alone have caused 21,000 premature deaths each year (Poudenx, 2008). On the contrary, studies conducted by the London Underground (2006), Transportation Research Board (2002) and US Environmental Protection Agency (2001) clearly show that rail transit systems tend to be less polluting on a per-passenger-kilometre basis. For example, light rail transit produces much lower levels of carbon monoxide (CO) and volatile organic compounds (VOCs) than cars. Banister (2007) arrived at a similar conclusion where he noted that rail transit systems tend to be environmentally less damaging than other modes of transport since they are powered mainly by electricity.

**Table 1.1**: Emission of pollutants from road vehicles 1978-1988

| Pollutants | From road vehicles % increase 1981-1990 | Road proportion of all emission sources | Effects |
|---|---|---|---|
| Carbon monoxide | +42 | 90% | Morbidity, Fertility |
| Black smoke | +85 | 46% | Toxic trace substance |
| Volatile organic compounds | +13 | 41% | |
| Nitrogen oxides | +71 | 51% | Acid rain |
| Carbon dioxide | +44 | 19% | Global warming |
| Lead | -67 | | Mental development |

*Source*: Adapted from Banister and Banister (1995)

As a public transportation system for the masses, rail transit systems play an important role in ensuring basic mobility needs and providing a highly dependable, comfortable travel mode with cost savings for tourists and many with limited finances such as the poor, the disabled, minorities, teenagers and the elderly. As highlighted by Baum-Snow and Kahn (2005) and Pucher (2004) tourists, teenagers, the elderly and minorities represent a large number of transit trips in many major cities in the US and Europe. Giuliano (2001) arrived at a similar conclusion where he noted that teenagers and the elderly are more likely to use rail transit than adults under the age of sixty-five. In the case of transit trips by economically disadvantaged minorities can be seen in the US rail transit systems. This can be clearly shown if we are to compare the proportion of the American ethnic groups against the observed percentage among these groups in using the rail transit systems. Although white Americans represent the highest percentage of 74 per cent of the total population, it is found that they only contribute 0.9 per cent of all trips made. Contrary to this, 5.3 per cent of all trips are contributed by African-Americans when they only make up 11 per cent of the total population. Similarly, 2.4 per cent of all trips recorded among Hispanic-Americans who contribute towards 8 per cent of the total population (Pucher, 2004)[2]. Another study by Pisarski (1996) confirmed that African-Americans and Hispanics are more likely to use rail transit than other ethnic groups.

[2] The percentage of trips numbers given are not included the trips for non-motorised such as walk and bicycle and private vehicle usage.

Furthermore, the construction of rail transit systems has potentially played a significant role in stimulating transit-oriented development (TODs). In more developed countries such as the UK and US, their rail transit systems have created compact, mixed-use and walkable urban villages around stations (Litman, 2007; Renne, 2005). As a result, residents around these areas tend to own fewer cars and drive less than if they were to live in more automobile-independent neighbourhoods. A study conducted by Renne (2005) in several US cities shows that the levels of vehicle ownership within transit-oriented locations were notably lower. He found that in 2000, 55.3 per cent households across the regions owned two or more cars compared to only 37.3 per cent within transit-oriented locations. Moreover, a study carried out by Podobnik (2002) in western Portland, Oregon indicates that households significantly reduce travel with their own car when they move to transit-oriented locations. By maximising the use of the public transport, the community has great opportunity to know one another while going through regular shopping routines within the local area.

Yet, it is important to note that the above mentioned benefits/values associated with the construction of rail transit systems such as congestion relief, reduced per capita road accidents, energy savings, environmental advantages, improved personal mobility for disadvantaged groups and transit-oriented development are well known. These benefits can conveniently be found through cost-benefit analysis – usually carried out by developers before any project can be implemented. Alongside the benefits of rail transit systems discussed above, other indirect benefits that are yielded from construction of rail transit systems have also been studied.

Over the past forty years, we have witnessed a number of studies in the North America and the UK on the indirect benefits of rail transit systems. Some studies focus on the effects of rail transit systems on land use and development (see for example, Webber, 1976; Dvett et al., 1979; Cervero and Landis, 1997) whilst others emphasise on land values (see Table A1.1 of Appendix A). Emphasis on land values has taken into account the research on locational externalities that are generated by the rail transit systems, which in turn affect the residential and commercial land. In the case of the effects of rail transit systems on residential and commercial land, it is expected that the existence of a rail transit system should be able to capitalise land values in the form of property values (residential and commercial property). Banister and Berechman (2000) argues that the improvements in accessibility for those areas that has been served by the rail transit systems can potentially trigger several major positive locational externalities, in particular for properties located within close proximity to railway stations. They argued further that these positive locational externalities should be viewed as additional benefits to the primary accessibility improvement benefits.

This positive effect, however, is not expected to be automatic. Instead this can be achieved through a well planned and managed rail transit system that could bring benefit to the local land use. The desired effect will not be realised if the system is deployed in the wrong areas or delivered in an unsatisfactory way. Therefore, this research intends to unearth the answer to this hypothesis. The framework to execute this is clearly illustrated in Figure 1.1 above, taking into account the subject being assessed, the outcome of the research and various inputs and methodologies employed in reaching the final conclusion.

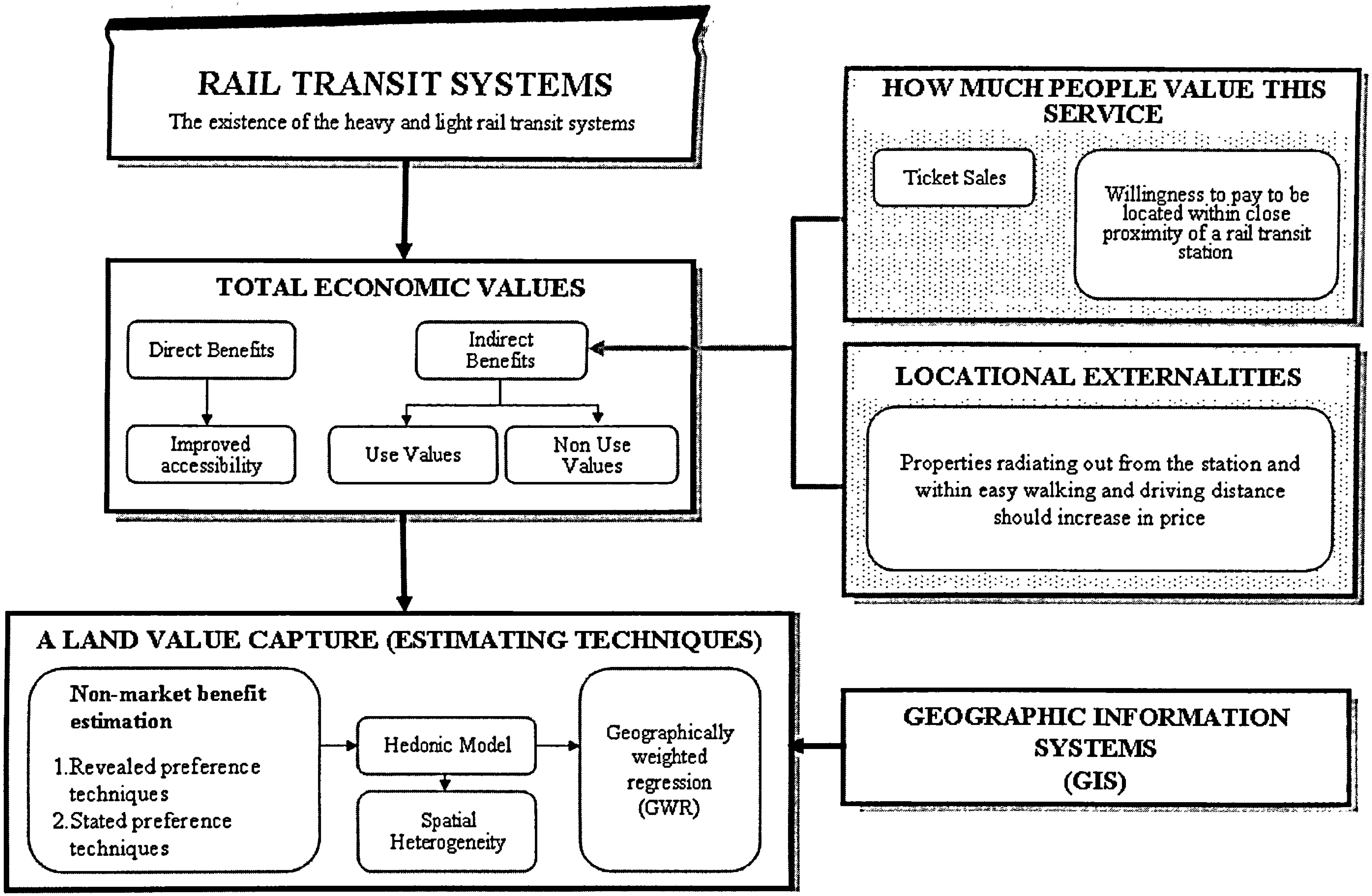



**Figure 1.1:** Structure of the main components of the light rail transit-house prices valuing framework

One question that needs to be asked however is, how are property values affected by rail transit systems? Transit systems can be reached by accessing their transit stations. Therefore, the ability to access transit stations conveniently and quickly should be capitalised in property values. In other words, higher property values are expected in places with superior access to stations. Yet, in the case of residential property it has been assumed that house prices have the potential to decrease for properties that are located too close to a rail station due to traffic congestion and noise pollution effects, whilst properties radiating out from the station and within easy walking and driving distance should increase in price (Hess and Almeida, 2007). While there is ample market evidence such as ticket sales to support on how much people value this service, this represents only their direct use value for the service. Any locational externalities (positive and negative) will be reflected in house prices and be additional to any payment for transit. Overall this is expected to represent a premium for proximity to railway stations.

As locational externalities are not directly traded they represent non-market benefits/costs, the measurement of which can be conducting using a variety of techniques. The literature has shown that there are two broad categories of non-market techniques: revealed preference techniques on the one hand and stated preference techniques on the other. In this study, revealed preference techniques namely hedonic price models will be used to measure the effects of light rail transit (LRT) on house prices in the Klang Valley, Malaysia. The justification of using these techniques will be given in Chapter 4. The estimated non-market values can be included within Land Value Capture (LVC) – a framework collating results and observations supporting how land value is affected from improving the accessibility provided by transport facilities. The results from LVC may be implemented by the local government as a policy that consist various taxes or betterment approaches such as property and sales taxes, real-estate lease and sales revenues, fare-box revenues, fees on everything from parking to business licenses, join development, tax increment financing, special assessment districts, equity participation and public-private partnership. This provides a foundation to potentially create a funding mechanism for the new transport infrastructure. This is due to the fact that the construction of rail transit systems should not be viewed as a subsidised service for the poor but as an investment that returns a profit through increased land values. Since the results of this study will be benefited the service provider which is the government, the benefits of positive locational externalities that are generated by the rail transit systems have to be quantified in monetary terms.

Hedonic price modelling is a well-established technique used for analysing a market for a single commodity with many attributes, in particular that of housing. In other words, hedonic price modelling is based on the idea that properties are not homogeneous and can differ in respect to a variety of attributes. These various attributes will determine the value of the house. For instance, a unit of housing located within walking distance from a rail transit station perhaps is more valuable than a unit of housing located further away because the more accessible a location, the higher its value, therefore the former would be more expensive than the latter. In this case, if residents value living within walking distance of a rail transit station, then price differentials should develop among the neighbourhoods due to differences in distance from a rail transit station. These price differentials are signals about the value that residents place on living in a neighbourhood where rail transit systems exist. Hedonic price models will capture the value of the rail transit systems only if the benefit from the systems accounts for those houses that are located within walking distance from a rail transit station.

Producing a hedonic price model, however, is best suited to non-spatial commodities such as washing machines or cars. For instance, the price of the car is commonly determined by non-spatial attributes such as model, engine, transmission, chassis, dimensions, exterior, interior, safety and security. The contribution of these attributes upon car prices can easily be measured since there is no spatial elements are involves. In the case of spatial commodities such as houses, the price of the house is contributed not only by structural attributes of the house but also by spatial elements such as locational and socio-economic attributes within which houses are located. Thus, it has been argued in the literature producing a hedonic price model is unlikely to sufficiently capture the spatial context and variation within which houses are located. Therefore a technique known as geographically weighted regression (GWR) will also be applied in this study which takes account of this spatial variation. By employing GWR, it allows local rather than global parameters to be estimated, and thus provides a way of accommodating the local geography of house prices-housing attributes relationships. GWR is used here in order to explore the spatial variations that may be present in the relationship between housing attributes variables and its regressors. Moreover, it is used to verify the heterogeneity of the relations, which in turn can indicate the degree of misspecification in the global model. In other words, GWR can be interpreted as localised versions of traditional global techniques. The results of the hedonic price modelling will be compared to the results of GWR. This is important in achieving conclusive judgements on the effect of the LRT system on house prices. In order to measure the distance to an LRT station and other amenities from a given house, geographic information systems (GIS), and in particular, network analysis will be employed in this study. For example, network analysis will create a series of polygons representing the distance that can be reached (on foot or by car) from the LRT station and other places within a specified amount of time. This type of measurement is able to capture much more accurately the time that people take to travel from one place to another, rather than using straight-line-distance that has been used in previous research. In other words, network analysis can improve the conventional way of measuring distance from merely the straight-line to using the road network. It has been suggested that a road network model has the potential to offer a means of calculating minimum travel time through a transportation network (Des Rosiers et al. 2001). In general, GIS will be used in this study to prepare the data for hedonic price models, particularly in the process of constructing locational externalities.

## 1.3 Research Issues

This section provides a brief introduction to the rail transit literature and illustrates its contested nature where empirical evidence is inconsistent in terms of the effects of rail transit systems on property values. This is important since the outcome of various researches on the subject matter that have been conducted since 1970s can act as a framework in developing a conceptual model of the relationship between the existence of light rail transit and house prices.

The heavy rail transit systems were first constructed in the UK circa 1860s in London and then in Glasgow in 1890s. It was not until the 1960s and 1970s that heavy rail transit systems (the first generation of rail system) were built in the US including San Francisco, California; Atlanta, Georgia; Washington D.C. and Toronto in Canada (Ryan, 1999). Since this construction, much attention has been given to the study of its effect on property values. In the late 1970s and 1980s, approximately twelve cities in the US, including San Diego, California; Portland, Oregon; and Buffalo, New York, initiated constructions of light rail transit systems (the second generation of rail system). The construction of both heavy and light rail transit systems did not stopped there, but continued in the 1990s in more than twenty US cities (Ryan, 1999). In developing countries several cities began constructing heavy and light rail transit systems in the 1980s and 1990s. Malaysia for example, only implemented its heavy and light rail transit systems in the 1990s in the Klang Valley. Yet, no empirical research of property values effects has been conducted following the implementation of these rail transit systems.

The evidence from empirical research both in the UK and North America suggest inconsistent results and varying magnitude on the effects of heavy and light rail transit systems on property values. This is due to the unique research methods, unique local transport systems and land use environments (Hess and Almeida, 2007). Over the past forty years, a considerable body of research has emerged on the question of the effects of transportation investment on property values. Throughout the 1960s, considerable attention was focused on the comparatively broad issue of how transportation investment influences urban form and consequently, urban property values. A driving force of this research was the notion that urban property values are influenced by accessibility, defined commonly as the straight line distance of any given land from the central business district (later referred to as CBD). In other words, any significant improvement in the transportation system that increases accessibility and reduces transportation costs should be capitalised in property values. In order to measure this relationship, the most common approach used is to examine how the distance from the transportation facility will affect property values. Unfortunately, this approach produces mixed results (see Table A1.1 of Appendix A).

Twenty-four of the thirty-five studies considering heavy and light rail transit systems suggest a positive relationship between property values and rail transit systems access. Early research highlights this relationship – for example Boyce et al., 1972; Lerman et al., 1978; Bajic, 1983; Dvett et al., 1979; Damm et al., 1980; Voith, 1991; Nelson, 1992; Al-Mosaind et al., 1993; Gatzlaff and Smith, 1993; Benjamin and Sirmans, 1994), and in more recent studies by Chen et al. (1997), Workman and Broad (1997), Dueker and Bianco (1999), Knapp et al. (1999), Chesterton (2000), FTA (2000), Weinberger (2000), Cervero and Duncan (2001, 2002), Du and Mulley (2006) and Hess and Almeida (2007).

However, some of the studies were dismissive of the effect. Eleven of the thirty-five both heavy and light rail transit systems studies suggest that there is no relationship between property values and rail transit systems access (see for example, Dewess, 1976; Nelson and McClesky, 1990; VNI Rainbow Appraisal Service, Inc., 1992; Cervero and Landis, 1993; Armstrong, 1994; Landis et al., 1995; Landis and Loutzenheiser, 1995; Forrest et al., 1996; Ryan, 1997; Henneberry, 1998). For example, in Atlanta, studies discovered that rail transit systems had virtually no effect on property values and a study of Miami's Metrorail system came to the same conclusion (Gatzlaff and Smith, 1993). Over the past decade, Portland's Metropolitan Area Express (MAX) rail transit system has also received attention. In two studies that were conducted, only very modest and localised effects on land values were identified (Al-Mosaind et al., 1993).

Preliminary results of a study on Toronto rail transit carried out by Dewess (1976) have shown virtually no effect on property values. However, a study on the same rail transit system carried out by Bajic (1984) revealed that the city's rail corridors have experienced intense development and that residential property values are significantly higher near a rail line than elsewhere. Moreover, in the study of Pennsylvania's commuter rail system, Voith (1991) concluded that houses served by a commuter rail system had a 4 per cent to 10 per cent premium over those who were not served by a commuter rail system. Nonetheless, he found that travel time to the CBD was significant in estimating property values. In the UK, measuring of the effect of rail transit systems on property values commenced in the 1990s. For instance, a study conducted by Centre for Urban and Regional Development Studies (CURDS) (1990) on the effect of Tyne and Wear Metro on house prices concluded that there was no effect. However, a recent study conducted by Du and Mulley (2006) on the same basis found that housing units in some of the areas that are located within close proximity to railway stations increased in value. An important question to ask is why the results are so inconsistent.

Several explanations are available for these inconsistencies resulting from the effects of heavy and light rail transit systems on property values (see for example Knight and Trygg, 1977; Landis et al., 1995; Ryan, 1999; Giuliano, 2004). An early explanation was given by Knight and Trygg (1977). They concluded that the determinants of property value in an urban area relate to land value controls and economic growth rather than transportation investment. Ryan (1999) noted that many supported the conclusions developed by Knight and Trygg. However, the inability to replicate the variables introduced by Knight and Trygg led to weak evidence in supporting earlier ideas of Knight and Trygg.

Alternatively, Landis et al. (1995) suggested different arguments to support research discrepancies, for example, new transportation facilities that could influence property values. However, the effect of new technology on accessibility levels will gradually decline over time. Even though new transportation technology is introduced, which benefits adjacent properties, they remain under-priced. Hence, the relationship between property value and transportation is still uncertain, but travel cost is still a strong factor to be observed (Ryan, 1999).

Yet another explanation as to why empirical evidence (particularly from the 1980s and 1990s) differs from theoretical expectations is provided by Ryan (1999). Ryan argued empirical evidence is different compared to theoretical expectations. She advocated that the distance of a property to the transportation as a variable has proved to be more accurate compared to other variables. Value of the properties where they are located will be bid up if there is apparent time saving. A relationship between access and property values is to be expected when the measure of access captures the essence of travel time savings. Inaccuracy in measuring changes in travel time leads to inaccurate changes in property value. Thus, studies should aim to answer whether transportation really improves travel time for a specific segment of travellers. Ryan argues that all of the benefits are internalised through the transport time dimension and that there is no reason to investigate further into the effect on property value.

The explanation given by Ryan seems to be realistic because as has been noted earlier, the main objective of introducing rail transit systems was simply to improve accessibility to the CBD. Hence for many households, the only way to improve accessibility to the CBD is by being located closer to the rail transit service; households need to purchase a house in the associated area if they wish to enjoy the advantage of the rail transit service. Capitalising the price of houses could be expected if the rail transit service has truly improved accessibility to the CBD. This is due to the argument that for those households who really appreciate the improvement of accessibility to the CBD will bid-up for such service.

Giuliano (2004) offers an explanation for the inconsistency and varying evidence of the effects of rail transit systems on property values. He believes that the first few studies of the effects of heavy rail transit systems on property values were too premature since it would take decades before the land market could respond to the availability of heavy rail transit systems in the area.

Another explanation notes the lack of clear evidence on the influence of transport on land use and development in general. For example, Atkinson (1988 cited in GVA Grimley, 2004) stated 'It is difficult to measure the degree of development and economic benefit that is generated by transit, as some of it may have taken place anyway, and it is even more difficult to measure the wider economic benefits' (pp. 83). In addition, Brinckerhoff (2001) notes that the magnitude of the positive effect of rail transit systems on property value is likely to vary according to; (1) how much accessibility is improved, (2) the relative attractiveness of the locations near station areas, and (3) the real estate markets in the region.

In addition, researchers have also quantified property value premiums added for different modes of rail transit systems. These modes are heavy rail transit, light rail transit and commuter rail. The literature has shown those properties that have been served by heavy rail transit produce greater effects than property served by light rail transit – owing to faster speeds, frequent trains and greater geographical coverage of heavy rail transit (Hess and Almeida, 2007). In the case of commuter rail, results from previous studies have shown that property located near to commuter rail stations have higher premiums than heavy and light rail transit.

On the basis of the aforementioned arguments, a partly empirical body of theories and explanations, the main purpose of this study as noted earlier was subsequently formulated. As far as the specific context of the Klang Valley is concerned, the researcher will give greater attention to the study design issue that needs to be considered when attempting to measure how transportation facilities affect property values.

It is important to note that there are basically several other significant reasons for conducting this study. As pointed by Powe et al., (1995) whilst the magnitude of the premium offered by a particular housing attribute may be estimated by experts in real estate and housing, little objective information exists which can be used to validate their estimation. In fact, Willis and Garrod (1992) demonstrated that considerable variation can exist between expert estimation of the premium added to a house by a particular attribute (in this case the added value to a property by transportation services, specifically LRT). In addition, if investors, developers or other participants wish to judge the attractiveness of individual real estate projects, an assessment of the prices in the market segment should constitute an essential element in the decision process. For example, institutional investors such as insurance companies and pension or investment funds require reliable information concerning the magnitude of the premium added to property value by rail transit systems.

Based on the above, information about the positive (such as added value) and negative profiles of rail transit systems, and their relationship with property value is of central importance. Moreover, due to the large amount of investment that is made towards construction of rail transit system, it in turn ignites a great interest among the public about the other benefits to be obtained by the construction of such transportation system. Finally, such studies will benefit the government sector in acquiring information regarding price changes on the house. Essentially, it allows a study to assess, plan and regulate the effectiveness of government intervention measures. This is made possible with complete understanding on positive and negative externalities of the government's moves in infrastructure provisioning and the affected housing areas.

## 1.4 Research Aims and Objectives

Previous discussion has highlighted the theoretical expectations of the effects of rail transit systems on property values and, inconsistent and varying evidence of the effects of heavy and light rail systems on property values. The discussion has also highlighted several other significant reasons for conducting this study. In relation to this, the study aims to critically investigate the effects of Kelana Jaya Line on house prices in the Klang Valley. The justification of selecting Kelana Jaya Line and the Klang Valley as the area of study will be given in Chapter six. This study can be used to measure and explain the effects of the LRT system on house prices, the appropriate approach that can be used to measure its effect on house prices and assist for investment in the LRT in other parts of Malaysia. It is noted that no previous research has indicated whether the existence of the LRT in the Klang Valley has increased house prices in the areas that have been served by the LRT. In line with this aim, this study has the following objectives:

1. To review the literature on the theory and effects of rail transit systems on property values, highlight techniques that can be used to estimate these effects and the role of GIS in this study.
2. To develop a hedonic house price model and GWR that can be used to measure the effects of Kelana Jaya Line on house prices in the Klang Valley.

3. To identify, collect and assess the quality of data available for a hedonic model and GWR in the case of the Klang Valley.
4. To implement the proposed model in order to examine the relationship between the availability of Kelana Jaya Line and house prices in the Klang Valley.
5. To evaluate the range and magnitude of effects of Kelana Jaya Line on house prices in the Klang Valley.
6. To identify other significant factors that influence house prices in the Klang Valley.

## 1.5 Thesis Structure

This chapter has introduced the indirect benefits (or added value) of rail transit systems on property values. It has been argued above that the existence of a rail transit system should be to capitalise land values in the form of property values (residential and commercial property), in particular for those areas that have been served by the system. However, as has also been argued above, the evidence from empirical research both in the UK and North America shows inconsistent results and varying magnitude on the effects of heavy and light rail transit systems on property values. The explanations of the inconsistent results were also provided in the above discussion and finally led to the broad aims and objectives of the study. In order to achieve the aims and objectives that have been set out in this chapter, the discussion shall be advanced in Chapter two. The discussion in Chapter two will be focused on basic urban economic theory, particularly on how changes in the behaviour of individual consumers and firms that have produced land uses and land values patterns in an urban area specifically with respect to the concept of trade-off and bid-rent function. These two concepts are important in order to understand the relationship between the existence of rail transit systems and land values. The discussion continues in Chapter three. The main aim of Chapter three is to extensively review the literature with respect to the effects of transportation investments on property values. The empirical evidence from the previous studies forms a base that in turn can be used in measuring the effect of the LRT system on house prices – which clearly the notion of this research. Chapter four continues this discussion where focus will be given to the technique that has been widely employed in this field: the hedonic price model. The discussion in this chapter also introduces the specification of the hedonic price model. However, since hedonic price models are global – they do not take into account the nature of spatial process – several new local techniques will also be introduced in this chapter to deal with the effects of spatial data consisting of spatial heterogeneity. Chapter five of the thesis identifies the structural and locational attributes that have been considered in the previous studies to be the determinants of house prices. The chapter also focuses on the role of GIS in hedonic house price studies. The discussion is continued in Chapter six, which describes the research methodology of measuring the effect of the LRT system on house prices in the Klang Valley, Malaysia. Chapter seven of the thesis discusses the process of developing the database and preparing the data for principal analysis. The results of the analysis are presented in Chapter eight. The results from hedonic house price models (a global model) are compared to the results from GWR models (a local model). By comparing these two techniques, one would realise which technique can best ascertain how well the determinants of house prices are being modelled, specifically with respect to the presence of spatial heterogeneity over space. The final chapter of the thesis concludes and discusses the findings of the study together with the suggestion for future work.

# CHAPTER 2

## Basic Urban Economic Theory

### 2.1 Introduction

During the last forty years a vast body of literature has emerged in the area of urban land economics. It can be broadly classified into: (1) analyses of urban land use (that is residential, commercial and industrial) and land values, and (2) studies of the growth, composition and spatial form of urbanised areas. This chapter concentrates on the heart of urban economic activities; urban land use and land value. In relation to this point, the theories of urban land use and land value will be discussed. The organisation of the chapter is as follows: Section I describes the urban land uses and land values. It also provides an empirical context and a number of stylised facts that the land use and land value literature has sought to explain. Section II provides a brief overview of the pattern of urban land use and land value. Section III discusses the theory of urban land use which is based on micro-economic theory. For the sake of clarity, it is necessary to explain several important aspects related to basic urban economic theory. Firstly, it is essential to provide the definition of theory since it will be used to examine LRT-land value relationship in this study. Secondly, it is also important to identify which urban economic theory needs to be included for purpose of this study. Section IV examines the theoretical justification for using micro-economic approaches in examining the effects of transportation facilities on property values.

The subsequent sections offer brief overview of the pattern of urban land uses and land values. They essentially discuss the important features of the location of the various types of economic activities in cities.

## 2.2 A Brief Overview of the Pattern of Urban Land Uses and Land Values

The pattern of urban land use and land values is complex and varies across cities (Muth, 1969; Carter, 1986). Although the patterns of urban land use and land values are dissimilar, certain normalities can be identified, and therefore related theory is essential to explain these normalities. This section attempts to illustrate some of the locations of the various types of economic activity in cities and the accompanying pattern of urban land use and land values.

The area which contains buildings and economic activity such as commercial, financial, retail, and service establishments within a city is known as the CBD (Muth, 1969; Balchin et al., 1988; Sirat, 2001; Han and Basuki, 2001). The other significant characteristic of this area is that it is generally the area of greatest concentration of employment and few residents are located within it. In addition it contains the major railroad and intercity bus terminal, and it is the hub of the intra-city transportation system. Furthermore a region of small manufacturing and wholesaling firms can be found around its outer limits.

Beyond the CBD, the most dominant land use which frequently exists is residential areas. Near to the centre, the other dominant structures that can be found are multi-storey apartment buildings. However, closer to the edges of the city, single-family units were considered to be significant occupants of the residential areas. In between these two areas, the heights of buildings decline and lot sizes increase, as does the proportion of single-family housing.

Finally, beyond the city itself, land use is dominated by agricultural areas. In the agricultural area also, the concentration of land use tends to decline with the distance from the city centre (Muth, 1969).

The spatial pattern of land use in cities can be described as a 'ring', with non-farm, non-residential uses predominating in the centre and agricultural tending to predominate the outer rings. However, their boundaries may be very irregular, and many exceptions to the ring structure are to be found. For example, along the rail lines and truck routes and near harbour areas, manufacturing areas predominate. Clusters of retail and service establishments, or shopping centres of various sizes are located in a fairly regular hierarchical pattern within the residential areas, often at the intersections of major roads. The CBD is the largest of these centres. Finally, there are many clusters of specialised establishments surrounding institutions such as universities and hospitals (Muth, 1969).

The pattern of urban land use is primarily determined by various decisions made by firms, households and governments (Harvey, 2000). For example, firms occupying shops, offices and factories occasionally have to decide whether to expand, to move from one place to another or perhaps to redevelop the existing site based on the demand of that particular site. Moreover, in the era of globalisation and a dynamic economy, firms need to be more reactive and to choose where to locate (see Harvey, 2000; Sirat, 2001). Similarly, households have to make a decision where to live and if many people move and tend to live in a particular direction and area it may profoundly affect the character of urban land use. Finally, government authorities influence land use through the control of development, overall transport policy and the planning of roads, and by local authority house-building and comprehensive redevelopment (Harvey, 2000).

Detailed explanations of the internal structure of cities can be found in traditional theories and these theories are still useful in many ways. The literature shows that there are three main theories that were constructed to explain the internal structure of cities. These theories are the concentric-zone theory by Burgess (1925), the sector theory proposed by Hoyt (1939) and the multiple-nuclei theory constructed by Harris and Ullman (1945) as cited in Muth (1969)

The concentric zone theory describes the characteristics of urban areas that expand from its centre within a monocentric city. Burgess classified the structure of city into three, namely the CBD, followed by a zone of transition which contains the poorest residences and is dominated by business and light manufacturing, a working class residential district which contains the better residential area, and finally a suburban commuting zone. In addition, Burgess gave little attention to the assignment of activities to specific areas and did not discuss the behaviour of land rents between the different zones (Muth, 1969).

In contrast, after examining patterns of residential rental in 142 American cities in 1942, Homer Hoyt concluded that levels of housing rentals tended to conform to the pattern of sectors rather than concentric rings (Muth, 1969). Hoyt noted that no two cities appear to have high and low rental areas of the same size or shape or in the same location relative to the CBD. However, Muth (1969) posits that none of the cities examined by Hoyt appeared to have an upward gradation of housing rentals from the CBD to the edges of the city in all directions. In other words, the highest rentals in the city tended to be located in one or more sectors, the location of which varied from city to city, and rentals tended to decline from these high-rental areas in all directions. However, Hoyt did not explain why the sector pattern of rental exists (Muth, 1969).

Another means of explaining economic activity is provided by Harris and Ullman. They argued that economic activity is built around multiple centres (polycentric) or nuclei and comprises of multiple functions. For example, these nuclei generate economic activity such as financial, retail, manufacturing or residential districts. Other economic activities may exist around cultural centres, parks, outlying business districts and small industrial centres. In other words, economic activity is not merely concentrated on a single centre or location of the CBD (Muth, 1969).

The three models described above have been criticised for merely being appropriate to cities in the US. According to McGee (1967), in Southeast Asian cities, which were originally developed during the colonial periods (from 1500s to 1950s) as trading and urban centres clustered around major ports, grew in a distributed radial manner along transport networks. Potter and Lloyd-Evans (1998) have arrived at a similar conclusion where cities in developing countries for instance, tend to show a different kind of urban structure. The core of urban areas consists of flea markets and high density commercial activities.

Since the CBD is the point of maximum accessibility to the city as a whole and may have other advantages, transport costs tend to be lower for producers who are located there. In the context of the household, the CBD is the most important, though not necessarily the only place for employment and the purchase of goods and services. The costs of transporting people for work or shopping tend to be lowest nearer to the CBD. The difference in land rents between any two locations devoted to the same type of use depends on the difference in costs, especially transport costs, associated with the two locations (Muth, 1969).

Note that the land use pattern in a city is determined by the pattern of land values. The pattern of land values within a city is quite similar to that of high rise buildings. Muth (1969) noted that land values reach their peaks near the centre of the CBD and decline rapidly towards its edges. But it is exceptional for housing areas where there is less rapid decline in land values. Finally, in the agricultural area beyond the city, land values continue to decline, but at a still slower rate. However, as with the pattern of land uses, there are many exceptions to the pattern of differential decline in land values. Factors such as being near shopping centres, universities, hospitals, the waterfront, rail lines, major roads (Muth, 1969), and physical factors such as the topography of a site, land use zoning and floodplain elevations are important in determining land values (Han and Basuki, 2001).

Consequently, Carter (1986) noted that factors such as soil types and climatic conditions are significant in determining land values primarily when agricultural and forestry are the major land uses. However, for some types of land use such as residential, commercial and industrial uses, factors such as location are more important than physical factors in dominating its values. Also, some locations are highly valued because of their degree of accessibility to large numbers of potential shoppers (commercial location), their convenience for travel to the CBD and work (residential location), or for ready access to markets (industrial location). In addition, the differences in land values can exist over distances of several kilometres or even several hundred metres, primarily within and around cities (Carter, 1986). As a result, the difference of land uses depends on their ability to pay for land.

Yet, factors such as economic forces (demand and supply) and political factors cannot be ignored in any analysis of land value, especially around cities. It was argued that urban land value is determined by the interaction of supply and demand in the market. Demand being the quantity of property available that is required at given prices or rents and supply being the amount of property available at those prices and rents (Balchin et al., 1988; Harvey, 2000). Factors such as profitability or utility have been reflected in the demand for land and these factors are derived from its use by current or potential users. The greater the benefit to be obtained from using a site for any particular purpose, the higher the rent or price the user is willing to pay. In addition, it has to be noted here that profitability and utility are largely determined by accessibility. The greater the accessibility of a location such as the lower the net economic cost of movement in terms of distance, time and convenience, the greater the comparative advantage and the greater the demand for property at that location (Balchin et al., 1988; Harvey, 2000).

Therefore, in what way does accessibility determine profitability and utility? In the case of business use, general accessibility refers to the proximity to transport facilities (rail stations and bus stations), labour, customers and service facilities such as banks and post offices. However, the importance of accessibility to residential land is illustrated when the utility of particular sites depends on monetary factors such as travelling costs to work, schools, shops and public and private open spaces, and non-monetary considerations such as peace and quiet, compatible neighbours, good environmental conditions and other less tangible amenities (Balchin et al., 1988; Harvey, 2000).

In other words, accessibility is a key aspect of location. Thus, investment in new transport infrastructure will alter a location's relative accessibility, inducing both localised and more general changes in land values (Henneberry, 1998). He has highlighted that the relationships between accessibility, land use and land value patterns preoccupied early theorists. He has described further that travel costs were traded-off against rents (Alonso, 1964) and population densities (Muth, 1969) from the CBD to the suburbs of a monocentric city.

As mentioned above, in the context of political factors, there are always government controls of some kind to regulate the possible uses to which land may be put, and hence sometimes to prevent the "highest bidder" bidding for that land. In Britain for example, there are negative planning controls which limit the kinds of development which might take place on any site. For instance, urban land might be zoned for commercial, residential or industrial use (Evans, 1983).

The subsequent sections provide a broad overview of various theories pertaining to urban land use and land value. Some of these theories are discussed in greater detail. The final section briefly evaluates the theories of urban land use covered. It also attempts to address the question of whether a general theory of urban land use is possible and meaningful or whether a synthesis of theoretical schemata is the most useful way of providing support to model building that is hedonic house price models.

## 2.3 The Theory of Urban Land Uses and Land Values

### 2.3.1 Introduction

A number of different theories and models have been used to explain real world phenomena such as urban land use and land values. These theories can be classified into two major groups; micro-economic and macro-economic approaches. The micro-economic approach attempts to describe the changes in behaviour of individual consumers and firms that have produced land uses and land values patterns in an urban area. Conversely, macro-economic approaches deal with aggregate behaviour and indicate how aggregate patterns may be produced (Briassoulis, 2000). The micro-economic approach is commonly used to understand the location choice of the household or firm. Examples of models in this group include the trade-off model (principally by Alonso, 1964; Muth, 1969; Evans, 1973) and the bid-rent function (Alonso, 1964). It has to be noted that these models trace their origins to the agricultural land rent and use theory first proposed by von Thunen in 1826. The study of the macro-economic approach must begin with a solid understanding of the individual behaviour of these households, business firms and government entities so that there is consistency of behaviour in the aggregate. In the case of the macro-economic approach, detailed explanations can be found in the pioneering work by Harvey (1973) and Castells (1977).

### 2.3.2 Definition of Theory

Johnston et al. (1994) defines theory as a set of connected statements used in the process of explanation. Therefore, theory means an idea or set of ideas that is intended to explain something and consequently it denotes knowledge, which is the result of observation. The other definition is offered by Chapin and Kaiser (1979) where they define theory as a system of thought which through logical constructs, supplies an explanation of process, behaviour, or other phenomenon of interest as it exists in reality. Theory also can be defined as the general principles through which a certain class of phenomena may be explained. However, theory is not an explanation but the principles through which explanation is achieved.

What is a theory of urban land use? Simply stated, theory of urban land use is a set of propositions used to understand the "what" of urban land use and the "why" difference urban land use is based on its values (see Hurd, 1924; Muth, 1969; Carter, 1986). In other words, a theory of urban land use describes the pattern of the land use based on its location and explains why these differences occur, what causes these differences and what mechanisms determine these differences.

Which theories of urban land use are included in this chapter? It is noted that the majority of theories of urban land use have to be sought in the more general theoretical framework of disciplines studying patterns of economic activities such as land use, land value patterns and urban structure. Hence, for the purpose of this study, a broad distinction is drawn between theoretical schemata which treat land, urban land use and more importantly land value. In other words, an attempt is made to cover theories where urban land use and land value pattern is defined.

The role of theories of urban land use in this study needs to be stressed. However, common to all analytical tasks is the need to have a strong understanding in order to structure the conception and explanation of reality such as a theory. The analysis of urban land use is no exception. In essence, theories of urban land use guide thinking about the differences of pattern of urban land use based on its values, they indicate conceptual and operational expressions of differences, its determinants and the relations between them, and suggest explanatory schemata for making sense of available empirical evidence in order to support model building (Briassoulis, 2000).

### 2.3.3 The Micro-Economic Theory of Urban Land Use and Land Value

#### 2.3.3.1 Introduction

As noted above, modern urban land use theory is essentially a revitalisation of agricultural land use theory by von Thunen. Two main modern urban land use theory-based theoretical schemata for the analysis of urban economics are discussed below, namely the trade-off model (Alonso, 1964; Muth, 1969) and the bid-rent function (Alonso, 1964). It should also be noted here that these are considered theories as well as models because their developers propose a theoretical structure which they have translated into a mathematical form that is a symbolic model.

Urban land use theory developed by Alonso and Muth draws on concepts from micro-economics. Within this theory, patterns of land use are determined by land values which in turn, relates to transportation costs. Since the introduction of this theory in the 1960s, urban land use theory has advanced rapidly and has inspired a great deal of theoretical and empirical work (Fujita, 1989). For example, urban land use theory plays an important role in shaping much of the hedonic house price model which is useful for estimating the house price gradient from the city centre. Perhaps the most prominent urban land use theory within the hedonic house price model is the trade-off model.

### 2.3.3.2 The Trade-Off Model

The development of our understanding of the trade-off model begins with the basic model of agricultural land rent model proposed by von Thunen (1966) as cited in Briassoulis (2000). The agricultural land rent model describes how transport costs and land prices from the city centre have altered the pattern of agricultural, dairy and forest production (Clark, 1967). The agricultural land rent model was developed with the assumption that a city is located centrally within an 'Isolated State' with a market in perfect competition.

The basic premise of the model was that land value varies only with distance from the city centre (Briassoulis, 2000). This is because transport costs increase with distance from the city centre. Following these assumptions, there is the inclination for economic activities to be located closer to the city centre. For example, products such as milk and fruits (for which transport costs are greatest), would be produced closest to the city centre and that other products would be produced in concentric rings in order of decreasing transport costs (Muth, 1969).

Given that transport costs increased from the city centre, this model suggests that the cultivation of a crop is only valuable within certain distances from the city centre. Beyond that, whether the cost of the land becomes too high with increasing distance from the city centre, or, if there is another product having greater yield or lower transport costs. In other words, the greater the distance from the city centre, the production of a crop becomes unprofitable, either because its profits drop to zero or the profits earned by other crops are higher, as von Thunen calculated them for products having different intensities (cattle, wood, grain, eggs and milk) (Muth, 1969). Evans (1983) argued that for each product there is a certain distance from the city centre where its production would be valuable.

In 1960s several economic analyses of urban land use and land value have been carried out. However, all of which mimic von Thunen's model of agricultural land rent (as discussed above). It was only after almost 140 years that Alonso (1964) and Muth (1969) attempted to describe residential location choice on the basis of the interaction of land use and land value based on von Thunen's original ideas. Perhaps the most fundamental idea of these models is the trade-off between accessibility and space (Fujita, 1989). Since then, several other economists such as Mills (1972), Evans (1973), McDonald (1979) and Fujita (1989) elaborated these models.

It is important to note that as in von Thunen's model, the trade-off model was developed under the assumption of a monocentric city (all economic activities are located at CBD) on an isotropic transport plane with a housing market in perfect competition (Orford, 1999). The basic premise of the model was that the determinants of household utility are assumed to depend on housing (of a given lot size), distance from the CBD (incurs annual transport cost and normally interpreted as commuting cost to the CBD) and followed by all other goods (Orford, 1999; Briassoulis, 2000).

An important underlying assumption of the monocentric model is that travel costs (that is, money and time) increase with distance to the CBD. The monocentric model assumes that the CBD is important for households as a place of employment and is important to firms as an export node, a source of secondary services and a place where managers can easily engage in face-to-face communication (Alonso, 1964).

Travel costs increase when the distances between households and employment locations increase or when distances between firms and the places they need to conduct business increase. Muth demonstrates that the price per unit of housing must decline with distance if the individual household is to be in equilibrium (Goldstein and Moses, 1973). In other words, the further the households live from the CBD, the greater their total transport costs. Hence, the lower the unit prices they pay for housing. Lower housing prices in turn mean lower prices for land (Muth, 1969).

This generalisation regarding the correlation between travel distance and travel costs is sensible in a monocentric city. Trip making is simplified in the monocentric model variations in that travel costs for households and firms are based on the distance to one centrally located concentration of activity (Ryan, 1999). In other words, there is a distance decay relationship between land rent and distance from the CBD. As a result, the greater distance a household lives from the CBD, the more it will have to spend on transport and thus will be able to spend less on housing. Orford (1999: pp. 8) concludes 'a stable housing market equilibrium was eventually reached by each household choosing their optimal location through a bid-rent function'.

### 2.3.3.3 The Bid-Rent Function of the Household

It is important at this stage to expand on the ideas discussed above on the housing market equilibrium and households choosing their optimal location. In general, the housing market equilibrium is determined at the intersection between the *rent gradient* and *bid-rent curve* of the city. In determining the optimal location of households, the utility level of the household must be maximised. In deriving these curves and functions, we need to know how an individual household chooses a location in the city.

For the aforementioned purpose, we will place this discussion within the context of bid-rent function. The bid-rent function was first developed by Alonso (1964) and since then it became the centrepiece of formal models of residential location and urban housing markets. A comprehensive description of the bid-rent function can be found in Fujita (1989). Bid-rent function is a concept that describes the ability and willingness of the household to pay per unit of housing at a certain distance from the city centre. This certain fixed payment is assumed to be equal to the maximum utility level attainable if the household is located at the city centre (Fujita, 1989; Orford, 1999).

This concept means that housing costs decrease with distance from the city centre, but transport costs would increase in response to the greater distance from the city centre. In this framework, a bid-rent schedule can be obtained that indicates the relative priorities for rent and travel costs. The bid-rent schedule can be used to calculate a bid-rent curve, which describes bid-rents as a continuous function of distance, whilst holding utility constant (Orford, 1999). It has been demonstrated that a lower bid-rent curve indicates a lower rent per unit of housing. Subsequently, the lower the rent per unit of housing will increase the utility level of every household (Muth and Goodman, 1989).

As mentioned above, the housing market equilibrium is determined at the intersection between the rent gradient and the bid-rent curve of the city. Let us assume that all the households in the city have the same income, tastes and preferences. In this case if all individuals are identical, this implies that the rent gradient will lie wholly along one of the bid-rent curves. At the same time, the households will achieve the utility level corresponding to the intersection between the rent gradient and bid-rent curve.

Incidentally, in reality households generally have different incomes, tastes and preferences. In this case, their set of bid-rent curves will not be identical; this implies the rent gradient will not lie along a single bid-rent curve, but will be made up of sections of the lowest attainable bid-rent curves of all the households in the city. Thus, a household's optimal location will be the point at which the rent gradient intersects to their lowest achievable bid-rent curve. At this point, the slope of the rent gradient is equal to the slope of their bid-rent curve and the household's utility is at its maximum (Orford, 1999).

## 2.4 The Theoretical Justification for Using Micro-Economic Theory

One criticism of much of the literature on micro-economic theories is that these theories are demand oriented, with no regard for the supply of housing. Similarly, other substantive criticisms concern the fundamental importance of accessibility to the monocentric city centre in determining housing location. Other housing attributes such as housing quality and population density, tend to be broadly correlated with distance from the city centre, and these may have more of an influence than issues of accessibility (Orford, 1999). Briassoulis (2000) has arrived at a similar conclusion in the context of monocentric city centre in explaining urban spatial structure.

The theory does not consider a number of interrelated factors which, on one hand, capture the particular forms that characterise modern urban agglomerations. For the purpose of argumentation to support the inadequacy above, there is lack of consideration on the existence of more than one centre (polycentric) in metropolitan areas, congestion, air pollution, neighbourhood quality effects, imperfect markets, technological change and inflexibility of the housing stock (see Anas et al., 1998; Briassoulis, 2000). Furthermore, Henneberry (1998) argued that the CBD has declined as the predominant location of employment and services in the modern city. This is because the peripheral centres of activity have grown significantly. Trips are made for employment and for a range of consumption purposes. Accessibility has become a more complicated phenomenon requiring more complex treatment. In addition, micro-economic approaches did not have a mechanism for allocating employment anywhere in the city except at the CBD, or in more recent polycentric formulations at specific discrete locations which act as agglomerations centres (Ladd and Wheaton, 1991). For example, the study conducted by Giuliano and Small (1991) proved that two-thirds of the employment in the Los Angeles region lay outside the entire thirty-two sub-centres (see also, Hanneberry, 1998).

Shukla and Waddell (1991) have arrived at a similar conclusion in the context of firm location. The probability of firm location at sites within the urban space of Dallas-Fort Worth depends on proximity to other firms and populations, but not to any important extent on distance from the CBD. Finally, whilst micro-economic theories are relatively successful at describing the location of housing patterns, they often fail to adequately explain them since they ignore the wider social structures and institutions that govern household decisions.

The weaknesses of the micro-economic theories have been acknowledged above, yet the strengths of the approaches spirited by micro-economic theories are plentiful. Micro-economic theories help us to understand how the land use in cities is determined in a static equilibrium setting, where it is assumed that the market clears and determines prices and rents of land and property. It has to be noted that the micro-economic theories have become a paradigm for much urban economic research (Orford, 1999). Moreover, their great strength lies in their heuristic power in yielding results consistent with data from real cities and with findings of earlier urban theory (Orford, 1999). Micro-economic theories primarily deduce the existence of a negative rent gradient from the city centre outwards, which decreases with increasing distance.

The micro-economic theory has been the most influential and provides the conceptual basis for all hedonic house price studies (Damm et al., 1980; Orford, 1999). Orford states that one of the motivations behind early hedonic house price research was to estimate this negative rent gradient, as this would strengthen the argument for the concept of the bid-rent function which is greatly discussed in the micro-economic theories. Nevertheless, in the context of the monocentric model, Orford (1999) pointed out that most of the hedonic house price studies have been theoretically underpinned by this model which proposes the existence of a negative house price gradient from the city centre, reflecting the trade-off between house prices and declining accessibility. Furthermore, Cheshire and Sheppard (1995) argue that if locational attributes are appropriately measured, then monocentric models can perform well for example in the UK context. However, this may not necessarily be true for modern US cities context in which rapid growth of sub-centres have been developed outside the CBD area particularly in early 1980s.

Finally, it needs to be recognised that one of the strengths of the micro-economic model has been, in the eyes of many urban analysts, that it has yielded the opportunity to analyse the trade-off between different products and product sectors by means of its subjectivist models of consumer demand. Nevertheless, it is a weakness of most Marxist approaches that they cannot model demand changes or take into account the role of consumer surplus in social reproduction (Bovaird, 1993). As far as the specific context of the effects of transportation facilities (such as rail transit systems) on house prices is concerned, the researcher considers the micro-economic approaches as essential to this study. Furthermore, this approach (rather than macro-economic approaches) has become popular among property researchers.

## 2.6 Conclusion

This chapter has reviewed the literature concerning land use and land value in an urban area. It began by introducing the pattern of land use as determined by the land value, in particular the choice of residential location. Micro-economic theory was then introduced, in which focus has been placed on the trade-off model and the bid-rent function. Micro-economic theory illustrates that the choice of residential location of the household is determined by the trade-off between accessibility to work, housing attributes and transportation costs. The foundation provided by the micro-economic theory has been an important basis in order to understand the relationship between the improvement in transportation system and its effect on land values. The next chapter will continue the discussion by examining the empirical evidence from previous studies on the effects of rail transit systems on land values, namely property values which have been estimated to decrease for every metre further away from a rail transit station.

# CHAPTER 3

## The Effects of Transportation Investments on Property Values: Rail Transit Systems

### 3.1 Introduction

In the preceding chapter, the urban economic theories have been examined. The theoretical foundation provided by urban economic theories has been important in understanding the relationship between transportation investments and property values. Following this discussion of urban economic theories, subsequent discussion will be centred on the effects of transportation investment on property values. The role of the transportation systems in fostering growth and affecting urban structure has been of great interest to academicians, planners, investors and politicians (Giuliano, 2004). Similarly, transportation investment decisions are the subject of much debate and lobbying among planners and policy makers at the local government level in particular. Moreover, it has also been of great public interest because transportation investments (such as rail transit systems) involve large sums of money.

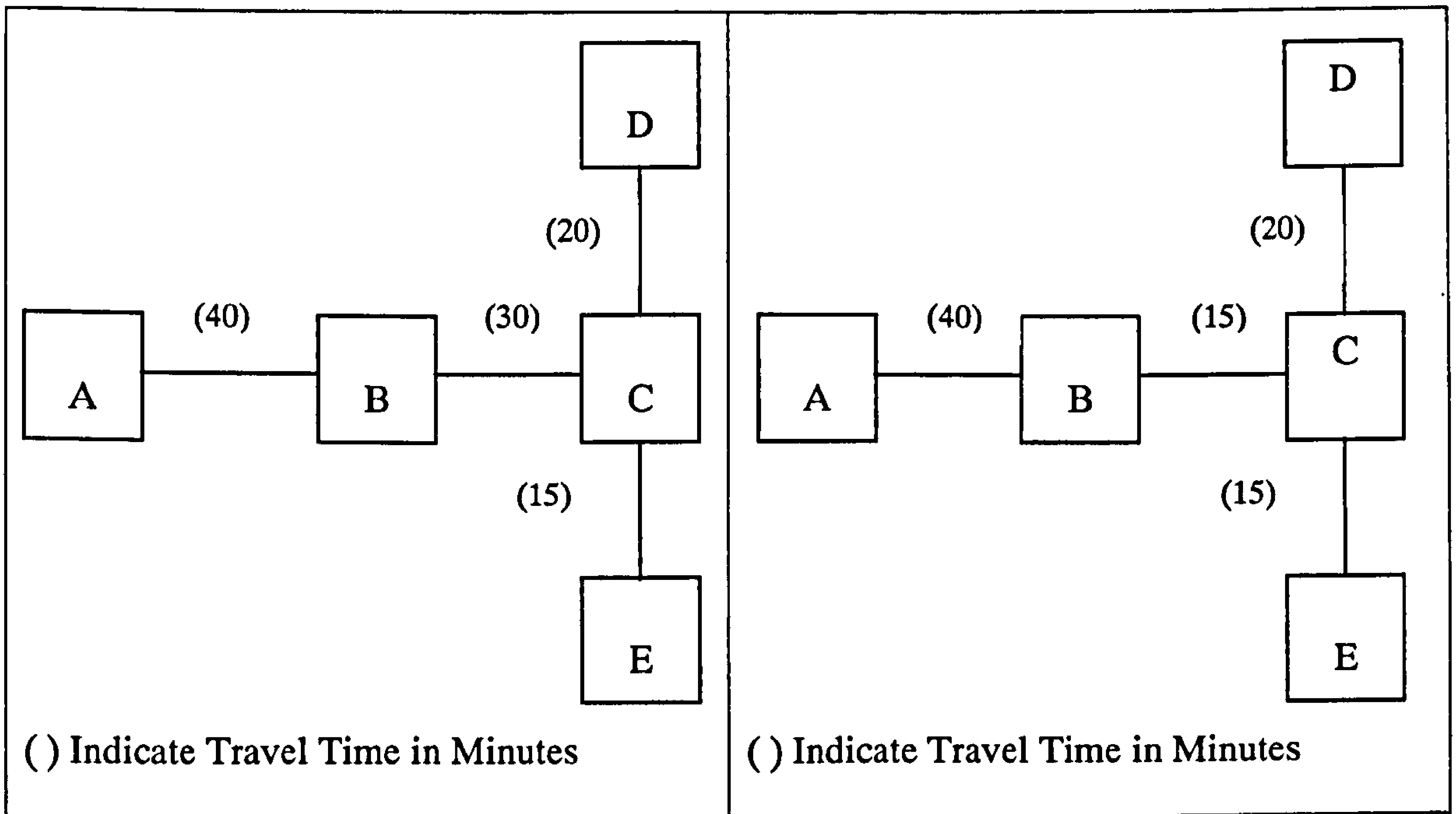
As noted in Chapter one, in the context of the relationship between transportation investments and property values, any significant improvement in the transportation system that increases accessibility and reduces transportation costs should result in an increase in property values. It has also been recognised that the provision of the public infrastructure (such as roads and railway systems) has a profound influence on the pattern of urban development and the spatial distribution of urban property values (Damm et al., 1980). Based on the urban economics theories, the benefits of these facilities and services are partially or wholly capitalised into urban property values.

This chapter provides a connection between urban economics theories and transportation-property values relationships. However, it should be noted that the primary focus of this chapter is the effect of rail transit systems (heavy rail transit and LRT systems) on house prices in an urban area. The theoretical basis for expecting transportation influences house prices and we determine the extent to which such effects can be measured. Discussion begins with a brief description of factors to consider when examining the effects of transportation investments on house prices. The second section of this chapter addresses the conceptual relationship between transportation and house prices within the context of accessibility. After establishing the existence of relationship between transportation and house prices, major theories that have been discussed are reviewed in the previous chapter to explain transportation and house prices relationships. Finally, the empirical evidence is summarised, specific case studies are discussed and conclusions made based on these findings.

## 3.2 Accessibility-Transportation-House Price Relationships

The understanding of transportation-house price relationships begins with the basic concept of *accessibility*. In this context, accessibility refers to the ease with which any places can be reached from a location using a transportation system (Dalvi, 1978; Giuliano, 2004; Hanson, 2004). However, Handy and Niemeier (1997) demonstrate that accessibility can be determined by the spatial distribution of potential destinations, the ease of reaching each destination and the magnitude, quality and character of the activities found there. The greater the number of potential destinations within a defined time or distance range, the greater the accessibility. The closer such choice destinations within this maximum range, the higher the level of accessibility (Church and Marston, 2003). Nonetheless, the structure and capacity of the transportation network could also affect the level of accessibility within a given area. In the context of the transportation-house price relationship, accessibility is the most fiercely contested and the single most important measure. The urban land use analysis in studying consumer behaviour to travel clearly indicates that movement becomes less costly that is reduction in time or money, when there is increased accessibility. In other words, the tendency for interaction between any two places increases due to the decrease of the cost and time of movement between them.

Giuliano (2004) draws attention to the concept of *attractiveness* in explaining accessibility. Attractiveness can be defined as opportunities or activities that are located in a given place. Consequently, the ease of movement between places, as well as attractiveness of these places as origins or destinations is expressed in accessibility. In light of this, accessibility can be defined as the attractiveness of a place as an origin and as a destination. In other words, the former concept refers to how easy it is to reach all other destinations from there, and latter how easy it is to reach from all other destinations (Giuliano, 2004). Note that these two measures are asymmetrical. The first case places emphasis on accessing opportunities located in other places, whilst the second emphasises the opportunities located in that place. Similarly, it is important to incorporate attractiveness in the concept of accessibility because of the unique function of transportation as the mechanism for spatial interaction. That is, trips are usually demonstrated as a "derived demand", where they are made in order to engage in other activities such as working or shopping.




(a) Network M-Before Improvements | (b) Network N-After Improvements

**Figure 3.1:** Accessibility in the context of a simple network
*Source*: Adapted from Giuliano (2004: pp. 240)

**Table 3.1:** Travel time accessibility matrix for network M and N

| Network M | | | | | | | Network N | | | | | | | Changes |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **From/to** | **A** | **B** | **C** | **D** | **E** | **Total** | **From/to** | **A** | **B** | **C** | **D** | **E** | **Total** | **(%)** |
| **A** | 0 | 40 | 70 | 90 | 85 | 285 | **A** | 0 | 40 | 55 | 75 | 70 | 240 | - 45 |
| **B** | 40 | 0 | 30 | 50 | 45 | 165 | **B** | 40 | 0 | 15 | 35 | 30 | 120 | - 45 |
| **C** | 70 | 30 | 0 | 20 | 15 | 135 | **C** | 55 | 15 | 0 | 20 | 15 | 105 | - 30 |
| **D** | 90 | 50 | 20 | 0 | 35 | 195 | **D** | 75 | 35 | 20 | 0 | 35 | 165 | - 30 |
| **E** | 85 | 45 | 15 | 35 | 0 | 180 | **E** | 70 | 30 | 15 | 35 | 0 | 150 | - 30 |

*Source*: Adapted from Giuliano (2004: pp. 241)

In discussing how a change in the transportation network affects accessibility, Giuliano (2004) illustrates this with a simple network example. This simple network example is shown in Figure 3.1. As an illustration in Figure 3.1, each node represents a possible origin/destination and the numbers near each link represent travel times. In order to emphasise how a change in the transportation network affects accessibility, we begin with the network on the left hand side of Figure 3.1 (Network M). Then, from Network M, we make an improvement such that travel time between nodes B and C is reduced by one-half, graphically, as depicted on the right hand side of Figure 3.1 (Network N).

The network accessibility is measured again graphically, in Table 3.1. Here, network accessibility is measured by calculating the travel time from each node to every other node and summing over each node. Each row in the matrix corresponds to travel times from one to every other node. Note that the row sums are the accessibility measures for each node. Since travel times have been used in the example, lower numbers indicate greater accessibility from one node to another. It is evident from Table 3.1 that the network improvement not only increases accessibility between nodes B and C. At the same time, it also benefits the entire network. This simple example demonstrates how a network improvement (for example the existence of rail transit systems link between two places) affects both the accessibility of the two directly connected places and the accessibility of the entire network. Hence, as accessibility increases, the level of spatial interaction increases because travel has, in effect, become less costly (Giuliano, 2004).

The next logical question is; how does this improvement affect house prices? It is important to note that as there is an increase in accessibility from one place to another (such as travel time savings and reduced transport costs), house prices will respond accordingly in those places that have become more accessible. As illustrated in examples from Table 3.1, this implies that nodes A and B have benefited most from the improvement, and thus the greater house price changes would be expected to occur at these nodes. As has been noted by Fujita (1989), it is usually more expensive to acquire space in a location with good accessibility. To a certain extent, households may have to sacrifice space for accessibility. It is widely recognised that accessible locations however, are typically lacking in environmental quality.

Hence, the household also confronts a choice between accessibility and the quality of the environment.

The network example above explicitly identifies the house price benefits generated by reduced travel costs and time saving on the B-C link. Reduced transport costs can lead to greater interaction by households from one place to another. For example, reduced travel costs from the household to the CBD might allow a household to travel greater distances. In addition, reduced transport costs effectively increases a worker's net wage, allowing him or her to spend more on other goods and services. However, it is important to note that as depicted in the network examples above, by reducing travel time and travel costs, households have to spend more on housing, particularly in those two nodes (A and B). Henneberry (1998) agrees that a property's location and its value are strongly interrelated. Investments in new transport infrastructure such as rail transit systems will alter the location's relative accessibility, inducing both localised and more general changes in house prices.

## 3.3 Theories of Urban Economics-Transportation Interaction

In the previous sections, the relationship between transportation and house prices in the context of accessibility has been examined. It is now appropriate to dissect the theoretical context of urban land use and transportation interaction. The contents of the section are based on those of Chapter two. Several major and interlinked theoretical expectations in relation to the transportation and urban land use with respect to change in house prices form the main thrust of the research as reported in this section. It has to be noted that these theories seek to explain the effect of transportation costs on location choice.

### 3.3.1 Basic Urban Economics Theories

As has been discussed in the preceding chapter, a number of urban economics theories and models have been adopted to explain the structure and organisation of urban areas and the importance of transportation systems in connecting one place to another. Our understanding of urban land use and transportation begins with a basic model, which focuses on the trade-off between accessibility and space. Urban economics theories of urban structure trace their origins to the agricultural land rent and use theory first proposed by von Thunen in 1826. As noted in section 2.3.2.1, this theory was developed to explain the basic structure of cities, meaning land value, population and employment distribution and commuting patterns. Specifically, von Thunen approach was that decisions as to 'which crop to grow where' are determined by profitability; which is a function for sale price at minus costs of production and shipment to the farm gate.

There is a monocentric city where all economic activities are located in the CBD. The city is populated by a large number of identical households and endowed with the same number of housing units. There is however, another urban economics theory, provided by Alonso (1964) and Muth (1969), which attempted to describe residential location choice on the basis of the interaction of land use and land values. Within these theories, household location is expressed as a utility-maximising problem in which choice depends on land rent, commuting cost and the costs of all other goods and services. Thus, land use activities can be described as a series of rings from a CBD. Although the theory manages to explain the spatial pattern of urban activities, the theory assumes that transportation cost is the same in all directions from the urban centre. Moreover, the urban economics theory rests on several simplifying assumptions (Giuliano, 2004). In addition to the usual assumption of rational behaviour, identical preferences and perfect information, the theory also has the following assumptions:

1. The city is monocentric; the total amount of employment is fixed and located at the centre of the city,
2. Each household has only one worker and only work travel is considered,
3. Housing is a function of capital and land, therefore location and lot size are the distinguishing factors; *and,*
4. Unit transport cost includes both time and monetary costs, and it is constant and uniform in all directions.

In this context, the only spatial characteristic of each location in the city that matters to households is the distance from the CBD. The city centre is envisaged as a circular residential area surrounding a CBD, in which all jobs are located. A household's utility is assumed to depend on housing (of a given lot size), distance from the CBD (incurs annual transport costs and normally interpreted as commuting costs to the CBD) and followed by all other goods. Moreover, the household allocates its fixed budget around these three components with the aim to maximise its utility. Its preferences determine that trade-off – it is willing to compromise on the above three elements. The price of housing and other goods is independent of the quantities purchased. Also, the price of housing and commuting depends on distance from the CBD.

In a very general way, there are two fundamental attributes provided by residential location theory; the CBD is a place with greatest population density and a place where all economic activities are located. Therefore, each individual or company has to pay a very high price just to be located in the CBD. It must be noted that the population density and land value will decline with the distance from the CBD. Since transport costs increase with distance, the unit cost of housing must decline with distance from the CBD. Consequently, the value of transportation costs savings is reflected in land as well as housing costs. If this were not the case, all households would be located in the CBD. It therefore follows that more housing will be consumed as distance from the centre increases, and therefore population density will also be constantly decreasing. Furthermore, the theory predicts commuting patterns where the average commuting distance corresponds to the mean distance of total population to the centre (Giuliano, 2004).

The best location for a given household is the point at which the marginal savings of housing are equal to the marginal cost of transport, or the savings in housing are just offset by the increase in transport costs. If households have identical preferences, they will be indifferent to any given location. If this assumption is relaxed, the particular location of any given household depends on relative preferences between housing and transport. It is generally assumed that housing preferences are the stronger of the two; the higher the household income, the more housing will be consumed, even at the cost of additional commuting. For example, in most of the US cities studied, there were trends where the higher income households had an inclination to live farther from the city centre (Giuliano, 2004).

Discussion can now be extended and the question on what does the theory predict in response to a change in transport cost can be answered. If commuting costs are reduced, the theory predicts a movement away from the centre or population decentralisation. This process can be approached graphically, as shown in Figure 3.2. In Figure 3.2, curve one is the land rent gradient before the transportation improvement and curve two is the land gradient after the transportation investment. It is evident from the figure that the decrease in transport cost reduces rent at the city centre. This is because the locational advantage of the centre declines.

As a result of rent reductions in the city centre, consumers take advantage by increasing housing consumption and commuting greater distances. As a result, the total amount of land consumed increased, and the city

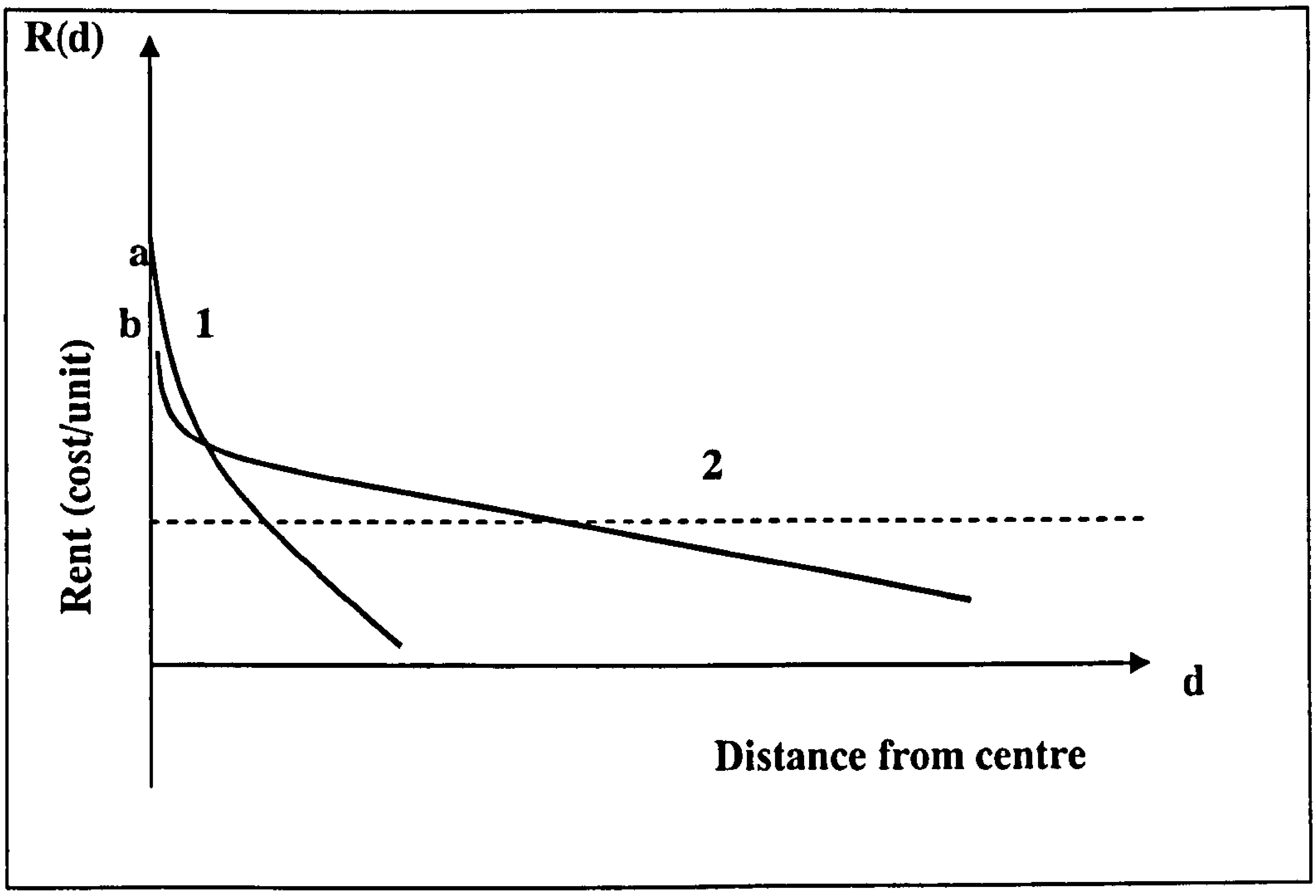



**Figure 3.2**: Response of rent function to a transport cost decline
*Source*: Adapted from Giuliano (2004: pp. 244)

boundary extends. However, if transport cost is increased, the reverse effect will be observed, in which households will economise on travel by locating themselves closer to the centre and spending more on housing. Giuliano (2004) concludes that in a very general way, empirical evidence tends to support the urban economics theory. Empirical evidence shows that population density declines with distance from the centre. For example, time series studies document that densities have declined historically in concurrence with transportation improvements.

According to the preceding discussion, commuting cost includes both time and money. Therefore, reduction in one of these two elements would result in a reduction of commuting, for example, cost-reducing the price of fuel or transit fares. In the same way, commuting cost can be reduced by increasing travel speed. That is, providing an express transit route or adding a lane to an expressway. Different types of travel cost are likely to have differing impacts across income groups. A simple price reduction will affect all income groups in the same way, in which more income would be available for housing, leading to more housing consumption and hence to more distant location costs (Giuliano, 2004).

The effects of travel time reduction across income groups tend to have a greater effect on higher income groups, because the value of time is a function of income. Therefore, the decentralising effect of a travel time reduction is greater for higher income households. Suppose that a transportation improvement is accompanied by a price increase. This can be seen from the construction of rail transit systems that reduce travel time but charge a higher fare. The fare increase could offset the value of travel time savings for low income households but not for higher income households. As a result, the benefit of this improvement would disproportionately affect higher income households (Giuliano, 2004).

## 3.4 Empirical Evidence of the Property Values Effects of Rail Transit Systems Investment

### 3.4.1 Introduction

This section examines the empirical evidence of the effects of rail transit system investments on property values. For this, it is important to consider a way of measuring the effect of rail transit systems investments on property values where this can be measured by employing an empirical approach. As has been noted by Giuliano (2004), empirical documentation has been of interest to researchers for many decades. For example, studies of specific projects in the US were conducted as early as the 1930s, and many more have been performed since then both in the US and the UK. However, it is interesting to note that there is little consensus on the conclusions drawn from the results of these studies, in which there are inconsistencies and varying evidence of the relationship between rail transit systems investment and property values, or in other words, the results contradict theoretical expectations. In order to understand why, it is useful to discuss the problems involved in measuring the effects of rail transit systems investments on property values.

### 3.4.2 Overview of Heavy and Light Rail Transit Systems

Before discussing the empirical evidence on the effect of rail transit systems on property values, let us first define heavy and light rail transit systems. The definition given in this subsection would provide us with a better understanding between these two systems and the magnitude of the effect of the implementation of these systems on property values.

*Heavy and Light Rail Transit Systems*: As highlighted earlier, the first heavy rail transit system was constructed for London and opened in 1863 (Smerk, 1992). Since then, many countries have implemented heavy rail transit systems that play a vital role in improving a country's public transportation. In general terms, heavy rail transit can be defined as a system with a "heavy volume" traffic capacity, high speed, high reliability, rapid boarding and fail-safe operation (Vuchic, 1992). Heavy rail transit system is completely "independent" from other traffic and serves at high frequency. In most countries, the heavy rail transit system is increasingly known as the "metro" and usually consists of large four-axle rail vehicles that operate in trains of two to ten cars. On the basis of the above mentioned characteristics of the system, typically, heavy rail transit systems transport large numbers of people and have a greater geographical coverage for example across metropolitan and suburban areas.

A light rail transit system on the other hand, is a metropolitan electric railway system characterised by its ability to operate single cars or short trains along exclusive right of way at ground level, on aerial structures, in subways, or occasionally in streets and to board and discharge passengers at track or car floor level (Vuchic, 1992). It is interesting to note that the term "light rail" was created in 1972 by the US Urban Mass Transit Association (UMTA) to illustrate the transformation of the streetcar which was taking place in Europe and North America. Unlike heavy rail transit systems, the LRT systems operated with lower speed and "light volume" traffic capacity. In addition, the LRT system was primarily constructed to serve in an urban area. Therefore, it could encourage residents to travel to an urban area by using the system rather than using their own vehicles.

On the basis of the definition given above, it is assumed that the effect of heavy rail transit systems on property values is much greater than that of the LRT system. Hence, the next subsection will focus on the empirical evidence on the effect of heavy and LRT systems on property values based on studies that have been conducted in the UK and North America.

### 3.4.3 Effects of Rail Transit Systems

#### 3.4.3.1 Introduction

Rail transit systems proved an important transportation facility in urban areas. Since the early 1860s and 1960s, the rail transit systems facility shaped the form and character of cities and regions in the UK and North America respectively. The construction of rail transit systems in the UK began in the 1860s through the construction of London Underground that covers most of Metropolitan London and its neighbouring areas. Since then, the construction of rail transit systems continued in other parts of the UK. For example, in the 1970s Tyne and Wear Metro systems were constructed for Newcastle and the surrounding towns. However, in the late 1980s and early 1990s, approximately seventeen areas including Blackpool, Manchester, South Yorkshire, Avon, West Midlands, West Yorkshire, Southampton, South Hampshire, Teesside, Nottingham, Edinburgh, Dundee, Liverpool, Reading, Swindon, Chester and Cardiff, initiated the construction of heavy and light rail transit systems (Taplin, 1990).

In the context of North America, since the early 1960s, several cities began constructing heavy rail transit systems including San Francisco, California; Atlanta, Georgia; and Washington D.C. in the US and Toronto in Canada (Ryan, 1999). According to Ryan (1999), in the late 1970s and 1980s, approximately twelve other cities in the US including San Diego, California; Portland, Oregon; and Buffalo, New York, initiated the construction of light rail transit systems (the second generation of rail transit systems). The construction of both heavy and light rail transit systems were not stopped there, but it continued in the 1990s in more than twenty US cities (Ryan, 1999). However, in developing countries several cities began constructing heavy and light rail transit systems in the 1990s. Malaysia for example, only implemented its light rail transit system in the 1990s, in the Klang Valley.

Since the early 1970s, interest in studying the effects of rail transit systems on land use and property values began to emerge with the construction of "first generation" heavy rail transit systems in North America. From the introduction of heavy rail transit systems in several cities in North America, empirical research on the effects of heavy rail transit systems on land use and property values were conducted. However, it is important to note that evidence from empirical research shows inconsistent results on the effects of rail transit systems, in particular light rail transit on property values. The purpose of this section therefore is to examine the empirical evidence in the UK and North America on the effects of rail transit systems on property values. The discussion of these effects will focus on both heavy and light rail transit systems.

### 3.4.3.2 Theoretical Expectations of the Effects of Rail Transit Systems

Before discussing the empirical evidence of the effects of rail transit systems on property values, it is useful to understand some of the theoretical expectations of the rail transit systems-property values relationship. As noted in the previous section, rail transit systems generate changes in accessibility only in the affected areas that are adjacent to the rail line itself. The construction of a rail transit system should improve accessibility along the rail line corridors compared to areas that are not served by the rail transit system. Assuming a rail transit system has improved the accessibility, properties located nearer the rail transit station much more attractive and therefore more valuable in equilibrium. In contrast, properties located further away from the rail transit station would be less attractive and therefore less valuable in equilibrium. Furthermore, since rail transit systems are focused on the CBD, the position of the CBD as the most accessible point in the area should be enhanced, leading to an increase in activities and property values in the CBD (Giuliano, 2004).

In his review of the impact of transportation investment on land use, Giuliano (2004) identifies two additional points. Firstly, it describes the potential effect of rail transit systems on property values based on the extent to which accessibility is changed. Note that rail transit service usually replaces existing bus service. As a result of rail transit service replacing existing bus service, its effect on accessibility can be quite small. In addition, as has been noted by Giuliano (2004), it is extremely difficult to expect rail transit service to produce a greater effect on the whole transportation network. This is because the rail transit system accounts for a very small portion of the entire transportation network. Even a large change in transit accessibility has little effect on the system as a whole. Secondly, a transit improvement is another form of transportation system improvement and therefore should have the same decentralising effect. To the extent that the transit improvement reduces transport costs and travel-time savings, households will use some of the reduced costs and travel-time savings to consume more travel. In addition, if the benefit of transport improvement reduces travel costs and travel-time savings, researchers generally assume that nearby households experience these benefits to bid up property values.

### 3.4.3.3 Heavy Rail Transit System Studies: Methods and Study Design

This section begins with the examination of empirical evidence of the effects of rail transit systems on property values. The literature on the effects of rail transit systems on property values is very broad, ranging from heavy rail transit systems to light rail transit systems.

Approximately thirty-five studies (both in the UK and North America) have examined how rail transit systems affect property values have been conducted over the past forty years. As noted earlier, interest in studying the effects of rail transit systems on property values began to emerge with the construction of "first generation" heavy real transit systems in the UK and North America. Since the early 1980s, a number of studies have been conducted to measure the relationship between rail transit systems and property values in the UK. CURDS et al. (1990) and Forrest et al. (1996) represent the first few attempts to study the effects of heavy rail transit systems on property values in the UK.

However, several other studies were undertaken to ascertain the effects of heavy rail transit systems on property values in the new millennium (see for example, Chesterton, 2000; Pharoah, 2002; Parker, 2002; Du and Mulley, 2006). Yet in North America, a number of studies have been undertaken since the early 1970s. Boyce et al. (1972), Dewess (1976), Lerman et al. (1978) and Dvett et al. (1979) represent the initial attempts to study the effects of heavy rail transit systems on property values. Following this, several other cities in North America began constructing and opening heavy rail transit systems in the late 1970s and 1980s. Several other studies have also been conducted (see for example, Damm et al., 1980; Bajic, 1983; Nelson and McClesky, 1990; Voith, 1991; Nelson, 1992; Cervero and Landis, 1993; Gatzlaff and Smith, 1993, Armstrong, 1994; Benjamin and Sirmans, 1994; Landis et al., 1995; Landis and Loutzenheiser, 1995; Hess and Almeida, 2007).

The methods and the study designs that have been used in previous studies will now be briefly discussed. It must be noted that all of the heavy rail transit systems studies indicate that regression analysis was used to measure the effects on property values. In addition, there is considerable variation in other aspects of heavy rail transit studies including the size of the study areas, the length of the study periods and the independent variables used to estimate property values. As has been noted by Ryan (1999), an important characteristic of the first generation rail studies is that two distinct measures of access are used as independent variables. Table A1.1 of Appendix A provides selected results of the heavy rail transit systems studies characteristics, in particular the approaches used to measure transportation access. It must be noted that four of the thirteen heavy rail transit studies used measures of access that were based on travel times (Dewess, 1976; Bajic, 1983; Voith, 1991; Armstrong, 1994). However, a number of studies have used measures of access based on a parcel's distance from a heavy rail transit station (see, for example, Dvett et al., 1979; Nelson and McClesky, 1990; Gatzlaff and Smith, 1993; Cervero and Landis, 1993; Landis et al., 1995; Chesterton, 2000; Cervero and Duncan, 2002).

As Ryan (1999) argues, even travel time and travel distance are both intended to measure accessibility levels, but they are quite different measures. Ryan has stressed that travel time variations should be more accurate measures of accessibility than distances to rail transit stations. This is because the distances between properties and rail transit stations may not always be correlated with the travel times between properties and the rail transit systems. In terms of the size of heavy rail transit studies, areas range from a five-county metropolitan area (Voith, 1991) to properties that are located within 0.33 miles from the rail transit corridors (Dewess, 1976). There is also considerable variation in terms of the study period. Finally, eight of the heavy rail transit studies are based on cross-sectional analyses and the remaining studies use longitudinal analyses that cover between three and nineteen years.

### 3.4.3.4 Summary of Empirical Results of Heavy Rail Transit System

There is extensive literature on the effects of heavy rail transit systems on property values both in the UK and North America (see Table A1.1 of Appendix A). In the UK, Tyne and Wear's METRO (see for example, Miles at al., 1981; CURDS et al., 1990; Du and Mulley, 2006) and several recent studies around the UK for example, Manchester's METRO (see for example, Forrest et al., 1996) and London's Jubilee Line Extension (see for example, Chesterton, 2000) were the subject of studies after they opened. Whilst in North America, the Philadelphia-Lindenwald commuter line (see for example, Boyce et al., 1972), San Francisco's BART (Dvett et al., 1979), Washington, D.C.'s METRO (see for example, Lerman et al., 1978; Damm et al., 1980), Toronto's Bloor-Danforth subway line (see for example, Dewess, 1976) and Toronto's Spadina subway line (see for example, Bajic, 1983) were the subject of studies after they opened. In addition, many recent studies were conducted in North America. Such studies include Atlanta's MARTA (see for example, Nelson and McClesky, 1990; Nelson, 1992; Cervero and Landis, 1993), New Jersey's commuter rail line (see for example, Voith, 1991), Washington, D.C.'s METRO (see for example, Cervero and Landis, 1993), Miami's METRO (see for example, Gatzlaff and Smith, 1993), Boston's Fitchburg-Gardner commuter line (see for example, Armstrong, 1994), California's BART (see for example, Landis et al., 1995) and San Francisco's BART (see for example, Landis and Loutzenheiser, 1995).

The results of these studies showed that there was varying evidence of the effects of heavy rail transit systems on property values. Expected relationships between property values and heavy rail transit systems are found in early studies (for example Boyce et al., 1972; Lerman et al., 1978; Bajic, 1983) and in more recent studies by Voith (1991), Nelson (1992) and Chesterton (2000), Du and Mulley (2006) and Hess and Almeida (2007).

*Tyne and Wear METRO System*: The Tyne and Wear METRO system was the first generation of rail transit system to be constructed in the UK. The Metro began operating in 1980 based around Newcastle city centre and surrounding towns. An additional line was constructed for connecting Newcastle and Sunderland (the green line), which opened in 2002 (see Figure 3.3). Note that the extension of Tyne and Wear METRO system to Sunderland will surely bring substantial benefits to Sunderland and its residents, particularly in improving accessibility to the other areas within Tyneside. This is due to the fact that residents who live in Sunderland had fewer rail transit opportunities by comparison with the level of services available on Tyneside. It is surely that six metro services per hour on the Newcastle to Sundeland line plus ARRIVA TransPennine services will result in a substantial improvement in rail services along this important transport corridor (Du, 2006). The Tyne and Wear METRO system can be considered evolutionary, as it was a pioneering system in the use of existing rights-of-way to create a modern rail transit system. When the METRO first opened, it was claimed to be part of the UK's first integrated public transport system (Gleave, 2005).

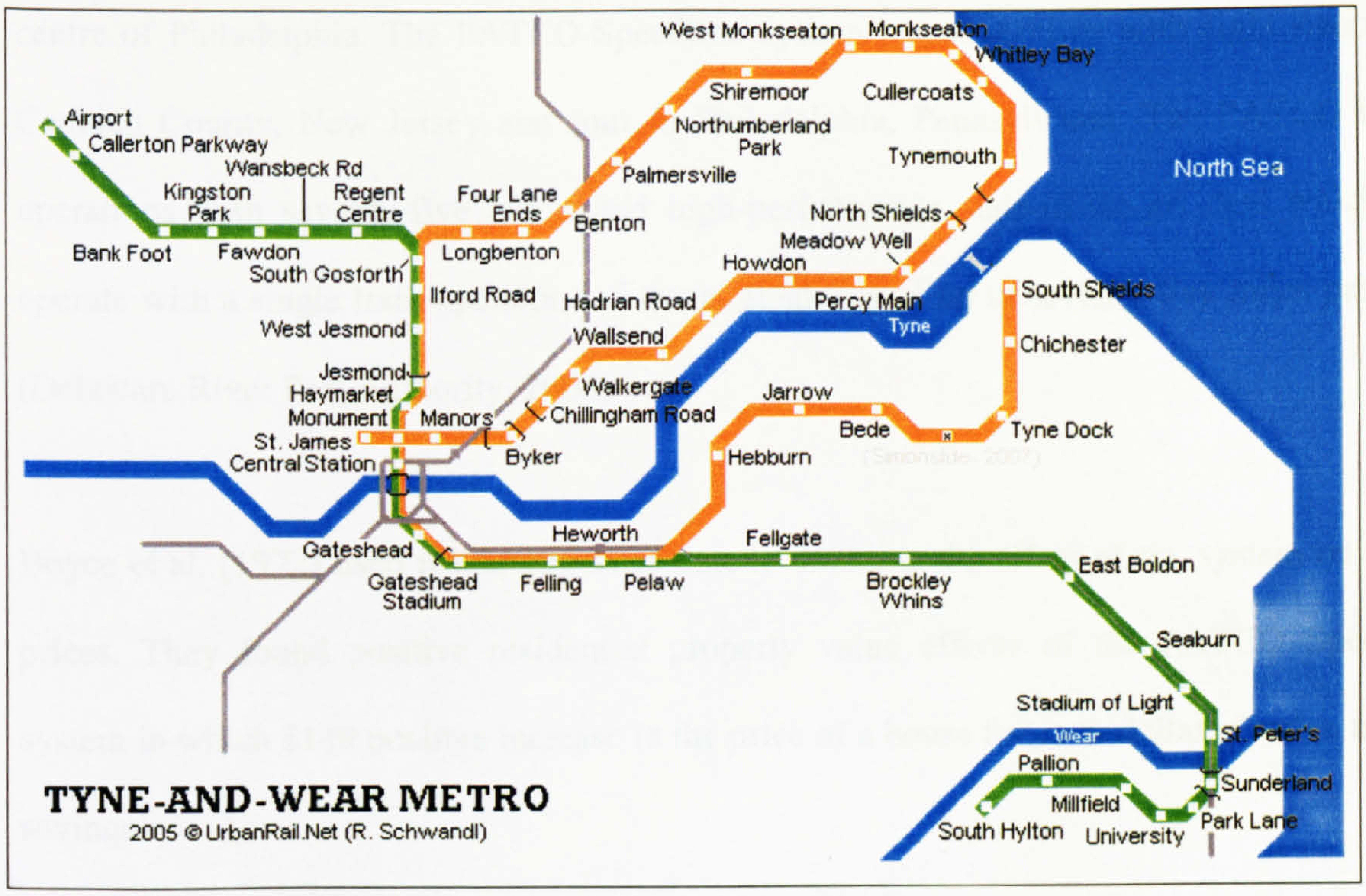



**Figure 3.3**: The Tyne and Wear METRO system
*Source*: http://www.tyneandwearmetro.co.uk/

CURDS et al. (1990) conducted a "Tyne and Wear METRO Study" to examine the effects of Tyne and Wear METRO on house prices (based on transaction data provided by the Halifax Building Society), which found no relationship between house price increases over the period 1984-1987. Interestingly, a recent study was conducted by Du and Mulley (2006) on a similar basis; the relationship between land value that is house prices and the existence of the METRO system. They found housing units in some of the areas that located within walking distance from metro station increased in value. For instance, house prices in the west end of the Tyne and Wear Region, Newcastle central area and around Shiremoor metro station area increased between £2500 and £5968.

*The Port Authority Transit Corporation (PATCO) Speedline System*: The PATCO Speedline system began operations in 1969 with the first trip from Lindenwold, New Jersey to the city centre of Philadelphia. The PATCO Speedline system began services with eight stations in Camden County, New Jersey and four in Philadelphia, Pennsylvania. The PATCO began operations with seventy-five automated high-performance state-of-the-art cars which can operate with a single train operator and travel at speeds of up to seventy-five miles per hour (Delaware River Port Authority, 2006).

Boyce et al. (1972) used residential sales data to examine the effect of the system on house prices. They found positive residential property value effects of the PATCO Speedline system in which $149 positive increase in the price of a house for each dollar of value in time savings.

*The San Francisco Bay Area Rapid Transit (BART) System* and The BART system were the first generation of rail transit systems to be constructed in North America (Giuliano, 2004). The first line began operations in 1972 and the seventy-two mile system was completed by 1974 (see Figure 3.4). An additional line was constructed along the I-580 corridor and opened in 1997. The BART service to San Francisco Airport opened in 2003. It has to be noted that the BART system was the first to use a variety of new technology such as automated fare collection systems and computerised train control. The system was beset with operating problems for several years and did not achieve its designed service frequency until a decade after its opening.

Dvett et al. (1979) was known as one of the early researchers who conducted studies on the effects of the BART system on property values. They found that residential properties near four of six stations had greater price increases compared to other residential areas which were not served by a BART system. In addition, they also found that office rents had increased slightly after station openings compared with other office areas. Landis et al. (1995) and Landis and Loutzenheiser (1995) conducted a study to examine the effects of the BART system on property values. The analysis was conducted at several levels, from super-districts to hectare grid cells and included many different sources of data. Interestingly, the results of their studies contrasted with the previous research in which they found that there is no relationship between the BART system and property values.

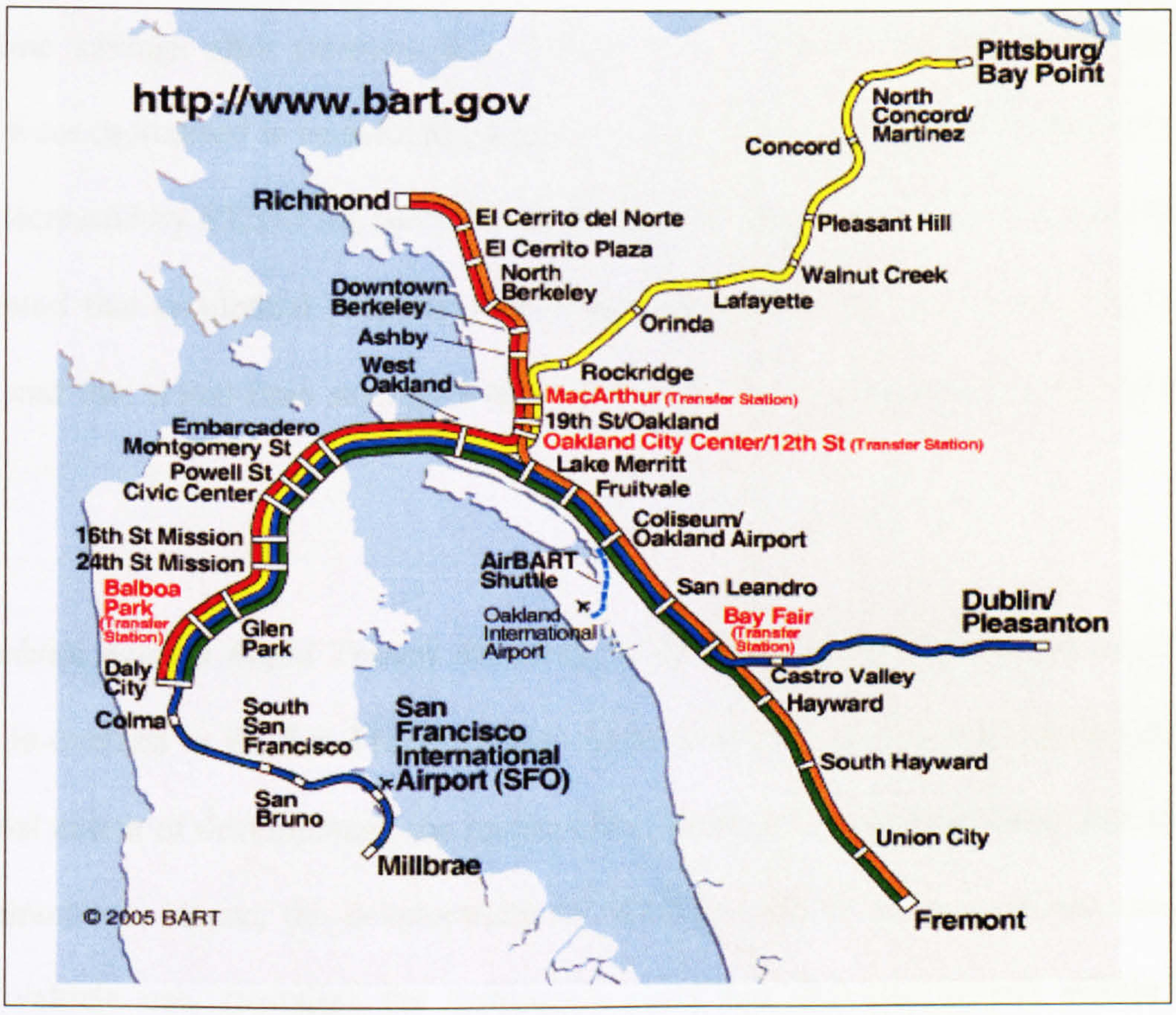



**Figure 3.4**: The BART system
*Source*: http://www.bart.gov/stations/map/systemMap.asp

*Toronto's Yonge subway system*: The Toronto's Yonge subway system was the very first subway line in Canada. The subway system began operating in 1954 and was conceived and built with revenues gained during the war when gas rationing limited the use of vehicles. An additional network has expanded to encompass four lines and sixty-nine stations. It must be noted that Toronto's Yonge subway system has several branches including Toronto's Bloor-Danforth subway line and Toronto's Spadina subway line (Toronto Transit Commission, 2006).

Dewess (1976) and Bajic (1983) conducted "Toronto's Yonge subway system study" which focused on Toronto's Bloor–Danforth subway line and Toronto's Spadina subway line. Dewess found that residents living within one-third of a mile of a subway line experienced travel time savings after transportation facility improvements and that these travel-time savings were capitalised in residential property values. Dewess noted that residential property values decreased by $2,370 for every additional hour of travel to the subway line. Likewise, Bajic found that residential property values increased by $2,237 after a new subway line opened and that travel-time savings were significant in estimating this change in property values.

*Metropolitan Atlanta Rapid Transit Authority or MARTA:* As has been noted by Giuliano (2004), in contrast to the San Francisco Bay Area, where the physical geography constrains the spatial extent of development, the metropolitan areas of Atlanta have been able to expand in all directions. Hence, the development of MARTA was to increase transit use, reduce private vehicle use, revitalize the downtown areas and promote growth within the rail corridors. The first MARTA line was the East Line and it began operating in 1979. The system was completed by 1996.

Several studies were conducted to examine the effects of the MARTA system on property values. For example, Nelson (1992) conducted a study to examine the effects of the MARTA system on house prices. He found that houses in low income groups gained value, but houses in high income groups did not. As noted by Ryan (1999), the results from this study indirectly support the idea that property values change in cases in which travel-time savings occur. It is clear here that low income households are more likely to use transit and experience travel time savings from improved service. Whilst higher income households are less likely to use transit and therefore less likely to experience travel time savings from improved transit service.

*Miami's Metrorail*: Miami's Metrorail system began service in 1984 and serviced the Dadeland South-North to Arena stations. An additional line was constructed and opened in 1985 and the most recent addition to the line opened in 2003. Miami might be considered a better candidate for rail transit than Atlanta with its large share of immigrants, large elderly population and much higher average population density (Giuliano, 2004). Systems planners saw Metrorail as a tool for potential economic development and sought to use it to revitalise economically depressed areas of the city.

Gatzlaff and Smith (1993) used residential sales transaction data to examine the effects of the Metrorail system on land values. They found that access to a station had either no effect or a negative effect on house prices. As deliberated by Giuliano (2004), these results are consistent with the lack of passengers on the Metrorail. It implies that there is no effect on accessibility.

*London's Jubilee Line system*: London's Jubilee Line system began operating in 1979 and an additional line was constructed along Fleet Street to stations at Aldwych, Ludgate Circus, Cannon Street and Fenchurch Street and then under the River Thames to New Cross. However, because of changes in land use (in particular the urban renewal of the Docklands area), caused the project to extend the line beyond Charing Cross and to change considerably in the 1990s. The Jubilee Line Extension opened in three stages in 1999, split from the existing line at Green Park, creating a one-station branch to Charing Cross, which is now closed. With the extension in place, the Jubilee Line is the only line on the London Underground network that has interchanges with all other lines.

Chesterton (2000) conducted "The Jubilee Line Extension (JLE) Impact Study" to examine the effects of the Jubilee Line Extension (JLE) system on property values. The analysis was conducted at several areas, namely City Fringe, East of City Fringe, Isle of Dogs and East London. The results of this study are as mixed as the study areas, years of data and type of housing. For example, in East of City there were significant effects on terraced house prices for the years 1994-1997 and 1998-1999. However, the most significant effects on flats and maisonettes house prices were found in the years 1989-1993 and 1998–1999. It has to be noted that, the JLE has had a very limited direct effect on commercial property values.

### 3.4.3.5 Light Rail Transit Systems Studies: Methods and Study Design

In the section above, the empirical evidence of heavy rail transit systems both in the UK and North America were summarised. Within the same context of effect, light rail transit system will now be discussed in order to understand its relationship with property values.

Ryan (1999) claims that light rail transit systems should have less effect on property values than heavy rail transit systems. This is because light rail transit systems have lower average speeds and capacities. Hence, light rail transit systems should result in less time saving than heavy rail transit systems. Table A1.1 of Appendix A provides selected results of the light rail transit system studies, particularly the approaches used to measure transportation access. Note that eleven of the twelve light rail transit systems studies use regression analysis (see for example, Al-Mosaind et al., 1993; Landis et al., 1995; Forrest et al., 1996; Ryan, 1997; Workman and Broad, 1997; Henneberry, 1998; Dueker and Bianco, 1999; Knapp et al., 1999; Weinberger, 2000; Cervero and Duncan, 2001; 2002). However, one of the studies employs a test-control technique (see for example, VNI Rainbow Appraisal Service, 1992).

It was found that all twelve studies use distance from a light rail station or line as a measure of access. For example, Henneberry (1998) measures the shortest straight line distance from a property to the tram line and station. Forrest et al. (1996) measures distance from only those properties within one kilometre to two kilometres walking distance of the nearest station. Al-Mosaind et al. (1993) used distance as a dummy variable and compares residents in and out of a 500 metre walking distance. They also used distance as a continuous variable and include only those properties within 500 metres walking distance from a light rail transit facility. Workman and Broad (1997) measure the street network-distance of residential properties from the light rail transit station. A study conducted by Ryan (1997) measures the straight line distance of properties (office and industrial properties) to the nearest light rail transit station. As has been noted by Ryan (1999), there have been no studies of light rail transit that use travel time savings as a measure of accessibility levels. It must be noted that three of the light rail transit studies are longitudinal analyses and the remaining studies are cross-sectional studies.

### 3.4.3.6 Summary of Empirical Results of Light Rail Transit System

In observing the effect of light rail transit system towards property values, the results of these studies showed some inconsistencies and varied evidence. This is very similar to that of the outcome of heavy rail transit studies. Comparing results (see Table A1.1 of Appendix A) we observed that Al–Mosaind et al. (1993), Chen et al., 1997; Dueker and Bianco (1999), Knapp et al. (1999), Weinberger (2000), Cervero and Duncan (2001; 2002) show positive effects of the light rail transit on property values. The remaining studies found negative effects on property values near transit stations, and some of the studies found positive effects on property values further away (see, for example, Forrest et al., 1996; Ryan, 1997; Workman and Broad, 1997; Henneberry, 1998).

*Manchester Metrolink*: The Manchester Metrolink system was the first of the "second generation" rail transit systems to be constructed in the UK. The first line began operating in 1992 – operating from Bury in North Manchester, through Manchester city centre to Altrincham in south Manchester, and the thirty-seven mile system with thirty-seven stations was completed by 1999 – operating from Manchester city centre west to Eccles (see Figure 3.5). An additional line will be expanded over the next few years and several areas will be served by this system; Manchester International Airport, Stockport, Rochdale and Ashton-under-Lyne (Manchester Metrolink, 2007). The Manchester Metrolink system is an impressive and efficient light rail transit system which is essential in connecting several areas of Greater Manchester.

Forrest et al. (1996) conducted a study on the impact of the Metrolink system on house prices after its opening. They found no significant effect of house prices for residential properties that served by LRT systems in Manchester.

*Sheffield Supertram*: Construction of the Sheffield Supertram began in 1991 and it was opened in 1994, shortly after the operation of a similar system in Manchester. The eighteen mile system served several prominent areas from Sheffield city centre northwest to Middlewood and Malin Bridge, via the University of Sheffield and Hillsborough; northeast to Meadowhall, via Attercliffe; and southeast to Halfway and Herdings Park, via Norfolk Park, Manor and Gleadless. The Sheffield Supertram consists of a mixture of on-street running, reserved right-of-ways and former railway alignment.


**Figure 3.5**: The Manchester Metrolink system
*Source*: http://www.lrta.org/Manchester/index.html

The construction of the Sheffield Supertram has attracted researchers to investigate the link between the system and property values. For instance, Henneberry (1998) conducted a study to measure the effect of the Sheffield Supertram on house prices in South Yorkshire. In order to measure the effect of the system on residential properties, house price transactions for three different time periods were collected; before the decision was taken to build the system that is for collection of public opinion, before any substantial construction work had started and after construction of the system was completed. Results from this study have shown that house prices had higher premiums before any plan to build was proposed and when the proposed project was made known to the public. However, he found no significant effect on house prices after construction was completed. It has been argued by Henneberry that no significant effect was found after opening the service due to the anticipated nuisance caused by the construction works.

*Los Angeles LRT*: There are two LRT lines operating in Los Angeles; the Blue Line and the Green Line. The Blue Line's LRT system began service in 1990 at a cost of $US 877 million. It follows the alignment of downtown Los Angeles and the 7th St/Metro Centre station and downtown Long Beach. The Blue line connects twenty-two stations along a twenty-two mile corridor and it is currently the longest LRT line in the US. In April 2002, daily passengers of the service reached 68,000 (Cervero and Duncan, 2002). The second line of the LRT service in Los Angeles is the Green Line; the twenty mile line connects fourteen predominantly elevated stations between Norwalk and the El Segundo costal area. It also serves Los Angeles International Airport via a free shuttle bus from Aviation station. The system began service in 1995 and cost $US 718 million. In April 2002, 27,000 passengers used the service each day (Cervero and Duncan, 2002).

The question here is; does the Blue Line and the Green Line affect property values for those areas that have been served by the system? In order to answer this question, Cervero and Duncan (2002) conducted a study to measure the effect of these two lines on property values. Interestingly, they found that the existence of LRT stations produced significant positive price effects on commercial and residential property values.

*San Diego LRT*: The San Diego Trolley light rail system has been operating since 1981. Over its twenty-five years of service, the system has expanded to a fifty-three mile (85.3 km) LRT network serving the San Diego County region. There are three distinct line segments; the Blue Line, Orange Line and Green Line. Among many distinctions, the San Diego Trolley was the first new LRT system to operate both LRT service and night time freight service through a temporal separation arrangement. The LRT system is operated and maintained by San Diego Trolley, Inc. (SDTI), a wholly owned subsidiary of the San Diego Metropolitan Transit System (MTS). The entire right-of-way over which the joint service is operated is owned by MTS through a Nevada Corporation, the San Diego Arizona Eastern Railway Corporation. Of the entire 108-mile right-of-way purchased from the Southern Pacific Railroad in 1979, only 30.5 miles represent joint-service territory.

The construction of the San Diego LRT system has attracted researchers to investigate the correlation between the system and property values. Ryan (1997) conducted a study analysing the effect of the San Diego LRT system on office and industrial properties. The results of this study showed that there were negative effects on office and industrial properties. In other words, the availability of the LRT system did not capitalise property values.

*Metropolitan Area Express (MAX)*: The Metropolitan Area Express (MAX) system is a light rail transit that has been constructed in the metropolitan area of Portland, Oregon. The first line (well known as the MAX Blue Line) began operating in 1986 with the Portland-Gresham, and the system was extended from downtown Portland to Hillsboro in 1998. An additional line (Red Line) was constructed along the Beaverton Transit Centre and Gateway Transit Centre; service to the Portland International Airport opened in 2001. The system was completed by 2004 through the operation of the Yellow Line to North Portland.

Chen et al. (1997) conducted a "MAX Study" to examine the effect of MAX on house prices (single-family residential) after its opening. The analysis was conducted for residential properties that were located near to the LRT line and station. The overall conclusion was that house prices were affected by being located near to the MAX stations, but no significant effects showed on residential properties located near to its line.

*Santa Clara Valley Transportation Authority (VTA)*: The Santa Clara Valley Transportation Authority (VTA) system was a light rail transit system consisting of 42.2 miles of track with sixty six stations in operation on the three lines; Alum Rock-Santa Teresa Line (thirty six stations on this line), Mountain View-Winchester Line (thirty four stations and fourteen of which are shared with the latter) and Almaden Shuttle Line (three stations on this line). Note that the system began operating in 1987 and has gradually extended since then.

In Santa Clara, Weinberger (2000) studied the effects of the Santa Clara Valley Transportation Authority (VTA) on commercial properties. He found that the availability of the VTA LRT system produced significant positive price effects. However, there were distance decay effects of the VTA LRT system on commercial rents and sales prices; positive price effects were found for commercial properties that were located within a quarter of a mile and a quarter to half a mile. As for commercial properties located beyond that, no significant effects were found.

## 3.5 Conclusion

This chapter has extensively reviewed the empirical evidence of the effects of rail transit systems on property values. It began by describing the accessibility-transportation-house price relationships, then leading to the theoretical expectations of these relationships. It has been mentioned above that the improvement of accessibility to city centres for those living in residential areas was due to the improvement in transportation systems such as through the introduction of rail transit systems. For instance, the introduction of rail transit systems such as heavy and LRT systems in many countries have been shown to improve accessibility along the rail line corridors compared to areas that are not served by the systems. Since the accessibility has improved it made houses located closer to a rail transit station much more attractive and hence more valuable than houses located further away. As a result, house prices were found to decrease for every metre away from a rail transit station. The empirical evidence indicates that there have been many studies in the North America and UK on the effects of rail transit systems on property values, leading to the following conclusions:

1. The effect of heavy rail transit systems on property values is much greater compared to the LRT system.
2. Studies that incorporate a direct measure of travel time savings tend to show positive property value effects.

3. A necessary but not sufficient condition for property value effects is the significant effect on accessibility. Rail transit systems typically have little effect on accessibility. This is because most of the rail investment replaces existing bus services and even many route-miles of rail serves only a small share of a city's origins and destinations.
4. Effects are highly localised and tend to occur in fast-growing and heavily congested core areas.

# CHAPTER 4

## Towards Estimating Total Economic Value of the LRT System

### 4.1 Introduction

The discussion in Chapter two presented the basic theory of urban economic, in particular the residential choice of the household as determined by the trade-off between space for living and accessibility to the CBD. The residential location behaviour of households is described in a micro-economic framework. Within this theory, patterns of urban land use (for example residential land use) are determined by land values that are in turn, related to transportation costs. In other words, there is a distance decay relationship between land rent and distance from the CBD. As a result, the greater distance a household lives from the CBD, the more it will have to spend for transportation and the less it will have to spend for housing. Therefore, any significant improvement in the transportation system that increases accessibility and reduces transportation costs should result in an increase in property values.

Evidently, as has been discussed in Chapter three, the improvement in the transportation system through the construction of rail transit systems that increases accessibility and reduces transportation costs results in an increase in property values – residents have to pay a higher price for the house that is located closer to the rail transit stations. Moreover, the theory of urban economics that has been discussed in the preceding chapter is a theory that has underpinned hedonic house price models, in particular the trade-off model of residential location and the distance decay relationship between land rent and distance from the CBD.

The theoretical foundation provided by the micro-economics theory has shaped much hedonic house price research. The motivation behind the early hedonic house price research was to provide empirical evidence of a negative land rent gradient as verification of the trade-off model (Orford, 1999). The aim of this chapter therefore, is to present the non-market valuation technique, namely the hedonic price model for the purpose of estimating the effects of Kelana Jaya Line LRT system on house prices in the Klang Valley, Malaysia.

The organisation of the chapter is as follows: the following section of this chapter contains a discussion on total economic value (TEV) which is the basic concept that needs to be understood – the focus, of course, will be given to the rail transit systems and its total economic value. It is important to note here that the discussion in this section would answer the question of what is being valued and how total economic value as a concept helps to understand this. Section 4.3 provides the justification of using revealed preference technique such as hedonic price models in this study. Section 4.4 provides a brief review of the hedonic price model which is the technique that can be used to estimate a monetary value for rail transit systems goods – its effect on land values such as house prices. Section 4.5 discusses of some of the theoretical constructs that provide the foundation of the hedonic price model – namely implicit markets and utility theory. Section 4.6 describes the hedonic price function. Section 4.7 discusses the hedonic price models and incorporation of space, whilst section 4.8 introduces new techniques of the study of housing prices, namely local techniques. In the concluding section (Section 4.9), the material presented is brought together to justify the approach proposed for use in the remaining chapters of this thesis.

## 4.2 Total Economic Value of the LRT System

As discussed previously, the decision to invest in public transportation such as rail transit systems are the subject of much debate and lobbying among planners and policy makers, and it has also been a great interest amongst the public because it involves large sums of money. Given limited resources, the construction of rail transit systems such as heavy and light rail transit systems can go ahead if it maximises net benefits to society as a whole. In the case of rail transit systems, it has been mentioned in Chapter one that rail transit systems are recognised to have a number of public benefits/values including congestion relief, reduction in per capita road-traffic accidents, energy savings, environmental advantages, improved personal mobility for disadvantaged groups and transit-oriented development. However, it is widely acknowledged that market transactions provide an incomplete picture of the total economic value of rail transit systems or other indirect benefits which are anticipated to result from the construction of rail transit systems. In order to examine the total economic value of rail transit systems, it is important for us to understand its concept which extends beyond market transactions.

Economists have clearly defined the economic value of public goods such as rail transit systems. In the case of rail transit systems, its economic value depends on the total amount of money that individuals would be willingly to pay in order to have an opportunity to be located within close proximity of a rail transit station. The total amount of money that individuals would be willing to pay represents the total economic value of the improvement of public transportation due to the construction of rail transit systems. Randall (1991) categorised the total economic value into two parts; use and non-use values/benefits. Use value is associated with the direct use of the goods or services. In the context of rail transit systems, direct use value is defined as the maximum willingness to pay (WTP) to be located within close proximity of a rail transit station in order to experience improvement in accessibility following the existence of rail transit systems. Yet, rail transit systems may generate benefits even to those who do not use the service. Non-use value includes benefits that residents enjoy because they know the system exists. These values might be motivated by a desire that the system be available for others to use (altruistic values), that the current non-rider may decide to become a rider in the future (option value) or simply that the system would improve the image of the areas where it is located (existence values). The TEV of rail transit systems will then include both use values and non-use values (locational externalities). Thus, the emphasis of this study is to estimate the increased value of land in the form of house prices due to the locational externalities that are generated following the construction of the rail transit systems such as LRT system since house price transactions reflect both use and non-use values.

In order to measure the locational externalities generated by rail transit systems upon residential property values, it may be useful to apply empirical techniques to estimate individual willingness to pay to be located near to a rail transit station. The literature shows that, there are two broad categories of non-market techniques: revealed preference techniques on the one hand and stated preference techniques on the other. This study uses the revealed preference techniques of hedonic pricing to measure the effects of light rail transit (LRT) on house prices in the Klang Valley, Malaysia.The justification of using revealed preference techniques namely hedonic pricing as opposed to a stated preference techniques is given in the following section.

## 4.3 Why Revealed Preference Techniques

As mentioned above, the locational externalities generated by rail transit systems upon residential property values will be obtained using perhaps the most widely employed revealed preference techniques that is hedonic price models (HPM), which involves the analysis of actual willingness to pay by households' using house price transactions. The question is why must revealed preference techniques namely hedonic price models be chosen as a technique to estimate locational externalities that are generated by the rail transit systems in this study as opposed to a stated preference technique? Before answering this question let us first define what it means by revealed preference techniques and stated preference techniques. In the valuation literature, revealed preference techniques such as hedonic price models, travel cost models, defensive behaviour and damage costs are defined as a technique to obtain households' preferences or willingness to pay for public goods or environmental amenities from actual choices that their make within markets (Boyle, 2003). On the other hand, stated preference techniques such as contingent valuation (CV), contingent behaviour and choice experiments are defined as a technique that ask households' questions that are intended to obtain their preferences or willingness to pay for public goods or environmental amenities without requiring the consumer to act accordingly (Loureiro et al., 2003; Carson et al., 1996). Boyle (2003) suggests that the main difference between these two techniques is the types of data used to estimate values of public goods or environmental amenities.

As noted earlier, between these two techniques a revealed preference technique namely hedonic price models is chosen in this study due to several reasons. Firstly, as has been criticised in the literature, there are several limitations that always being associated with stated preference techniques. The common criticism of any stated preference technique is due to the hypothetical nature of the questions and actual behaviour is completely ignored from the observation (Earnhart, 2001; Mitchell and Carson, 1989). For instance, studies carried out by Champ et al. (1997), Loomis et al. (1996) and Navrud (1992) found the willingness to pay value derived from the contingent valuation to be a less satisfactory predictor of actual value. Chung (2008) offers an explanation for this unsatisfactory value. He suggests that the unsatisfactory value may occur due to the presence of potential biases inherent to the design of the CV survey such as yes-saying, protest answers and information bias. As he suggests further, some of these biases overestimate while others underestimate actual willingness to pay therefore produced unsatisfactory value. In addition, it has been argued further that survey households' may ignore their budget constraint in answering hypothetical questions (Azevedo et al., 2003). There are also concerns with the issue of willingness to pay fail to vary sufficiently with the scope of the resource being valued or the so-called embedding effect (Azevedo et al., 2003).

On the contrary, the main strength of any revealed preference technique is that it is based on observed behaviour (Earnhart, 2001). For instance, in hedonic price models willingness to pay of households' is derived from decisions to purchase a house from among choices that have different levels of attributes such as structural, locational and socio-economic attributes. This in line with the intention of conducting this study in which to examine a real market rather than a hypothetical market that is the basis in CV surveys. In addition, the selection of revealed preference technique is due to the availability of the data. Yet, the revealed preference technique, in particular hedonic price models also suffers from several weaknesses. The common criticism of hedonic price models is collinearity between independent variables especially when many variables are included in the model leads to large standard error of estimators (Freeman, 1993). Since hedonic price models is a well-established technique there are various measures are available to cope with collinearity issue in the models. These measures will be discussed in great details in the subsequent section. The other criticism is related to the issue of being depends critically on the control of all important factors behind location choices. To handle with the issue, hedonic studies incorporate numerous independent variables (Freeman, 1993). The subsequent sections will discuss how to value the locational externalities generated by rail transit systems upon residential property values using hedonic price models.

## 4.4 A Brief Overview of the Hedonic Price Models

The hedonic price model is a well-established technique used for analysing a market for a single commodity with many attributes. In other words, the hedonic price model is based on the idea that properties are not homogeneous and can differ in respect to a variety of characteristics. The hedonic price model uses market goods within which the non-market goods are implicitly traded. Take accessibility improvement through introducing a new transport facility such as rail transit systems for example. We assume that in general, people would prefer a highly accessible mode of transport for commuting from one place to another, but since no market exists for accessibility, we have no direct market evidence on how much they value this accessibility. However, accessibility is implicitly traded in the property market. Individuals can express their preference for an accessible location through purchasing a house near the rail transit station or major roads. A measure of the value of accessibility could be taken as the extra that is paid for one of two identical houses that is highly accessible. This difference is known as a price differential.

The hedonic price model has been applied to a number of non-market goods. In addition, the hedonic price model expresses the market value of some composite goods as a function of its various intrinsic and environmental attributes and reflects the envelope function of both supply and demand sides (Rosen, 1974; Can, 1990, 1992; Dubin, 1998). This model was originally developed by Lancaster in 1966 and Griliches in 1971, and became well known after expansion by Rosen in 1974, later summarised by Freeman (1979b; 1985) and recently by Palmquist (1991). This approach is derived from the consumer theory that states the characteristics of any commodity determine its utility (Lancaster, 1966). Since this theory has been extended to the housing market by Rosen, housing hedonic analysis has become widely used as an assessment tool and for a property market and urban analysis. In the context of housing study, numerous applications have proven that the hedonic house price model is a powerful econometric tool, in particular capturing important determinants of house prices based on its structural and locational attributes.

Moreover this model has been used to explain disparity in house prices by differences in the attributes of the house. In other words, house prices are regressed on a package of inherent attributes (Rosen, 1974). This is because each unit of housing has an exclusive package of attributes such as its structural attributes, accessibility to work, transport and the amenities, the socio-economic and public sector attributes of the neighbourhood, the aesthetic and environmental attributes of the neighbourhood and the property rights or legal constraints regulating the use of the property may be included in the analysis (Powe et al., 1995; Tse, 2002). The relationship between house prices and location quality has been explored by using a variety of theoretical and econometric approaches (see for example, Muth, 1969; Evans, 1973; Lerman, 1979). Nevertheless, it is important to note that a hedonic equation helps to clarify house prices in terms of the housing's own attributes.

There are two common reasons behind using the hedonic price model in the housing price study (Powe et al., 1995). Firstly, this model can be used to directly model a house price as a function of the levels of various attributes. Secondly, it can also assume the coefficients of the estimated hedonic price function that reflects public willingness to pay for those attributes. These coefficient values are particularly useful in deriving the marginal willingness to pay for a unit enhancement in the level of that attribute. This is achieved by evaluating the partial derivative of the hedonic price function with respect to the attribute, whilst holding all other variables at their mean values.

However, one of the main problems in studying property values or specifically house prices is how to handle and integrate the spatial dimension. Property values for instance, are considered by many authors to be the outcome of the complex combination of externalities and location rents. In the context of housing study, house prices cannot be simply determined by the individual attributes of the dwelling itself because the number and nature of influences on house prices are large and heterogeneous. For example, the composition of the typical housing package is likely altered as a result of an increase in transport costs. Therefore, it reflects adjustments in consumer behaviour in responding to changing in relative prices of housing. The effect of accessibility improvement on house prices also varies based on income groups, since workers tend to value their travel time at their salary rates. In addition, households and local communities are increasingly concerned with transport costs and time for commuting from home to the CBD or workplace and sensitive to the overall quality of their neighbourhood.

Following Tse (2002) the relationship between house prices and location effects can be a result of unobservable links across house attributes that is influenced by the heterogeneity of the market and of its players. Tse has argued that it is important to differentiate between structural spatial dependence through observations and spatial dependence in error terms. As Tse (2002: pp. 1168) illustrates, 'generally due to omitted variables, which are themselves spatially correlated or due to errors in measurement that are systematically related to location'. Tse has stressed that house prices are not merely determined by the demand for the attributes of the dwelling units themselves, but also by the region in which the units are located. Tse, however, noted that a good hedonic study has to include neighbourhood quality measures, at as disaggregated a level as possible. If each neighbourhood has its own effects then the hedonic price model would ideally require a separate indicator variable for each neighbourhood.

In the context of the relationship between property location and accessibility to the CBD or workplace, several studies have highlighted the positive effect of heavy and light rail transit systems on property values (see for example, Boyce et al., 1972; Lerman et al., 1978; Bajic, 1983; Dvett et al., 1979; Damm et al., 1980; Voith, 1991; Nelson, 1992; Al-Mosaind et al., 1993; Gatzlaff and Smith, 1993; Benjamin and Sirmans, 1994; Du and Mulley, 2006), whilst also showing the negative effect (see for example, Dewess, 1976; Nelson and McClesky, 1990; VNI Rainbow Appraisal Service, Inc., 1992; Cervero and Landis, 1993; Armstrong, 1994; Landis et al., 1995; Landis and Loutzenheiser, 1995; Landis et al., 1995; Forrest et al., 1996; Ryan, 1997; Henneberry, 1998; Du and Mulley, 2006; Hess and Almieda, 2007). The following section of this chapter discusses some of the theoretical constructs that provide the foundation of the hedonic price model – namely implicit markets and utility theory.

## 4.5 Theoretical Foundation

Before discussing the definite estimation and use of hedonic price models of housing markets, it is important to understand some of the theoretical constructs that form the foundation of this approach. The purpose of this section is twofold. Firstly, it describes the *utility theory* and secondly it describes the *implicit market* that forms the foundation of hedonic price models.

### 4.5.1 Utility Theory and Implicit Markets

The foundation of hedonic price model is about – when the households purchased these commodities and consumed them as a type of input, transforming them into *utility*, the level of which depends on the quantity of characteristics embodied in the commodities purchased (Orford, 1999; Sheppard, 1999). Historically, the word utility has been used in economics to indicate subjective feelings such as satisfaction and pleasure. According to Orford (1999) when a commodity is consumed, some benefit or satisfaction is derived. This is called utility. Utility has been conceived as the property of an object that produces benefits, advantages, pleasure and happiness (Veldhuisen and Timmermans, 1984). Utility theory identifies a consumer's utility function based on either assumed or revealed preferences and predicts choices constrained by the consumer's level of income or budget (Fujita, 1989). The conventional utility maximisation problem can be specified as U (x, p), where x represents a vector of commodities ($x = x_1 \ldots, x_n$) and p represents a vector of prices ($p = p_1 \ldots, p_n$). The consumers face the budget constraint Y per unit time, where Y represents annual income, which is spent on a vector of commodities. We can express the conventional utility maximisation problem as (Orford, 1999):

$$\text{maximise } U(x), \qquad \text{subject to } \sum (p_i x_i) = Y \tag{4.1}$$

It is clear here that the choice of x is restricted to $p_i = Y$. It is reasonable to assume that the subsistence of the consumer needs a positive amount of both x and p. Therefore, the consumer utility function U(x, p) needs to be defined only for positive x and p. This is equivalent to saying that the indifference curves in the consumption space do not cut axes (Fujita, 1989). Considering this, Orford (1999) introduces a set of ordinary utility functions; the utility function is continuous and increasing at all $x > 0$ and $p > 0$.

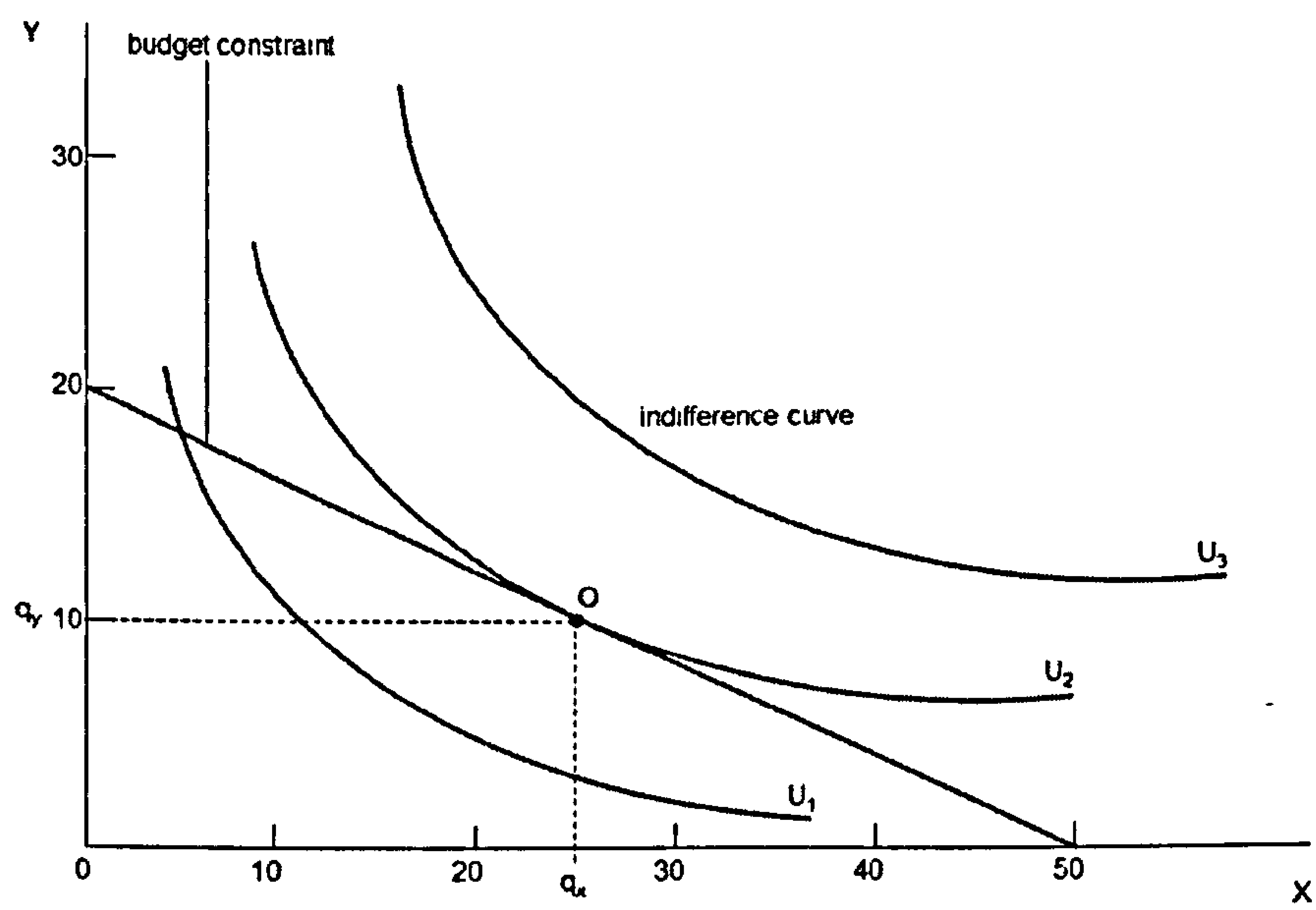



**Figure 4.1**: A hypothetical utility function for two commodities
*Source*: Adapted from Orford (1999: pp. 15)

Indifference curve in the consumption space can be depicted as in Figure 4.1. Graphically, as depicted in Figure 4.1, an indifference curve ($U_2$) joins together all the combinations of two commodities (x and y) which provide the same utility to the consumer. The slope of the curve is the marginal rate of substitution and reveals the combinations of the two commodities to which the consumer is indifferent. To determine which combination is chosen, income levels and the price of the commodities also have to be taken into consideration. This is the budget constraint faced by the consumer and is shown by the budget line in Figure 4.1. The optimum point on the indifference curve that intersects the budget line is called the point of consumer equilibrium. Also, it is the point at which the consumer is maximising his or her utility subject to their budget constraint (point 0 in Figure 4.1). The indifference curve with utility level u can be expressed in implicit form as u = U(x, y) or solving u = U(x, y) for x. The equation of the indifference curve with utility level u can be expressed as (Orford, 1999):

$$x_i = x_i(P, Y) \tag{4.2}$$

A second foundation of the hedonic price model comes from implicit markets. The concept of implicit markets was originally based on Rosen (1974) and later Follain and Jimenez (1985). This study provided an insightful discussion of the theoretical foundations in the application of hedonic techniques to the estimation of housing demand, which they defined the process of production, exchange and consumption of commodities that are primarily traded in *bundles* (Megbolugbe, 1989; Sheppard, 1999). According to Sheppard (1999) the explicit market, with observed prices and transactions is for the bundles. Sheppard has explained that such a market however, might be thought of as constituting several implicit markets for the components of the bundles themselves. This is of particular importance when the bundles are heterogeneous and differ due to the varying amounts of different components that they contain. For example, commodities such as houses are assumed to be made up of bundles of attributes such as the size of the house, age, floor, social and economic characteristics of the neighbourhood including the presence of amenities such as views, schools, universities and community services. In addition, attributes include physical characteristics of the house, accessibility of the location in relation to the CBD, employment centres and other recreational facilities. As Rosen (1974) demonstrates, commodities like houses that contain bundles of attributes and are not explicitly traded on the market are however traded as part of a package of housing services.

The implicit markets are incapable of being analysed with the common economic models because they are not characterised or even approximated by a single price, but rather by a variety of prices that depend on the quality of the commodity and the characteristics it contains (Sheppard, 1999). In order to deal with this difficulty, the hedonic approach provides a methodology for identifying the structure of prices of the component attributes. Moreover, these can then be used to estimate the market valuation for particular housing attributes and subsequently the demand for these attributes. However, the demand for these attributes is constrained only by their incomes and the price of the resulting bundle. The next section of this chapter will continue by describing the hedonic price function.

## 4.6 The Hedonic Price Function

In section 4.5, the theoretical constructs that provide the foundation of this approach that is utility theory and implicit markets have been introduced. The discussion in this section however, will provide a more detailed account of the hedonic price function, describing the underlying concepts such as bid-rent functions and marginal willingness to pay. Indeed, the hedonic price functions are estimated for two primary reasons. First, it is used to describe how the quantity and quality of a property's characteristics determine its price in that particular market. The hedonic price function for any particular property market will be unique to that market reflecting the specific conditions of supply and demand that exist in that locality.

Secondly, the hedonic price function can be used to determine how much more should be paid for a property with an extra unit of a particular housing characteristic. This is known as the *implicit price* of a property characteristic. The hedonic price function is used for constructing the overall prices indices that account for changes in the quality of commodities produced and as an input in the analysis of consumer demand for attributes of heterogeneous commodities. In addition, it can be used to understand the appropriate estimation techniques and problems and to interpret the results. We have begun with an understanding of how a market for heterogeneous goods can be expected to function and what types of equilibria we can expect to observe (Sheppard, 1999).

### 4.6.1 The Theory and Overview

As mentioned above, the primary impetus for research in the area has come from Rosen's (1974) conceptual framework of hedonic prices and implicit markets. As described by Rosen, houses or similar heterogeneous products (such as vehicles) as single commodities are differentiated by the various attributes they contain. Moreover, the market price of the commodity varies as the attribute varies. For example, the composite price for a unit of housing depends on the specific amounts of attributes associated with them namely structural and locational attributes. In other words, for those properties with larger quantities of good qualities such as high accessibilities to the CBD command higher prices, and those properties with larger quantities of poor qualities such as pollution and noise command lower prices. More formally, let Z represent a unit of housing; therefore, any unit of Z, could be described by a vector of its attributes as (Orford, 1999):

$$Z = (z_1, z_2, \dots z_n) \tag{4.3}$$

where $z_i$ (i = 1 to n) is the level or amount of the $i^{th}$ attributes contained in each good. In Rosen's model of implicit markets, P (Z) emerges from the interaction between buyers and suppliers of the commodity, regarding packages of attributes bought and sold. Formally, this can be stated as follows (Orford, 1999):

$$P(Z) = P(z_1, z_2, \dots z_n) \tag{4.4}$$

P (Z) is the hedonic price function and describes the house price emerging from the interaction between buyers and suppliers of housing. In other words, the price of a house (P) is determined by the vector of values (Z) describing its attributes. Households and developers take this price function as given in a competitive housing market. In general the P (Z) which is the relationship between housing attributes and house prices is non-linear. According to Orford (1999), non-linearities may exist due to the nature of the housing market which may not be in long-run equilibrium since housing supply is generally not very responsive to short term and long term changes in demand. Perhaps the most fundamental reason for the non-linear relationship between housing attributes and houses is given by Rosen. As has been argued by Rosen (1974: pp. 37-38), bundles of housing attributes cannot be untied and repackaged to reflect to the consumer's desired mix of housing services. Therefore, it is more reasonable to assume that the suppliers of housing sell bundles of housing services, Z, as part of a package.

Since the price of a unit of housing is a realisation of the price of its attributes, P (Z) can be estimated from observations of prices and attribute bundles of different houses. In addition, the marginal implicit price of any attribute can be found by differentiating the hedonic price function with respect to that attribute. This estimation is given as (Orford, 1999):

$$\delta P(Z) / \delta (z_i) = P(z_i) \tag{4.5}$$

Based on this estimation, it gives the increase in expenditure on Z that is required to obtain a house with one more unit of $z_i$, ceteris paribus. However, it is only under uncertain conditions that the function P $(z_i)$ reflects the household demand for attribute $z_i$. According to Orford (1999) the estimation of a household's marginal willingness to pay for an additional unit of $z_i$ requires a further stage of analysis and an understanding of the relationship between marginal implicit price function, P $(z_i)$, and housing market supply and demand functions.

### 4.6.2 Bid-Rent Functions and Marginal Willingness to Pay of the Household

This subsection develops basic measures of the price of an attribute as a function of supply and demand interactions in a housing market. The point of departure is a marginal willingness to pay functions analysed by Follain and Jimenez (1985) and Orford (1999).

As mentioned in the previous chapter, bid-rent function is a concept that describes the ability and willingness of the households to pay for per unit of housing under a certain fixed equal to the maximum utility level. It is reasonable to assume that a household needs to have a strongly separable utility function. That is, both goods are essential (for example, housing and non-housing goods). Considering this, the following set of assumptions are introduced; U

= u (x, z), where x is the composite commodity of non–housing goods whose price is set equal to one and z is the vector of housing attributes. Households then maximise utility subject to the budget constraint Y = y (z) + z, where y is the annual household income. The partial derivatives of the utility function with respect to a housing attribute are the household's marginal willingness to pay function for that attribute. The derivatives of the utility function can then be derived as (Orford, 1999):

$$Uz_i / Ux = P(z_i) = \delta P(Z) / \delta (z_i) \tag{4.6}$$

i = 1,....,n, under the usual properties of U

It has to be noted that, the bid-rent function is considered as a fundamental feature of Rosen's model. The bid-rent function can be defined as (Orford, 1999):

$$\theta = \theta (z_i, U, Y, \alpha) \tag{4.7}$$

where α is a taste determining variable which varies from household to household. This can be characterised as the trade-off a household is willing to make between alternative quantities of a particular attribute at a given income and utility level, whilst remaining indifferent to the overall composition of consumption. In other words, households measure the value they might realise from the different properties available in the market and bid amongst each other. If one household has the ability such as available income and is prepared to offer more for a property than the value that the present residents realise from that property, then it will make sense for a bid to be accepted (Bateman et al., 2001). From the utility function (4.6) the amount that a household would be willing to pay for a house as a function of the embodied attributes can be derived, given the income and achieved utility level for the household. The bid-rent function of the household is defined implicitly by (Orford, 1999):

$$U = U(Y - \theta, Z, \alpha) \tag{4.8}$$

Tracing out these trade-offs generates a household's bid-rent function for the given attribute, represented by $\theta^1$ in the upper schedule of Figure 4.2. The household represented by $\theta^1$ is everywhere indifferent along $\theta^1$. $\theta$ schedules that are lower correspond to higher utility levels. At maximum utility, the bid-rent curve is tangential to the hedonic price function P (Z). At this point it can be stated as follows (Orford, 1999):

$$\theta_i = Uz_i / Ux \tag{4.9}$$

which in the additional expenditure a consumer is willing to make on another unit of $z_i$ and be equally well off that is the demand curve. Figure 4.2 illustrates two such equilibria namely A for household $\theta^1$ and B for household $\theta^2$. Yet, since P (Z) is determined by supply and demand, the supply side should also be considered. Like buyers, suppliers also accept P (Z) as given, then the marginal cost of providing an attribute whilst maximising profits will be a concave offer curve $\phi$ that is tangential to P (Z). The equilibrium points are achieved when supply equals demand. Since there are many consumers and many suppliers of housing attributes, there are many bid-rent and offer curves. Hence, P (Z) represents a function consisting of the joint envelopes of various supply and demand tangencies (Orford, 1999). This is illustrated in the lower schedule of Figure 4.3.

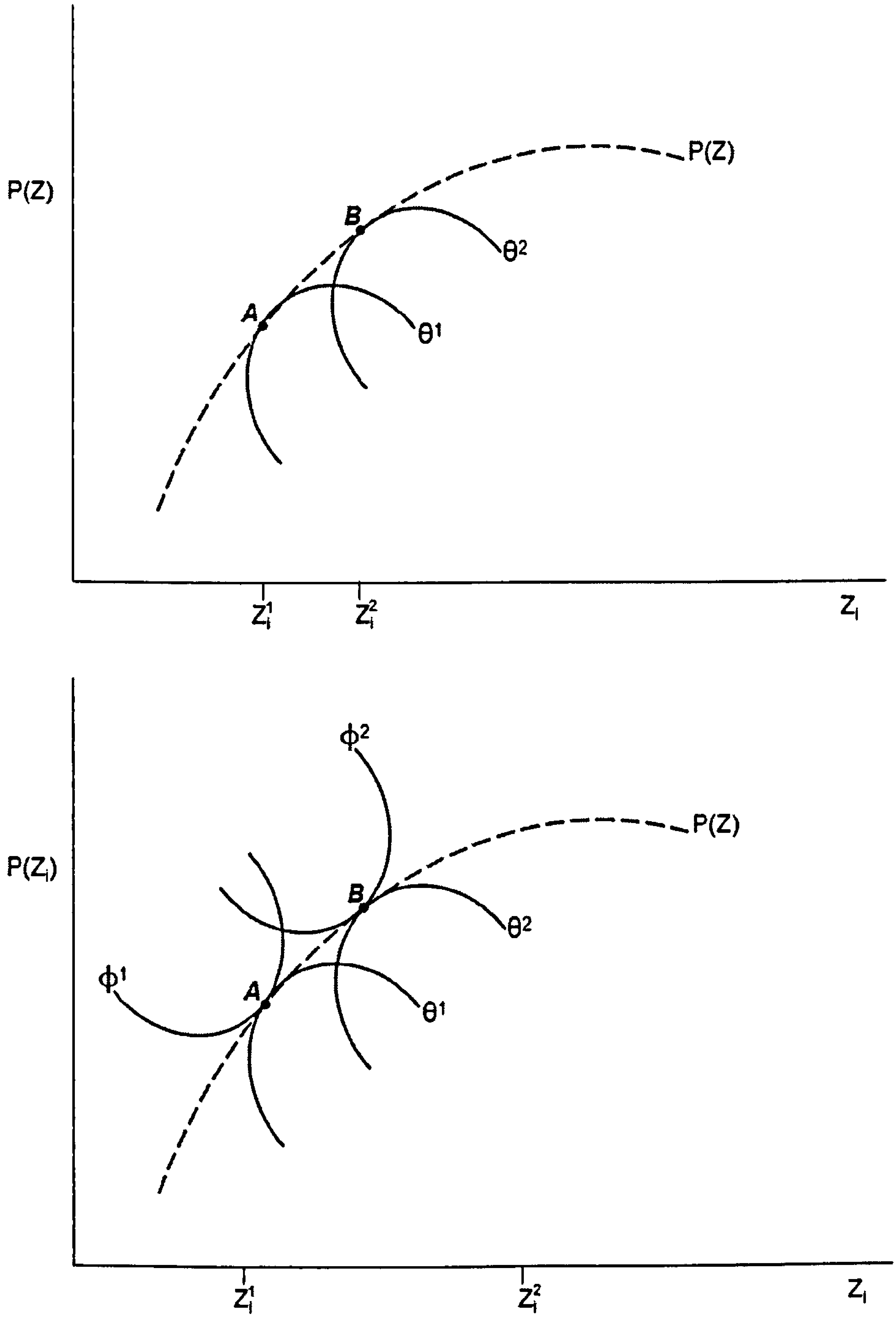



**Figure 4.2**: Demand and offer curves of the hedonic price function
*Source*: Adapted from Orford (1999: pp. 19)

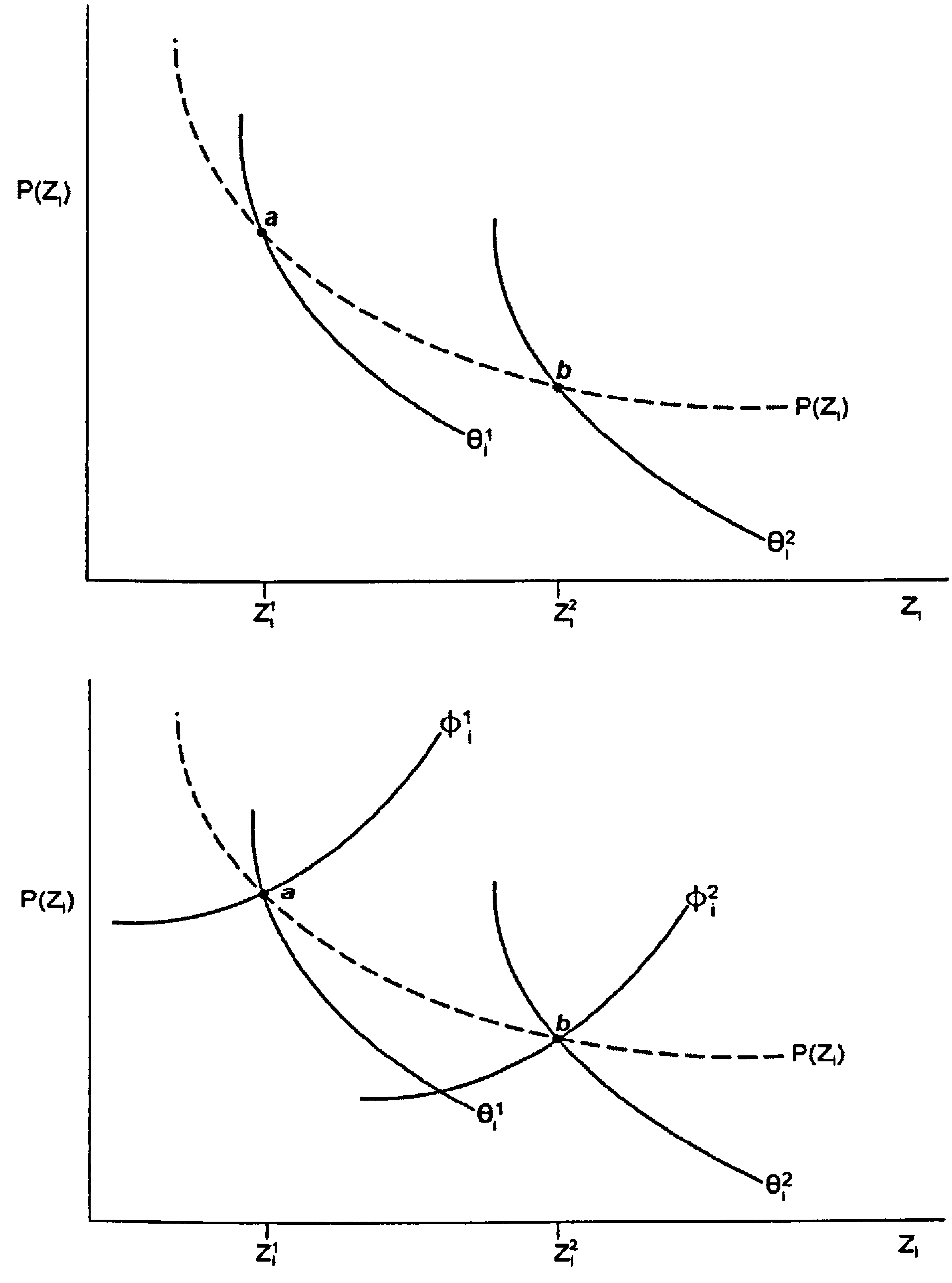



**Figure 4.3**: The marginal implicit price of an attribute as a function of supply and demand
*Source*: Adapted from Orford (1999: pp. 21)

Orford (1999) and Freeman's (1979b) studies show that a household maximises utility by simultaneously moving along each implicit price schedule for a vector of housing attributes until it reaches a point where its willingness to pay for an additional unit of that attribute just equals the implicit price of that attribute. But households with different characteristics will have different marginal willingness to pay curves so they will be located at different points on the implicit price schedule. Thus, the marginal implicit price is generally expressed as (Orford, 1999):

$$\theta i = P\,(z^i) \tag{4.10}$$

This is illustrated in the upper schedule of Figure 4.3. Therefore, if a household is in equilibrium, the marginal implicit prices associated with the chosen housing bundle are equal to the corresponding marginal willingness to pay for those attributes. Hence, the marginal implicit price function of an attribute P $(z_i)$ is the locus of marginal supply curves and marginal bid-rent curves for that attribute by different households (see the lower schedule of Figure 4.3). The implicit price is the point of tangency between the buyers and the suppliers offers function for a given attribute, keeping the quantities of all other attributes fixed. It must be noted here that Rosen's model is very similar to the urban model of residential location described in Chapter two. As Orford illustrates, this is because the trade-off model can be viewed as a special case of Rosen's model, which focuses on two attributes. First, access to the CBD and secondly, everything else about a house that generates utility.

The hedonic approach assumes that the implicit prices of the estimated hedonic price function P $(z_i)$ reflects the assessment of attribute $z_i$ as a result of demand and supply interactions of the entire market. Yet, in general it can be demonstrated that P $(z_i)$ will overstate the inverse demand function for the assessment of an additional unit of the attribute since to the right of point (a) and (b), P $(z_i) > \theta_i^1$ and $\theta_i^2$ (see Figure 4.3). Only in extreme cases when all consumers have identical incomes and utility functions will the marginal implicit price curve be identical to the inverse demand function for an attribute (Orford, 1999; Freeman, 1979b). This happens because P ($z_i$) is the locus of points on the household's marginal willingness to pay curves $\theta_i$. With identical incomes and utility functions, these points all fall on the same marginal willingness to pay curve. In general therefore, the implicit price of an attribute is not strictly equal to the marginal willingness to pay and thus demands for that attribute.

## 4.7 Hedonic Price Models and the Incorporation of Space

### 4.7.1 Introduction

The hedonic price model was developed within an econometric framework and has been implemented to study non-spatial composite commodities such as vehicles, refrigerators and washing machines. For example, Griliches (1971) used the hedonic price model to investigate the relationship between vehicle prices in the US to the various dimensions of vehicles. The hedonic price model has also been widely used to analyse other commodities such as houses. In the context of housing study, the hedonic price model is commonly advocated to estimate the effect of physical housing attributes and spatial attributes, or in other words, the locational attributes.

As has been extensively discussed above, locational effects can be defined as all attributes that are related to the geographic location of a house, both its absolute location and the neighbourhood in which it is located. Indeed, locational effects on house prices have proved more difficult to model and attempts to capture these effects have included the use of postcodes, school districts and neighbourhood groupings (Fletcher et al., 2000) and this has presented a fundamental problem of using hedonic price model. The main issue is how to integrate the spatial element into a non-spatial econometric model. Orford (1999) highlights that ignoring the spatial element of these commodities (such as houses) can result in problems such as spatial heterogeneity and multicollinearity that can fabricate distortions in the econometric model. In addition, these problems can also occur if the spatial element is only partially accounted for. The purpose of this section therefore is concerned with the evaluation of the specifications of hedonic price models, in particular with respect to their capability to handle spatial data.

### 4.7.2 The Traditional Hedonic Specification

Based on discussion in the previous section, it can be argued that housing is a composite and heterogeneous good that provides utility to the consumer. As was noted earlier, housing is composed not only of its structure (such as number of rooms, age, type of house, and size), but also characteristics determined by location (such as neighbourhood and environmental factors). Different authors have grouped these characteristics in different ways; however, Wilkinson (1973b) fundamentally makes the distinction between dwelling specific or structural attributes and location specific attributes. The structural attributes are concerned with factors pertaining to the physical structure of a property such as the number of rooms of various types, floor area and age. Whilst the location attributes are concerned with factors pertaining to the property location such as proximity to transportation services (such as rail transit systems station), accessibility to the CBD, shopping centres, parks, schools, and other recreational facilities. However, far more econometric attention has been paid in the literature to dwelling specific attributes than to location specific ones (Cheshire and Sheppard, 1995). The traditional hedonic specification is the most typical specification employed for housing price index construction. The general form of a hedonic price function can be represented as (Orford, 1999):

$$P\,(Z) = f\,(S, L) + \varepsilon \tag{4.11}$$

where,

P = a vector of observed house prices;
S and L = the vectors of structural attributes and locational attributes respectively;
$\varepsilon$ = a vector of random error terms.

Typically, the specification of this function has been represented as:

$$P_i = \alpha\, X_i + \sum \beta_k\, S_{ki} + \sum \gamma_q\, L_{qi} + \varepsilon_i\, X_i \tag{4.12}$$

where,

i = 1, ..., N is the subscript denoting each property;
$P_i$ = the price of property i;
k = 1, ..., K is the number of structural attributes;
q = 1, ..., Q is the number of locational attributes;
$\alpha$, $\beta$, $\gamma$ and $\varepsilon$ are the corresponding parameters;
$X_i$ = a column vector that consists entirely of ones.

This has been termed the traditional hedonic specification and has been the basic model in the most of the studies (Can, 1992). If the attributes are taken as divergence of their mean, then the model suggests that the price of house *i* is a function of the average price of a typical property ($\alpha$), the cost of structural and locational attributes ($\beta_k$) and ($\gamma_q$) and the price related with the characteristic elements of the individual house ($\varepsilon_i$). Moreover, the model is estimated by ordinary least squares (OLS) regression, in which the regression coefficients represent the implicit price of each attribute (Orford, 1999).Therefore, the hedonic price model has to persuade the following OLS regression assumptions:

1. Linear relationship between dependent and explanatory variables.
2. No perfect multicollinearity among the independent variables.
3. The errors terms are normally distributed with a mean of zero.

4. The error terms are independent, that is, they are not autocorrelated.
5. The error terms have a constant variance, that is, they are homoscedastic.

Any violation of these assumptions can lead to unreliable and biased parameter estimates (Orford, 1999). Orford has stressed that the violations of assumptions four and five are common characteristics of many studies. In addition, it is commonly caused by the misspecification of the hedonic price model. It must be noted that misspecification issues have tended to be concerned with omitted variables and functional relationships. Butler (1982 cited by Orford, 1999) indicated that finding the correct specification of the hedonic relationship for housing necessitates that we identify both the correct list of independent variables and the true functional form. In the following section, the functional forms which are applied are described in order to estimate the hedonic price function.

### 4.7.3 Functional Form

The hedonic price function must be specified correctly, that is, the researcher must choose the functional form which best portrays the relationship between a property's market price and each of the variables describing its characteristics. In other words, the functional form is the exact nature of the relationship between the dependent variable (a vector of house) and the explanatory variables (such as structural and locational attributes). The choice of the functional form has usually been restricted both by theoretically unwarranted restrictions and by convenience in dealing with the problem in hand (Husin, 1990; Watkins, 1998a). However, the convenience of choosing the functional form has caused frequent criticism of hedonic studies (Halvorsen and Pollakowski, 1981).

As noted above, unfortunately, economic theory does not generally give clear guidelines on how to choose a particular functional form for property attributes (Tu, 2000). The question is how then can researchers ensure that they are specifying the correct relationship between the dependent and explanatory variables? The functional form may not be determined from information pertaining to either the underlying supply or demand equations (Quiley, 1982). Instead its shape is determined by the distribution of housing bundle types and household types within a particular market area.

Yet, the four common functional forms used in hedonic house price models are linear specification (both the dependent and explanatory variables enter the regression in their linear form), semi-log specification (the log of the dependent variable is regressed against linear explanatory variables), log-linear specification (a linear dependent variable is regressed against the log of the explanatory variables) and inverse semi-log (both the dependent and explanatory variables enter the regression in their log form (Palmquist, 1984). However, Husin (1990) noted that in thirty-one out of sixty-one studies dated between 1958 and 1987, linear functional forms have been used.

The determination of the appropriate form of functional relationship is as important as the selection of the variables and the quality of the data by which they are measured (Orford, 1999). In other words, an inappropriate choice of functional form may lead to misspecification errors in the hedonic house price function, which may in turn lead to errors in the estimation of the implicit price of a given attribute. However, the main problem in devising the appropriate functional form lies in structuring the model. As a result, it reflects the interrelationships among the independent variables. As Fleming and Nellis (1984) highlighted, misspecification of functional form may introduce a potential source of bias into the regression equation. Since there are no guidelines from the theory, many functional forms are possible and the determination of which form is most appropriate to a particular model is an empirical one. However, the Box-Cox and occasionally the related Box-Tukey generalisation methods of transformation are often used to evaluate various functional forms (see for example, Freeman, 1979b; Halvorsen and Pollawski, 1981). It must be noted that it is since Halvorsen and Pollawski's (1981) contribution that this form has become widely used in most hedonic studies (Cheshire and Sheppard, 1995).

The flexibility of the Box-Cox model and the lack of theoretical guidance on an appropriate function form makes it an attractive model for estimating hedonic price function. For example, Freeman (1979b) demonstrated that out of eight alternative hedonic price functions specified, only the Box-Cox transformation allows the implicit price of an attribute to depend on the level of other attributes and to either decrease or increase as the level of the attribute varies. In light of Orford's findings, even though a full Box-Cox model may be specified, in which all the variables may be on a different power transformation factor, the usual procedure is to use a constrained version where all the continuous independent variables have the same power transformation factors, usually within a range of reasonable values. The specification of a full Box-Cox model can be specified as (Orford, 1999):

$$P(\theta) = \alpha + \sum \beta_k Z_k^{(\lambda k)} + \mu \tag{4.13}$$

where:

$$P^{(\theta)} = \frac{P^{(\theta)} - 1}{\theta}, \qquad \theta \neq 0$$

$$= \text{In } P, \qquad \theta = 0$$

$$Zk^{(\lambda k)} = \frac{Z_k^{(\gamma k)} - 1}{\lambda_k}, \qquad \lambda_k \neq 0$$

$$= \text{In } Z_k, \qquad \lambda_k = 0$$

and Z is the vector of housing attributes. Then, in the constrained version, all $\lambda_k = \lambda$. In addition, if the values of $\theta$ and $\lambda$ are constrained equal to 1, the model reduces to the linear form. If $\theta$ and $\lambda$ are constrained equal to 0, the model reduces to the log-linear form. If the value of $\theta$ is set equal to 0 and the value of $\lambda$ is set equal to 1, then the semi-log model results. The opposite of the latter specification results in the inverse semi-log. As a result all the restricted functional forms commonly used are subcategories of the Box-Cox model and statistical tests are used to determine which functional form best suits the data (Orford, 1999). However, the Box-Cox model is not free of difficulties. For example, Dunn et al., (1987) have argued that the Box-Cox and Box-Tukey transformations are an undesirably mechanistic means of deriving functional form and are unnecessarily clumsy and unmanageable in comparison to graphical diagnostic tests and explanatory data-analytic approaches in general. Longley and Dunn (1988) have arrived at a similar conclusion where they argued that there is no reason why the testing of hypotheses should be 'straight-jacketed' into these most common functional forms. Also, it may be difficult to choose between two or more specifications due to the same scores on the statistical tests that they have.

As pointed out by Ohlsfeldt (1988), in the context of hedonic house price studies where the main objective is to obtain accurate estimates of marginal prices, the functional form that generates the best fit for the hedonic price function may not be the same as the functional form that generates the best marginal price estimates. For example, in the work by Halvorsen and Pollakowski (1981), fewer counter–intuitive negative marginal price estimates were obtained using less complex functional forms (Orford, 1999). However, the interesting study of Cropper et al. (1988) investigates precisely this issue. In a simulation study by Cropper et al., they simulate housing market equilibria using housing stock data from an actual urban area and varying the parameter of the household utility functions.

In order to estimate hedonic price functions and marginal bids, they evaluated linear, log-linear, quadratic, linear and quadratic Box-Cox specifications and obtained surprising results; complex functional forms produced much greater errors in marginal price estimates. They noted that a simple linear Box-Cox specification of the hedonic price model generates the smallest errors in marginal price estimates, whilst the quadratic Box-Cox specification generates the biggest errors in marginal price estimates. Moreover, with regards to the effect of transportation facilities on property values, this study concluded that the best specification for the functional form is a semi-log (see for example, Garrod and Willis, 1992b; Forrest et al., 1996). Yet, several authors have estimated only linear and semi–log specification and of the two, good results are produced by the semi-log (see for example, Damm et al., 1980; Bajic, 1983; Laakso, 1992; Forrest et al., 1996; So et al., 1997; Henneberry, 1998). However, the problems of using such mechanistic and restrictive methods, especially with respect to unusual data points such conclusions can be considered as fairly inexperienced (Orford, 1999).

### 4.7.4 Main Sources of Hedonic Problems

In the traditional hedonic approach, the structural attributes are treated as direct determinants of housing prices in fixed coefficient specifications. Therefore, it is assumed that each house will have equal marginal implicit prices. Moreover, locational attributes are incorporated as an additional set of housing attributes, where it is independent from the structural attributes. Based on this assumption, it can be suggested that a household assesses the structural attributes of a house and the attributes of its location separately. In this kind of conceptualisation, location can be considered as an additional premium on the price of a house which is independent of the cost of the structural attributes (Can, 1990). Also, this specification suggests that there is no relationship between the structure of a house and its location within a city, which contradicts urban economic theory as was noted in the previous chapter. As has been noted by Can (1990), some of the housing price studies fail to take into account the spatial element of the data in the traditional hedonic model.

The presence of spatial effect on the validity of traditional statistical methods has long been recognised as a potential problem (Anselin, 1988a). For example, spatial effects such as heteroscedasticity can pose severe problems, particularly a violation of underlying independence assumptions, identically distributed errors in the ordinary least squares (OLS) regression model (assumptions four and five) used to estimate the hedonic model. Under classical assumptions, OLS regression model gives the best linear unbiased estimators. But, with heteroscedasticity, OLS estimators are unbiased, however not the best that is there is no minimum variance. These two issues are in fact topics that require attention in empirical study (Goodman and Thibodeau, 1998).

Thus, it is important to acknowledge the spatial effects such as spatial heterogeneity if multiple regression models are used in evaluating hedonic house prices. It has been argued by Fotheringham et al. (1998) that the global model (hedonic house price model) parameter estimates are assumed to apply equally over the whole region. In other words, the relationships being measured are assumed to be 'homogenous/stationary' over space. Sandberg (2004) arrived at a similar conclusion, where he noted that the notion of global model test refers to the fact that they consider the overall data pattern and only return a single value, which either confirms or rejects the hypothesis. In addition, no information is given about the prevailing pattern. It has been argued by Loftin and Ward (1983: pp. 121) that 'models which exclude considerations of spatial processes are incomplete and that therefore parameter estimates for such models are misleading'. Fotheringham et al. (1998, 2002) have argued further that social process appear to be heterogenous which the measurement of a relationship depend in part on where the measurement is taken. Therefore, the process we are trying to investigate might not be constant over space. Leung et al. (2000a) have arrived at a similar argument in the context of real life situation. They pointed out that there is plenty of evidence for the lack of uniformity in the effects of space.

Spatial heterogeneity in relationships over space commonly exists in spatial data sets and the assumption of homogeneous or structural stability over space may be highly unrealistic (see for example, Fotheringham et al., 1996, 2002; Fotheringham, 1997a; Anselin, 1998). As shown by Fotheringham et al. (2002) through an empirical example of the determinants of house prices in London which the '$R^2$' value for the global model is 0.60 indicating a reasonable explanatory performance, but it still leaves 40 per cent of the variance in house prices unexplained. This study argued that this unexplained variance probably results from assuming the relationships in the model to be constant over space. In other words, we have assumed a homogenous process to be operating when it might be heterogeneous. However, as observed by Orford (1999), the effects of spatial data in hedonic models have been generally ignored by many researchers. Indeed, it is important to note that if the hedonic model suffers from the spatial effects, the estimated parameters may be incorrect and therefore the subsequent demand equations.

The following subsection discusses the issues of spatial heterogeneity in hedonic house price models. In addition, it is also necessary to consider the issue of multicollinearity, because the presence of multicollinearity in hedonic models leads to a large standard error of estimators (Gujarati, 1999). The two issues presented here should be considered as a way to better understand measuring the determinants of house prices in an urban area, and therefore very little attention on these issues can pose severe problems in the statistical methods used in evaluating the hedonic house price model.

#### 4.7.4.1 Heteroscedasticity

The discussion above highlighted that estimating hedonic pricing equation using OLS assumes that the variance of the error term is constant. However, if this estimation is violated, the error terms will be heteroscedastic. The presence of heteroscedasticity in the error terms will undermine model estimation. The presence of heteroscedasticity will be tested by performing visual examination of residuals as suggested by Pryce (2002) and these examinations are easily accessible in SPSS. There are three examinations of residuals that can be found in SPSS; histogram of residuals, normal probability plot of residuals and scatter plot of the standardised residuals. If heteroscedasticity is present it is shown by the plot fans out in (or fan in) a funnel shape.

### 4.7.4.2 Spatial Heterogeneity

As is now increasingly recognised, it is important to resolve the spatial effects consisting of spatial heterogeneity if the multiple regression models are used in evaluating hedonic house prices. This is supported by empirical evidence about the presence of spatial heterogeneity of hedonic prices over space (Basu and Thibodeau, 1998; Goodman and Thibodeau, 2003). According to Anselin et al. (2000), statisticians have long been aware of the problems associated with analysing geographical/spatial data. However, spatial statistical techniques did not disseminate into the empirical practice of the mainstream social sciences until recently. Anselin (1988a) has noted that spatial heterogeneity and spatial dependence are data problems which violate the basic assumptions (that the observations be independent or non-autocorrelated) underlying classical regression analysis.

Spatial heterogeneity in short is instability of the relationships between pairs of variables we are trying to investigate over space. The measurement of a relationship depends in part upon where the measurement is taken (Fotheringham et al., 2002). In the case of spatial analysis however, the data is drawn from geographical units, and a single regression equation is estimated. Following this estimation, average or global parameter estimates are produced, and it is assumed to apply equally over space. In other words, we assumed the relationships being measured to be stationary over space.

However, relationships are arguably not homogenous and said to exhibit spatial heterogeneity. Fotheringham et al. (1998) have pointed out that this spatial heterogeneity is a possible cause of problems for the interpretation of parameter estimates from a regression model. It must be noted that any relationship that is not homogenous/stationary over space will not be represented well by global statistics. It was argued that this global value may be very misleading locally (Fotheringham et al., 2002). In addition, spatial heterogeneity is effectively known to result in a number of estimation pitfalls, most notably spatial error autocorrelation and parametric structural instability in the form of non-constant error variances (heteroscedasticity) or model coefficients (Anselin, 1999; Paez et al., 2001). Perhaps, the presence of spatial heterogeneity and why we might expect measurements of relationships to vary over space is due to sampling variation. Some relationships are intrinsically different over space and the model from which the relationships are being estimated is a gross misspecification of reality (Fotheringham et al., 2002).

#### 4.7.4.3 Multicollinearity

As noted above, OLS regression assumes that there is no multicollinearity among the independent variables. However, it has been argued by Husin (1990) that it is very rare for no perfect multicollinearity to be found in any study since imperfect multicollinearity between two or more independent variables is a common occurrence. Note that if two variables are perfectly correlated, it is not possible to estimate the coefficients (Rogerson, 2006). The occurrence of multicollinearity in hedonic models leads to large standard error of estimators. Thus, the degree of multicollinearity needs to be measured before any further analysis can be done. Various measures have been employed for purpose of measuring the degree of multicollinearity in hedonic models.

Husin (1990) for example, lists seven multicollinearity detection measures; pair-wise correlation, auxiliary regression, variance inflation factors (VIF), direct observation on the consistency of parameter sign with the expectation, coefficient of partial determination, the Fararr-Glauber test and the Belsley-Kuh-Welsch (BWK) approach. Among these detection measures, Belsley-Kuh-Welsch (BWK) is found to be the most effective measure. Yet, it has been argued by Ismail (2005) that the BWK measure is difficult to interpret. A study conducted by Orford (1999) employed variance inflation factors (VIF) as a measurement for the occurrence of multicollinearity. The VIF measures appear more convenient to use and therefore will be employed in this study. According to Orford (1999), a VIF above ten indicates harmful collinearity. This implies that a VIF value of variables below ten is desired since this will ensure the model does not face serious multicollinearity.

Orford (1999) and Wheeler et al. (2004) have proposed that there are other two possible methods in detecting multicollinearity; step-wise regression and factor analysis or principal components analysis. Step-wise regression is a method in which 'variables are added or subtracted successively from the dataset until an optimum resolution with respect to the number of variables and the degree of explanation has been achieved' (Wheeler et al. 2004: pp. 226). Factor or component analysis on the other hand, is a method that can take several variables and identify potentially useful combinations of those variables. This method primarily aims to reduce a large volume of explanatory variables to a smaller and more manageable set of variables. Orford (1999) for instance used factor/principal components analysis in handling neighbourhood quality variables due to the presence of multicollinearity in his study.

## 4.8 Local Techniques in Measuring LRT-House Price Relationships

### 4.8.1 Introduction

This section introduces new techniques to measure LRT-house price relationships, in order to handle the effects of spatial data consisting of spatial heterogeneity that has been discussed in the preceding section. Having mastered the basic model of hedonic house price models or global models (equation 4.12), it is appropriate to incorporate some of the important factors (spatial effects) that have been previously neglected. This discussion initially considers the spatial aspects of house price data, especially in the context of model specification. As mentioned in the previous chapter, misspecification resulting from the presence of spatial heterogeneity often causes the traditional hedonic house price models. Therefore, the spatial aspects of house price data should be modelled explicitly within the specification.

Based on the criticism that traditional hedonic house price models do not take into account the spatial nature of the data sets used for estimation, a group of techniques known as spatial econometrics has been developed by several researchers to allow the inclusion of spatial nature in hedonic house price models (see for example, Casetti, 1972, 1997; Can, 1990, 1992; Jones and Bullen, 1993, 1994; Brunsdon et al., 1996, 1999; Fotheringham et al., 1997b, 1998, 1999, 2002; Goodman and Thibodeau, 1998; Orford, 1999; Leung et al., 2000a, 2000b; Nakaya, 2001; Huang and Leung, 2002; Paez et al., 2002a, 2002b; Longley and

Tobon; 2004). In recent years there has been an increased interest in the development and employment of local forms of spatial analysis in many different social sciences (Fotheringham and Brunsdon, 1999; Johnston et al., 2000). An alternative approach to the specification and measurement is required of the hedonic function, by considering the presence of spatial effects in investigating and modelling the urban housing market dynamics (Orford, 1999).

Such specifications can be regarded as 'local forms', since they take into account the context of the housing market dynamics and identify the presence of spatial heterogeneity. Three methods however are discussed here with regard to the local variability of the relations in the multivariate dataset; the spatial expansion method (Casetti, 1972, 1997; Can, 1990, 1992; Jones and Casetti, 1992; Orford, 1999), multilevel modelling (Goldstein, 1987; Jones and Bullen, 1993, 1994; Orford, 1999) and geographically weighted regression (Brunsdon et al., 1996; Fotheringham et al., 1998, 2002).

In the first subsection, the spatial expansion method will be introduced, in particular reference to the specification in order to deal with spatial effects. In the second subsection, the spatial expansion method is extended by incorporating contextuality into the specification by expanding what Jones (1991) has described as the multilevel specification, in which lie the fixed parts of the hedonic model. The third subsection will introduce geographically weighted regression (later referred to as GWR) in order to explore the spatial variations (spatial heterogeneity) that may be present in the house prices-housing attributes relationships. In addition, the results of GWR can also be used to indicate the degree of misspecification in the global model.

### 4.8.2 The Spatial Expansion Method

The preceding discussion has highlighted that the presence of spatial effects in hedonic house price regression models require an alternative approach namely, the specification and measurement. In relation to this point, this section aims to explore the spatial expansion specification proposed by Can (1990, 1992) which has been used by many researchers. A series of hedonic model specifications to handle spatial effects developed by Can were originally based on Casetti's (1972, 1997) expansion method, which is a technique for generating mathematical and statistical models by expanding the parameters of simpler models (Orford, 1999). This method has become a well known procedure for 'contextualising' existing models (Foster, 1991). In addition, the expansion method allows for the presence of spatial heterogeneity on the implicit prices of structural attributes, and can eliminate the part of heterogeneity resulting from structural instability (Can, 1990).

The most fundamental concept of the expansion method is 'parameter drift' (Casetti, 1997), whereby parameters are said to 'drift' if their estimates significantly differ with context. Therefore, the purpose of the expansion method is to measure parameter drift. In the case of housing study, parameter estimates of housing attributes are thought to drift across submarkets. It must be noted that in the traditional hedonic specification, these parameters are assumed to be stable and invariant. However, Casetti (1997) argues that in the social sciences, functional relationships are likely to represent subsystems that will perform differently in different environments and circumstances rather than invariant laws (Orford, 1999: pp. 33).

### 4.8.2.1 Model Specification

Based on the criticism that traditional hedonic house price models do not take into account the spatial nature of the data sets used for estimation, the presence section advances an alternative approach to the specification of spatial effects in the current hedonic house price specifications through using the expansion method. There are three distinct stages involved in generating expanded models (Casetti, 1997).

1. An initial model is specified.
2. Some or all of the letter parameters of the initial model are modelled by redefining them into functions of expansion variables.
3. A terminal model is generated by placing the expansion parameters into the initial model.

By allowing each of the parameters to be functions of other variables or spatial elements (stages 2), therefore, it is called an expanded model or a spatially expanded model (Orford, 1999). With this expanded model, space has been explicitly incorporated into the specification. Can (1990) has argued that the structural parameters may take different values across urban space, varying with respect to location. Therefore, using the three stages method, the hedonic house price function may be expanded using traditional hedonic specification as the initial model and location as the expansion equations. Orford (1999) correctly argued that this is still problematic, since the functional form and the attributes to be included in the expansion equations cannot be known *a priori*. This most general model is defined as:

$$P(Z) = f(L(f(S))) + \varepsilon \tag{4.14}$$

where,

P = a vector of observed house prices;

L = is a measure of location;

S = are the structural attributes

$\varepsilon$ = a vector of random error terms.

which is called the spatial expansion hedonic function.

With these identities, a typical expansion specification is one that accommodates discrete space. For example, the intercept in the traditional hedonic model (equation 4.12) may be allowed to vary for M submarkets. At this point, it is also convenient to define:

$$\begin{aligned} \alpha &= \alpha_0 + \alpha_1 D_1 + \alpha_2 D_2 + \ldots + \alpha_{m-1} D_{m-1} \\ &= \alpha_0 + \sum \alpha_j D_j \end{aligned} \tag{4.15}$$

where $j = 1, \ldots, M - 1$

From this, the intercept has been expanded with respect to a series on (M-1) dummy variables ($D_j$) that represent the individual submarkets. As noted by Orford (1999), each of the intercept terms ($\alpha_1$ ... $\alpha_{m-1}$) represent the submarkets differentials from the base submarket price of $\alpha_0$. Then the expansion equation is placed into the initial equation (equation 4.12), the spatially expanded hedonic specification is stated as:

$$P_i = \sum (\alpha_0 + \alpha_j D_j) X_i + \sum \beta_k S_{ki} + \sum \gamma_q L_{qi} + \varepsilon_i X_i \tag{4.16}$$

The equation above shows that the average house prices varies between submarkets, but since the structural and locational attributes have not been expended, the functional relationship between price and the housing attributes are invariant across space. To correct this, let us re-specify the model in a way that structural attributes will vary across submarkets. Then, the model can be expressed as:

$$B_k = \beta_{10} + \beta_{11}D_1 + \ldots + \beta_{20} + \beta_{21}D1 + \ldots + \beta_{kj-1}D_{j-1} + \beta_{kj}D_j$$
$$= \beta_{k0} + \sum \beta_{kj}D_j \qquad (4.17)$$

where $k = 1, \ldots K$, and $j = 1, \ldots, M - 1$

and substituting this into equation 5.3:

$$P_i = \sum (\alpha_0 + \alpha_j D_j)\, X_i + \sum (\beta_{k0} + \beta_{kj}D_j)\, S_{ki} + \sum \gamma_q L_{qi} + \varepsilon_i\, X_i \qquad (4.18)$$

Now, the average house price varies between submarkets as well as marginal implicit prices of the structural attributes. Therefore, locational attributes can be expanded in a similar way as follows:

$$P_i = \sum (\alpha_0 + \alpha_j D_j)\, X_i + \sum (\beta_{k0} + \beta_{kj}D_j)\, S_{ki} +$$
$$\sum (\gamma_{q0} + \gamma_{qi}D_j)\, L_{qi} + \varepsilon_i\, X_i \qquad (4.19)$$

The result is equivalent to fitting a separate regression model between price and housing attributes for each submarket, which is very similar to the switching regression approach (Jones and Bullen, 1994). In addition, they stress that these two expansion models (equations 4.16 and 4.19) are nothing other than ANOVA and ANCOVA models. The major conceptual difference between the fully expanded model (equation 4.19) and the switching regression model (4.14) is that the former has a single error term and thus assumes that the error variance is constant throughout the housing market (Orford, 1999). Since switching regression estimates separate models for each submarket, this assumption is relaxed. If this is the case, then the fully expanded model will be more efficient than the set of separate regression. However, Jones and Bullen (1994) argue there may be no real gain in stinging together the separate regressions in the fully expanded model since the estimated coefficients will be identical, although the estimated standard errors of the coefficients may differ if the latter model is indeed more efficient.

Due to implicit prices varying with submarkets, an alternative expansion is to contextualise discrete space with locational attributes. To do this, it is sufficient to construct a measure of neighbourhood quality from the census data which is then used as a locational attribute (see for example, Can, 1992). Therefore, the two expansion equations of locational attributes must be specified. For this purpose, we will consider the linear and quadratic functional form. The linear expansion equation of $\beta$ can be specified as:

$$B_k = \beta_{10} + \beta_{11}NQ + \ldots + \beta_{20} + \beta_{21}NQ + \ldots + \beta_{k0}NQ + \beta_{k1}NQ$$
$$= \sum (\beta_{k0} + \beta_{k1}NQ) \qquad (4.20)$$

where $k = 1, \ldots K$ and NQ is a measure of neighbourhood quality.

It is then not difficult to place the expansion equation into the initial model:

$$P_i = \alpha X_i + \sum (\beta_{k0} + \beta_{k1}NQ) S_{ki} + \varepsilon_i X_i \qquad (4.21)$$

The terminal model (equation 4.21) has stated that location has no implicit price, but instead is seen as 'driving the spatial variation in the housing price determination process' (Can, 1990: pp. 258). This concept is supported by Witte et al. (1979) who have argued that implicit markets do not exist for locational attributes (neighbourhood quality and accessibility), but rather are the result of multiple independent decisions of the residents. Orford (1999: pp. 36) correctly argued that 'they serve to shift both the supply and demand curves of structural attributes and hence the implicit price of the attribute'. However, it was argued that as the implicit markets do exist for locational attributes, and hence implicit prices, they do not at the level of the individual house.

Therefore, under the expansion models, the existence of spatial heterogeneity will be absorbed entirely by allowing the structural attributes to 'drift' with neighbourhood quality, namely measured by census data. This implies that the geography of the census tracts is a good proxy for submarkets (Orford, 1999). In addition, the spatial heterogeneity of submarkets can be adequately captured by neighbourhood quality differentials and that the relationship between parameter drift and neighbourhood quality is consistent across the housing market. Moreover, since the intercept is left unexpanded, the model implies that the price of the average house is the same across the entire market, independent of neighbourhood context and submarkets.

Yet, Fotheringham et al. (2002) argued that the spatial expansion method does have some limitations. Firstly, the local variance over space depends primarily on the complexity of the expansion equations. Secondly, the form of the expansion equations needs to be assumed *a priori*, although various other functional forms are available to be used. Finally, the expansion equations are assumed to be deterministic so that problems of estimation in the terminal model could be removed.

### 4.8.3 The Multilevel Modelling

Multilevel modelling is another approach that has gained significant interest in the recent literature and is being used by geographers in certain sub-disciplinary areas, in particular, political and health geography, since it is claimed to be capable of analysing data which has a complex structure (Gould and Fieldhouse, 1997). This approach was originally developed in the mid-1960s and in the 1970s and in the early 1980s, they were the subject of theoretical elaboration, specification and estimation. It was only in the mid and later 1980s that efficient and practicable computational strategies were developed (Gould and Fieldhouse, 1997).

In the context of housing studies, this approach became well known after Jones and Bullen (1993) used it to investigate the variations in the domestic property prices of Southern England based on the data for 1980-1987. Multilevel models are examples of models that have simple concepts but they enable researchers to take appropriate account of the intrinsically hierarchical organisation of much social life. It must be noted here that multilevel models have now reached a degree of technical development where it is possible to offer considerable insight into the nature of spatial heterogeneity at different levels of analysis. Moreover, multilevel hedonic models allowed the influence at submarkets to be explicitly modelled (Orford, 2000).

Jones and Bullen (1994) and Orford (1999, 2000) provide an extended worked example of applying a multilevel model dealing with spatial heterogeneity. Thus, the traditional hedonic specification can now be written in terms of fixed and random parts, algebraically detailing the house and submarket levels. Note that locational and structural attributes have been reduced to a vector Z of K housing attributes (Orford, 1999). Then the hedonic house price model can be expressed as:

$$P_{ij} = \alpha_j X_{ij} + \sum \beta_k Z_{kij} + \varepsilon_{ij} X_{ij} \tag{4.22}$$

where: $j = 1, \ldots, M$ (submarkets)

$i = 1, \ldots, N$ (houses)

$k = 1, \ldots, K$ (attributes)

which is called a micro-model since it is based on individual data. Here, Z is the vector of K housing attributes and M is the number of submarkets and N is the number of properties. To achieve the equivalent multilevel model to that of the discrete-space fixed expansion of equation 4.16, the intercept has to be allowed to vary at a higher level. Let us consider the following model of level 2 between submarket by the expansion equation:

$$\alpha_j = \alpha + \mu_{\alpha j} \tag{4.23}$$

which is called a macro-model since it is based on aggregated data. The price of the typical house in submarket j ($\alpha_j$), is seen as a function of the market-wide price, $\alpha$, plus a differential for each submarket, $\mu_{\alpha j}$. The micro-model is the within-place equation, whilst the macro-model is the between-place equation in which one of the parameters of the within-place model, in this case the intercept, is the dependent variable. The micro and macro models combine to form the terminal model:

$$P_{ij} = \alpha_j X_{ij} + \sum \beta_k Z_{kij} + (\mu_{\alpha j} X_{ij} + \varepsilon_{ij} X_{ij}) \tag{4.24}$$

where the two random terms in the brackets are assumed to be independent of each other (Goldstein, 1987). Since the intercepts are allowed to vary according to a distribution, Jones (1991) termed these random intercepts models. For these fully random multilevel hedonic models, it is also convenient to allow the attribute parameters to vary according to a higher level distribution. By specifying an additional macro-model, the following equation can be obtained:

$$\beta_{kj} = \beta_k + \mu_{\beta kj} \tag{4.25}$$

which conceives the attribute's implicit prices as an average market-wide price plus a submarket differential. By combining the two (initial model and two macro-models) it produces a terminal model:

$$P_{ij} = \alpha_j X_{ij} + \sum \beta_k Z_{kij} + ( \mu_{\alpha j} X_{ij} + \mu_{\beta kj} Z_{kij} + \varepsilon_{ij} X_{ij}) \tag{4.26}$$

Here, $\sigma^2_\varepsilon$ at level 1, $\sigma^2_{\mu\alpha}$, $\sigma^2_{\mu\beta}$ at level 2, and $\sigma_{\mu\alpha\mu\beta}$ at level 2 represent, respectively, random terms and the covariance terms. In other words, this model now has four random terms. The covariance term allows the random intercepts and attributes parameters to co-vary according to a higher level, namely joint distribution. As has been noted by Goldstein (1987) the concept of a higher level distribution is the key to multilevel models. It is noted that the differential intercepts and implicit prices are not specified as fixed, separate and independent as in the usual fixed-part expansion model. However, the differential intercepts and implicit prices are specified as coming from a distribution at a higher level. Since these distributions do not concern houses but submarkets, it is identical to treating places as a sample drawn from a population. The means of these higher level distributions are simply the usual intercept and implicit prices representing the average market-wide relationship. It must be noted however, that it is the variances/covariances of the higher-level random terms that capture the parameter drift. Furthermore, if these variance terms are effectively zero, there is no parameter drift; hence, there is no need for macro-models. Thus, since there are no significant submarket effects, the traditional hedonic specification is adequate in describing house price variation (Orford, 1999).

Arguably, the application of multilevel modelling to analyse spatial phenomenon such as the dynamics of house prices is problematic (Fotheringham and Brunsdon, 1999). This problem occurs due to the spatial processes that are based on an *a priori* definition of a discrete set of spatial units at each level of hierarchy in multilevel modelling. Fotheringham and Brunsdon (1999) argued further that 'the definition of a set of spatial units in which spatial behaviour is modified by the attributes of those units depends on such units being identified'. In this framework, the spatial processes being modelled are discontinuous. However, in reality the operation of spatial processes does not work that way due to the effects of space which are continuous. Note that imposing a discrete set of boundaries on most spatial processes is unrealistic.

On the basis of the limitations between spatial expansion methods and multilevel modelling, the other method of local techniques that will be employed for this study, that is, GWR will be introduced. The next discussion of this chapter will be focused on the GWR technique and how it can be used to estimate the relationship between each independent variable and dependent variable, in particular with regards to the issue of spatial heterogeneity in house price study.

## 4.8.4 Geographically Weighted Regression (GWR)

### 4.8.4.1 Background

In this section, GWR is discussed in order to handle the effects of spatial heterogeneity in hedonic house price models (global model). As has been discussed in the previous section, hedonic house price models assume that the relationship between house prices and housing attributes are stationary over space. However, this relationship may not be representative of the situation in any particular part of the study area and may hide some very interesting and important local differences in the determinants of house prices (Fotheringham et al., 2002).

In explaining the local differences in the determinants of house prices, Fotheringham et al. have shown that the global parameter estimate for the age of the house is close to zero. Following this assumption, house prices are relatively independent of the age of the house. However, there are arguably contrasting relationships in different parts of the global parameter estimate. As explained by Fotheringham et al. in rural parts of England for example, old houses might have character and appeal, hence generating higher prices than newer houses. In contrast, older houses in urban areas built to low standards to house workers in rapidly expanding cities in the middle of the nineteenth century, might be in poor condition and have substantially lower prices than newer houses. This local variation or spatial heterogeneity in the relationship between house prices and age of the house would be completely lost if all that is reported is the global parameter estimate.

Based on that principle, let us now turn our attention from the global model (hedonic house price model) to the local model. The GWR model was developed in 1996 by Brunsdon, C.F., Fotheringham, A.S. and Charlton, M.E. As has been noted by Fotheringham et al. (2002), GWR allows local rather than global parameters to be estimated, and thus provides a way of accommodating the local geography of house prices-housing attributes relationships. GWR is used here in order to explore the spatial variations that may be present in the relationship between housing attributes variables and its regressors. Moreover, it is used to verify the heterogeneity of the relations, which in turn can indicate the degree of misspecification in the global model. In other words, GWR can be interpreted as localised versions of traditional global techniques (Longley and Tobón, 2004). As such, in the present case study, it provides an important method of identifying local differences in the determinants of house prices-rail transit systems relationships in the Klang Valley, Malaysia. The results of this technique will be compared to the results from the global model.

### 4.8.4.2 Geographically Weighted Regression Specification

The development of GWR techniques begins with the extension of the traditional regression framework which focuses on local rather than global parameters to be estimated (Fotheringham et al., 1998). In the context of this study, it provides an important method of identifying spatial heterogeneity in each of the predictors of house prices. The GWR can be mathematically expressed as (Fotheringham et al., 1998):

$$P_i = \alpha_0 (u_i, v_i) X_i + \sum \beta_k (u_i, v_i) S_{ki} + \sum \gamma_q (u_i, v_i) L_{qi} + \varepsilon_i X_i \tag{4.27}$$

Based on equation 4.27, a continuous surface of parameter values is allowed, and measurements of this surface are accepted in the certain items to indicate the spatial variability of the surface. Note that a continuous surface of parameter values is estimated under the assumption that locations closer to *i* will have more influence on the estimation of the parameter $a_k$ for that location. In other words, data from observations close to *i* are weighted more data from observations further away. Then the weighting of an observation close to *i* can be expressed as (Fotheringham et al., 1998):

$$\hat{a}(u_i, v_i) = [X^tW(u_i, v_i)\,X]^{-1}X^TW(u_i, v_i)y \tag{4.28}$$

where the bold type represents a matrix, â represents an estimate of a and the n x n weights matrix $W(u_i,v_i)$ has diagonal elements ($w_{i1}$, $w_{i2}$, ..., $w_{in}$) that represent the weighting of observed data on the calibration of the model around point *i* and off-diagonal elements equal to zero. Note that the weights are defined as continuous functions of distance.

#### 4.8.4.3 Choice of Spatial Weighting Function

According to the previous discussion, $W(u_i, v_i)$ is a weighting scheme based on the proximity of *i* to the sampling locations around *i* without an explicit relationship being stated (Fotheringham et al., 1998). To begin with, let us first consider the implicit weighting scheme of the OLS framework in the global model (equation 4.12).

$$W(u_i, v_i) = \begin{matrix} 1 & 0 & 0 & \cdots\cdots & 0 \\ 0 & 1 & 0 & \cdots\cdots & 0 \\ 0 & 0 & 1 & \cdots\cdots & 0 \\ 0 & 0 & 0 & \cdots\cdots & 1 \end{matrix} \tag{4.29}$$

The above equation suggests that in the global model each observation has a weight of unity; it excludes the model calibration observations that are further than some distance *d* from the locality. Thus, their weights are set to zero. At this point, it is also convenient to give a weighting function (Fotheringham et al., 1998):

$W_{ij} = 1$ if $d_{ij} < d$

$W_{ij} = 0$ otherwise (4.30)

which simplifies the calibration procedure because for every point for which coefficients are to be computed, only subsets of the sample points need to be included in the regression model. However, the concern is with the discontinuity problem of the spatial weighting function. As Fotheringham et al. (1998: pp. 1909) notes:

> As *i* varies around the study area, the regression coefficients could change drastically as one sample points moves into or out of the circular buffer around *i* and which defines the data to be included in the calibration for location *i*. Although sudden changes in the parameters over space might genuinely occur, in this case changes in their estimates would be artefacts of the arrangement of sample points, rather than any underlying process in the phenomena under investigation.

One reasonable means of dealing with this is to specify $w_{ij}$ as a continuous function at $d_{ij}$, the distance between *i* and *j*. Therefore, in this particular case it has (Fotheringham et al., 1998): where;

$$W_{ij} = \exp(- d_{ij}^2/\beta^2) \tag{4.31}$$

$\beta$ = is represent the bandwidth

The above equation represents a continuous function of $d_{ij}$ for the distance between *i* and *j*. The weighting of data at that point is counted unity when *i* and *j* coincide, and the weighting of other data will decrease when the distance between *i* and *j* is great. Fotheringham et al. (1998) noted that in the latter case, the inclusion of data in the calibration of a model for point *i*, if $wij$ = 0.5 then data at point *j* contribute only half the weight in the calibration procedure as data at point *i* itself. For data a long way from *i* the weighting will fall to virtually zero, effectively excluding these observations from the estimation of parameters for location *i*. In other words, large weights are given to points near to *i* and smaller weights are assigned to observations far away from *i*. It is important to note that the bandwidth is increased where data points are more widely spaced. As highlighted by Fotheringham et al. (1998), the selection of the continuous function does not appear to have an effect on the results, but the selection of the bandwidth is crucial. Too small a bandwidth leads to large variance in the local estimates, whereas too large bandwidth leads to large bias in the local estimates. However, the GWR software is programmed to choose the optimal bandwidths by seeking to minimise the Akaike Information Criterion (AIC) (Fotheringham et al. 2002).

## 4.9 Conclusion

This chapter has presented a literature review of the hedonic price model. It began by introducing the basic economic theory that has provided the foundation of the model. It noted that the model has widely been accepted as a technique that can be used in the study of housing prices. The discussion proceeded with the specification of the hedonic price model. However, it has been highlighted that most of the previous studies associated with the hedonic price model has ignored the nature of spatial process in which the interaction between house prices and its determinants are assumed to be stationary over space, although in reality the spatial processes are in non-stationary fashion. Ignoring this issue would make the interpretations of the local parameter estimates misleading. To handle this problem, local techniques for example the spatial expansion method, multilevel modelling and GWR has been introduced in this section. Between these three local techniques, it was concluded that the GWR technique was found to be conceptually and empirically more appropriate in estimating the contribution of each of housing attribute on house prices. The next chapter will continue the discussion by examining the determinants of house prices and how they have been incorporated into the hedonic price model.

# CHAPTER 5

## The Dynamics of Housing Attributes-House Price Relationship and Hedonic Modelling

### 5.1 Introduction

It has been discussed in the previous chapter how hedonic price models can be used in housing price studies. As has been noted previously, hedonic price models regard housing as a composite commodity, distinct bundles of housing attributes that differentiate between properties and house price is regressed on a package of inherent attributes, although they are never directly observed in property transactions. It has also been pointed out in Chapter three that the overall effect of rail transit systems on house prices can be measured by taking into account changes in the prices of all housing attributes. This is because it was difficult to attribute house price increases to the LRT system alone. The next questions to be addressed are; what housing attributes should be included in the hedonic model to take into account as contributory factors in determining house prices (structural and locational attributes)? Specifically, how challenging it is to define the locational attributes effects? What variable specification is appropriate in the context of hedonic price models? Finally, are there specific problems associated with modelling such data?

This chapter will attempt to unearth the answers to these questions. It must be noted that the contents of the chapter are parallel to those of the preceding chapters. First, the structural and locational attributes are introduced in order to understand their effects on house prices. The locational attributes lead to the concept of *externalities* or *locational externalities*. In Chapter four, the techniques in estimating locational externalities that are generated by the rail transit systems are discussed at length. In order for a complete assessment of total economic value in relation to the effects of the LRT system on house prices, within the framework of this research, it is vital to dissect locational externalities when it comes to understand the advantages and disadvantages brought about by the existence of the LRT system in a particular location.

Then, in section 5.3 the discussion will go on to deal with the measurement of housing attributes of hedonic price models. Consequently in subsection 5.4, the problems encountered with modelling spatial data using hedonic price function and how this has been historically limited by the resolution of the data will be examined and lie in the role of GIS in hedonic price study heading.

## 5.2 The Dynamics of Housing Attributes-House Prices Relationship

### 5.2.1 Introduction

Firstly, various kinds of housing attributes are introduced and focus will be given with respect to their effects on house prices. In order to examine the effect of housing attributes on house prices, the housing attributes themselves must be classified more explicitly. In the literature, it is traditional to classify housing attributes as structural attributes and locational attributes. In this chapter the focus will be given to housing attributes (structural attributes and locational attributes) and their relationship with house prices as depicted in Figure 5.1. The structural attributes of the house include the age of the house, the number of rooms (bedrooms and bathrooms), the house style (terraced, semi-detached, detached and high rise unit), the presence of central heating, air conditioning, hot water, garage, attic, full insulation, lot size, storey height and the quality of a house. The locational attributes may be pure or impure and include, among others, CBD, rail transit systems, roadways, highways, parks, schools, universities, museums, open spaces, woodlands, commercial and industrial areas, air quality, water quality, and neighbourhood quality. Deliberation in the preceding chapter advocates that these attributes are primarily traded in bundles and are not explicitly traded on the market. However, it has been traded as part of a package of housing services. Now, structural attributes and their effects on house prices are introduced.

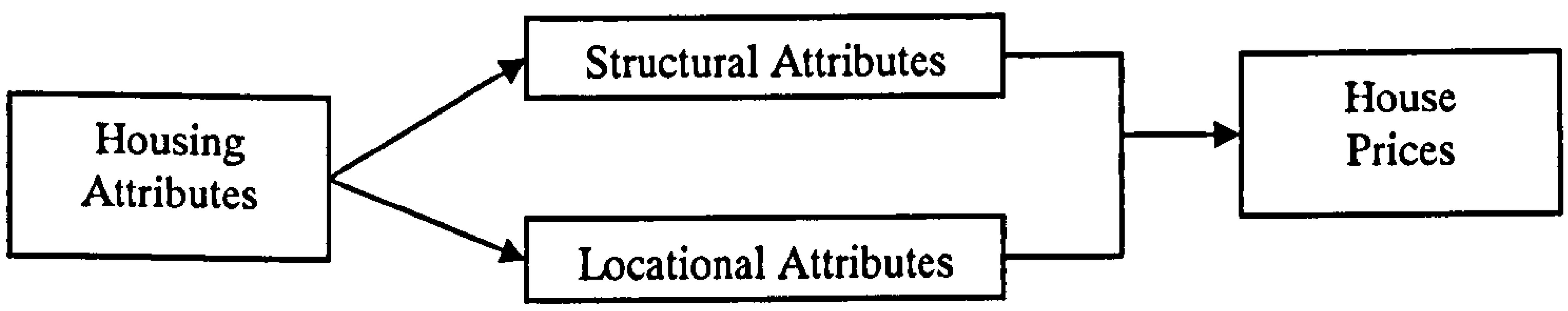



**Figure 5.1**: The housing attributes-house prices relationship

### 5.2.2 Structural Attributes of Housing

Structural attributes are in short, those physical structures of a property and the land parcel within which it is located. Orford (1999) explained that structural attributes represent the shelter afforded by housing and the physical investment by the owner. Orford argued further that structural attributes are conceptually more tangible compared to locational attributes. Since the nature of structural attributes are more tangible, it is a much easier and straight forward process to measure the effects of structural attributes on house prices. For example, it is far easier to measure how much the number of bedrooms or floor size contributes to the value of the property than being located in a good neighbourhood. Structural attributes can be categorised into two groups; attributes that can be associated with living space and structural quality (Follain and Jimenez, 1985). According to Kain and Quigley (1970a) the latter has had a strong positive effect upon house prices.

### 5.2.3 Locational Attributes of Housing

Locational attributes are in short, those attributes whose benefits are realised mainly in the form of externalities, and hence they are collectively shared by a large number of people and houses. Locational attributes can be categorised into two groups; fixed and relative locational attributes. Fixed locational attributes are those attributes that capture the location of a property with respect to the whole urban area, and pertain to some form of accessibility measure, typically access to the CBD. Relative locational attributes are those attributes that reflect the externalities of the local neighbourhood and are unique to an individual property such as environmental quality (Orford, 1999). In considering the decentralised mechanisms for the efficient provision of such attributes, their spatial attributes are found to be crucial. Locational attributes tend to be spatially concentrated in their impact on the quality of people's lives and the value of their property.

However, it is important to note that the magnitude of benefits from locational attributes vary over space. This is owing to most locational attributes being supplied by public facilities with fixed locations, and the quality of people's lives and the value of their property can derive more benefits from it as they inhabit closer to it. However, we must note that they are unpriced in the sense that they are not paid for directly, but indirectly through housing purchase. For example, house buyers have to pay a higher price for a house that is located in a good location such as having good air quality and neighbourhood quality, and nearer to the CBD, rail transit stations, highways, parks, open spaces, woodland areas, schools, colleges, and universities. In addition, locational attributes are conceptually less tangible and usually more difficult to measure compared to structural attributes. For example, it is far more difficult to measure the effects of rail transit systems on house prices. The effects of rail transit systems on house prices could be positive or negative. Discussion on the effect of locational attributes leads to the concept of *locational externalities*. Next, the discussion begins to explore the concept of locational externalities.

Externality is an effect of one person's action on another, over which the latter has no control (Johnston et. al., 2000). Externalities can be positive (beneficial) and negative (harmful). For example, externalities from locational attributes which were discussed in the preceding section, such as rail transit systems, can generate positive externalities (improve accessibility from one place to another) whereas racial composition (some white people may have a prejudice against living near black people) can create costs for people in the locality. It has to be noted that each type of externality may have an influence on property value. However, most externalities are local in their impact, with a distance decay effect in their extent and intensity. For instance, externalities such as noise created by crowded major roads; the further people are from its source, the less it affects them.

Johnston et al. (2000) have shown that, people compete through the pricing system in the property market to be near positive externalities such as the CBD, rail transit systems, major roads, highways, schools, parks, and so on in order to obtain benefits from it (as shown in studies of the effects of locational attributes on house prices) and may become involved in political action in order to exclude negative externality generators from their neighbourhood. For example, neighbourhood activists known 'as not-in-my-back yard' (NIMBY) in the US often oppose the proposal of building a new sport facility. They argue that the construction and operation of the sports facility would bring about traffic congestion, air and noise pollution, thus cause property values to decline. The NIMBY attitude exists across the US and has delayed the development of many new sport facilities (Tu, 2005).

Now that the concept of locational externalities, (which is a concept unique to housing attributes) has been introduced, it is useful to understand the locational externalities concept in order to understand the locational attributes–house prices relationships. Next, the discussion will be focused on locational externalities effects depending on whether or not they impose positive (beneficial) or negative (harmful) externalities to the house prices.

### 5.2.4 The Effects of Externalities on House Prices

In this section, various kinds of effects of locational externalities on house prices will be discussed. First, the discussion will address the externalities of the CBD and its effects on house prices. The CBD is the most accessible location that draws workers with diverse skills from all directions and provides the best access to metropolitan–wide markets. The CBD also generates important positive externalities for surrounding areas. Then, owing to the greater concentration of business, finance, insurance, real estate employment, public service and entertainment in most CBDs, studies show the expected positive externalities of the CBD on house prices (see Alonso, 1964; Muth, 1969; Mills, 1972; Evans, 1973). In other words, the price of a unit of housing declines with distance from the CBD.

In the case of rail transit systems externalities however, the empirical evidence has been mixed (see Chapter one and three). Many of studies of the effects of rail transit systems externalities have focused on whether rail transit systems significantly affect house prices, where the proximity to rail transit system is supposed to capture the effects of the positive externalities on house prices. As has been extensively discussed in the preceding chapters, some studies have shown evidence to support the hypothesis that rail transit systems increase house prices. Others have indicated that there is no support for the hypothesis. In many of these studies, the use of proximity to rail transit systems implies that the externalities are localised in their impacts on house prices.

Next, in the case of highways externalities, empirical evidence shows the expected positive highways externalities on house prices (see Burton and Knapp, 1965; Cribbins et al., 1965; Eyerly, 1966; Golden, 1968; Gambled et al., 1974; Palmquist, 1982). As has been noted in those studies, accessibility improvement in terms of travel-time savings through the existence of highways resulted in an increase in house prices. For example, properties within approximately one mile of a freeway right-of-way appreciated 12 to 15 per cent more than comparable properties that were located beyond a mile from the freeway (Palmquist, 1982). Highway and road can also produce negative externalities such as noise and safety effects for residents who reside too close to highway and road, hence, may negatively affect property values. In order to assist comparison of the results of hedonic price studies researchers normally employed a Noise Sensitivity Depreciation Index (NSDI) (Bateman et al., 2001). NSDI is defined as a percentage change in price arising from a unit increase in noise. A study carried out by Nelson (1978) in Washington found that the NSDI of around 0.87. In other words, this study suggests that an increase in noise pollution of 1 decibel (dB) will reduce the value of a property by 1 per cent. Another study conducted by Soguel (1991 as cited by Anderson et al., 2009) in Neuchatel, Switzerland found that the NSDI of around 0.91. This suggests that an increase in noise pollution of 1dB will also reduce the value of a property by 1 per cent. A study conducted by Lake et al. (2000b) in Glasgow, Scotland based on over 3500 property sales suggests that property prices is decreased by 0.2 per cent of 1 dB increase in road noise. In a recent study carried out by Anderson et al. (2009) in Lerum, Sweden found the range of NSDI from 1.35 to 2.90. The mean for this study is an NSDI of around 2.04. This study suggests that an increase in noise pollution of 1 dB will reduce the value of a property by over 2 per cent. Turning to the case of air quality externalities on house prices, the empirical evidence shows that good air quality would increase house prices (see Ridker and Henning, 1967; Harrison and Rubinfield, 1978; Nelson, 1978; Li and Brown, 1980; Palmquist, 1982; Murdock and Thayer, 1988; Graves et al., 1988; Zabel and Kiel, 2000).

However, a major problem is how to measure the range of these effects. As has been argued by Pinch (1985), many studies have used arbitrary thresholds around a facility to represent a catchment's area, but this does not take into account the distance decay effects which may not be a monotonic function and negative impact on house prices. For example, although a location near to the CBD may be beneficial with respect to accessibility; this benefit may be negated due to environmental quality.

As the density of households in a neighbourhood increases, the environmental quality tends to diminish partly because of an increase in noise, littering, crimes and so on and partly because of a decrease in the amount of open space and green areas in a neighbourhood. Thus the distance decay function will be non-monotonic with the optimal location viewed as a trade-off between the benefits of accessibility improvements and the costs of environment quality (Orford, 1999). Next, the discussion will focus on the housing attributes and the measurement of its effects in hedonic price model.

## 5.3 The Attributes of Housing and the Measurement of Its Effects in Hedonic Price Model

### 5.3.1 Introduction

Over the past three decades, the hedonic price model has been used extensively in the housing market study to investigate the housing attributes-house prices relationship. Since the publication of Rosen's work (1974), many have adopted this approach to estimate the housing attributes-house prices relationship. The literature shows that the attributes that determine the house prices can be viewed as a package of inherent attributes relevant to structural and locational attributes. By regressing the transaction prices of housing against corresponding structural and locational attributes, the determinants of the attributes to house prices can be estimated.

Unfortunately, theory offers few guidelines and there is little consensus as to which of these attributes should be properly included in the hedonic model (Dubin and Sung, 1987; Ohsfeldt, 1988). For instance, Ball (1973: pp. 229) notes that while 'only two results shown had $R^2$ less than 70 per cent even though there were considerable differences in the explanatory variables used'. The question is; how then can researchers ensure that they have included the appropriate housing attributes in the hedonic model? It was argued by Orford (1999) that the lack of widespread agreement has resulted in a diverse range of variables entering the hedonic specification.

Some of the studies give greater attention to structural attributes (for example, Kain and Quiley, 1970; Cubbin, 1970; Lane, 1970; Wilkinson, 1971; King, 1976; McMillan, 1979; Can, 1990; Waddell et al., 1993; Henneberry, 1998; Cervero and Duncan, 2002; Tse, 2002; Tu, 2005), whereas other studies focus more on locational attributes (for example, Ridker and Henning, 1967; Anderson and Crocker, 1971; Diamond, 1980a; So et al., 1997; Irwin, 2002). Among the housing attributes that have been used to determine the house prices, significant attention has been paid to structural attributes (Cheshire and Sheppard, 1995). Evidently, all previous models have contained similar structural attributes to the extent that they represent the majority of the variables in the model. The purpose of this section is therefore to discuss the housing attributes which are to be included in the hedonic model.

On the basis of the above mentioned purpose, the following discussion will refer to the classification provided by Graves et al. (1988) and later comprehensively discussed by Orford (1999). Graves et al. (1988) have categorised the variables included in the hedonic models into three distinct groups. The first is known as free variables; those that are known to affect house prices, though are of no special interest in the study. The second are focus variables; focus variables are those variables of particular interest, and it may vary from study to study. For example, proximity to rail transit stations for those studies that focus on the effect of rail transit systems on house prices. In the third group are doubtful variables; doubtful variables may or may not affect the independent variables, but whose *a priori* omission may bias the results. It was argued by Orford (1999) that since doubtful variables have generally been applied to locational attributes, their importance in the previous models has been regarded to be very inconsistent, and to such an extent that hedonic research can be classified on the basis of the inclusion of locational attributes. This section will proceed as follows – in the following subsection, housing specific models will be presented, which is subsequently followed by a discussion on location specific models.

### 5.3.2 Housing Specific (Locationally-Insensitive) Models

First, this subsection introduces housing specific models and discusses how it has been presented and measured in the hedonic price models. The housing specific model, in short, focuses only on structural attributes as an important factor in determining house prices. Following these models, house prices are determined solely by the structural attributes of the house, such as the age of the house, the number of rooms (bedrooms and bathrooms), the house style (terraced, semi-detached, detached and high rise unit), the presence of central heating, air conditioning, hot water, garage, attic, full insulation, lot size, storey height and the quality of a house. In other words, these models ignore the importance of locational attributes in determining house prices. As mentioned above, these models have been given greater attention in the literature, particularly in the early research. The literature has illustrated that, the types of structural attributes used have varied, and to some extent seem to have been determined by data availability.

Table 5.1 summarises the most common structural attributes from the literature. As shown in Table 5.1, structural attributes have been classified into two categories; living space and structural quality. However, in order to measure the structural attributes-house prices relationship, living space has been reduced to lot size, floor area and the number of rooms, whilst structural quality is concerned with age, style and interior and exterior quality. In the case of the size and structure of the house, it can be obtained from the floor area and number of rooms. In order to avoid overlap between lot size and size of the house, much attention has been given to outside lot area and internal floor instead of total lot size (Orford, 1999).

**Table 5.1**: A summary of commonly used structural attributes

| Classification | Attributes |
|---|---|
| Living space | Interior attributes<br>- Total interior living space<br>- Total floor area<br>- Number of stories<br>- Number of rooms<br>- Number of bedrooms<br>- Number of recreation rooms<br>- Number of bathrooms<br>- Basement<br>- Attic<br>Exterior attributes<br>- Lot size<br>- Off road parking<br>- Number of garages |
| Structural quality | Index of dwelling quality<br>Age of house<br>Presence of full insulation<br>Brick exterior<br>Style of house<br>Presence of fireplace<br>Double glazing<br>Air conditioning<br>Full central heating |

*Source*: Adapted from Orford (1999: pp. 49)

In the case of structural quality however, the situation is more difficult since it is more subjective and associated to the physical condition of both the interior and exterior (Orford, 1999). Yet, as has been deliberated in the literature, structural quality has been measured in various ways. Kain and Quigley (1970a) and Ohsfeldt (1988) have provided a succinct guideline of measuring structural quality. For example, Kain and Quigley constructed an index ranging between one (excellent condition) and five (requires replacement) in rating the particular aspects of each dwelling unit.

The structural attributes of a dwelling that have been measured in their study are overall structural condition, general housekeeping, condition of ceilings, condition of walls, condition of floors, condition of lighting, condition of windows, condition of structure exterior, landscaping, trash on parcel, nuisances affecting parcel and condition of drives and walks. Ohsfeldt (1988) has employed a similar approach in measuring structural quality – by constructing an index based on a scale ranging between zero and six. Furthermore, measures such as central heating, double glazing and insulation were also included for the purpose of capturing variations in the structural quality of dwellings. Thus far, the discussion above has shown that how structural attributes have been presented in the hedonic price models. Now let us move our discussion onto location specific models.

### 5.3.3 Location Specific Models

In the study of house prices, locational attributes play a significant role. The discussion in this subsection will introduce location specific models and discuss how it has been presented and measured in the hedonic house price models.

As has been discussed in previous section, the effects of locational attributes on house prices have led to the concept of locational externalities. Having understood the concept of locational externalities, it is important to expand our understanding on how locational attributes are presented and measured in the hedonic house price models. Most of the studies have grouped locational externalities in terms of fixed and relative locational attributes. Fixed locational attributes capture the location of a property with respect to the whole urban area, and relate to some form of distance and accessibility measure, such as access to the CBD. Contrary to this, relative locational attributes can be explained as follows; measures that reflect the externalities of the local neighbourhood and are unique to an individual property, such as presence of amenities. It must be noted that several approaches have been used on the determinants of locational attributes-house prices relationship. Some studies emphasise accessibility measures, while others stress neighbourhood quality measures (Richardson et al., 1974; Follain and Jimenez, 1985). In the following discussion, each of the two types (fixed and relative) of locational attributes will be considered separately and investigate how it has been measured for the purpose of the hedonic house price models.

#### 5.3.3.1 Measuring Accessibility for Fixed Locational Attributes

*The monocentric urban model*: Accessibility variables provide an important measure of location in hedonic house price models and in the micro-economics theory. As described in the previous chapter, an accessibility measure estimates the level of access to an activity from one location to another of that activity given a travel mode, distance, time and cost constraints. In the context of monocentric urban models, where all economic activities are located at the CBD, the accessibility level is measured in terms of distance or travel time to the CBD. It must be noted that in most of the empirical house price studies, accessibility has had a significant impact on house prices.

The role of accessibility in house price studies relate to the measurement of the bid-rent curve as proposed in the micro-economics theory. As has been shown in the micro-economics theory, accessibility includes both monetary loss and time costs related with commuting between residences and work places, shopping, visiting relatives and friends, and other such activities. The micro-economics theory that works on estimating the rent gradient was first established by Alonso (1964) and Muth (1969), which attempted to describe residential location choice on the basis of the interaction of land use and land values, and land values significantly rise from the trade-off between accessibility and transport costs. This theory, of course traces their origins to the agricultural land rent theory of von Thunen (1826). This theory stipulates that the city is monocentric – all economic activities are located in the CBD. Hence, there is a distance decay relationship between house prices and distance from the CBD. An important underlying assumption of the monocentric model is that travel costs increase with distance from the CBD. As noted earlier, the theoretical foundation provided by micro-economics theory has shaped much hedonic house price research. In addition, the motivation behind the early hedonic house price research was to provide empirical evidence of a negative land rent gradient as verification of the trade-off model.

The literature shows that, various approaches have been used to measure the effect of accessibility on the house price gradient. There are two main types of measures for accessibility levels that have been the subject of a number of papers; travel distance (straight-line-distance) to the CBD and travel time to the CBD and monetary loss. It must be noted that although travel distance, travel time and monetary loss are intended to measure accessibility levels, they are quite different measures.

The simplest measure involves a measure straight-line-distance between residences from the CBD. Indeed, the straight-line-distance measure of accessibility captures distance only in terms of maximum distance of travel between residences from the CBD. Arguably, this approach ignores the more important questions of how travel time and monetary loss from the CBD are reduced (the monocentric model assumes that distance to the CBD, where all activity is located, is positively related with travel costs). A second type of measure involves measuring travel time and monetary loss to the CBD. This measure captures accessibility levels in terms of travel time and costs from the CBD (see for example, Bajic, 1984; Sanchez, 1993). However, Mieszkowski and Mills (1993) have shown that real transportation costs are a better measure of accessibility than the distance to the CBD.

In the case of distance to transport systems such as highways, main roads, rail transit systems and bus routes, proximity measures have been used as a yard stick to measure its effects on house prices. Since the improvement of public transportation will increase the level of accessibility from one place to another such as travel time savings and reduced transport costs, it is assumed that house prices will respond accordingly in those places that have become more accessible.

The literature demonstrates that there are several approaches that have been used by researchers in order to measure the effect of transport systems on house prices. For example, there are very extensive studies that have been conducted on the effects of highways and rail transit systems on house prices. The effects of these systems have been measured by using proximity measures such as straight-line-distance and network-distance. As noted in the previous section, transport systems also have a potential in creating negative (harmful) externalities such as noise, air pollution and congestion, particularly in an urban area. Therefore, it will reduce the prices of houses which are located near to it.

In the context of the functional form of the accessibility measure, Orford (1999) has generalised that it is not necessarily smooth or continuous since structural features such as main roads, rivers and railway lines have a tendency to deform accessibility. In addition, the transport systems and costs are not necessarily the same across an urban area, but are varied (Cheshire and Sheppard, 1995). As a result, since transport systems and costs vary across an urban area, it has been assumed that the accessibility function may vary with direction from the city centre. These accessibility measures were explored by Dubin and Sung (1987) and Waddell et al. (1993). They both divide the urban area into sectors and use dummy variables to allow shifts in the slope of the price gradient which would allow a complex functional form to be represented in a simple manner, thus avoiding specifying the functional form in an *a priori* manner.

The above discussion has shown how accessibility has been presented and measured in the monocentric model. However, it is argued further by Orford (1999: pp. 53) that the empirical literature provides no consensus on the magnitude of the existence of a price gradient. Orford has noted that, 'it is quite common for empirical studies to fail to find a statistically significant between city centre access and price'. Orford also notes 'several studies have even reported statistically significant accessibility influences of the wrong sign, that is, price increasing with distance'.

There are a number of possible reasons for this apparent inconsistency and weakness of evidence between the studies. Ball (1973) offers an early explanation for the inconsistent and weak evidence of the magnitude of the existence of a price gradient from the CBD in the monocentric model. He concludes that factors such as poor data in measuring various variables such as linear distance, log of distance, travel time, multiple accessibility and job accessibility could contribute towards the inconsistency. Orford's (1999) explanation of this inconsistency is based on the inadequacy of traditional accessibility measures. McMillen (2003) offers another explanation as to why the empirical literature diverges from the theoretical expectations. He suggests that in most American cities, the wealthy people tend to live farther from the city centre and spend more on housing. This tendency leads to a bias towards a positive house price gradient.

However, more recent work in this area has acknowledged the complexity of accessibility and residential location. It has been suggested that the monocentric model be substituted for the emergence of urban sub-centres known as polycentric urban models. In addition, as has been argued extensively in the literature, the most fundamental reason for the inconsistency and weak evidence of the magnitude of the existence of a price gradient from the CBD in monocentric models particularly in US metropolitan areas are due largely to the emergence of urban sub-centres. The next discussion focuses on the emergence of the polycentric urban model and the role of accessibility as a measure of house price gradient in polycentric urban models.

*The polycentric urban model*: Arguably, the monocentric model is apparently no longer appropriate to describe modern urban form. Cities rarely have a simple monocentric structure, since employment and amenity centres located outside of the CBD may cause the rent gradient to be complex (Dubin and Sung, 1987). Over the last three decades, in particular since the late 1970s, the rapid growth of suburban nodes of economic activity and the emergence of urban sub-centres has been widely recognised. This situation can be seen in most US cities where jobs have been decentralised from the CBD to the suburbs as early as the 1960s (Hanson, 2004). Garreau (1991) argued that the dominance of the CBD has increasingly been challenged by the growth of suburban employment centres or in essentially exurban locations, exemplified most notably by 'edge cities'. In addition, one of the most interesting features of the modern urban landscape is the tendency of economic activity to cluster in several centres or well known as polycentric models (Anas et al., 1998).

Polycentric model refers to the existence of several population and employment centres in one area, although the CBD is still envisaged to be the most important one (Griffith, 1981). Studies have shown that the existence of several new population and employment centres are most representative of modern North America, Europe, and Japanese cities (Klossterman and Musterd, 2001). Cervero and Wu (1997) noted that the geomorphology of most US metropolitan areas such as Los Angeles, Chicago, Cleveland and Dallas has changed from a single-centred to a more polycentric form over the last half of the twentieth century.

Several studies show how polycentric models statistically explain recent spatial distribution of population and employment better than monocentric models (see for example, Gordon et al., 1986; Dubin and Sung, 1987; Heikkila et al., 1989; Giuliano and Small, 1991; Shukla and Waddel, 1991; Small and Song, 1992; Waddell et al., 1993; McDonald and Prather, 1994; McMillen and McDonald, 1997; Bogart and Ferry, 1999). Since several population and employment centres have increasing relevance to modern urban form, there are reasons to expect the house price gradient to be complex, and challenge the relevance of the house price gradient from the CBD (Orford, 1999). For example, a study conducted by Heikkila et al. (1989) found that the price-distance function is positive, not the expected sign. They have shown that the accessibility to the CBD is statistically insignificant.

As has been noted by Heikkila et al. (1989: pp. 229), 'this is very striking evidence of the power of the polycentric city concept and the irrelevancy of the CBD, at least in Los Angeles'. McMillen (2003) has arrived at a similar conclusion in the context of metropolitan city of Chicago. The house prices in the city of Chicago were not affected significantly by distance from the CBD in the early to mid 1980s. McMillen has noted that in the case of Chicago which has been long viewed as a monocentric urban model, Chicago's CBD has declined steadily in importance over time. It is argued further that house prices are not the ideal test of the monocentric models. However, Cheshire and Sheppard (1995) correctly argued that in the context of the UK, if locational attributes are appropriately measured, then monocentric models can perform well.

Measuring the house price gradient within a polycentric urban model is difficult because the exact nature of what is being measured is questionable (Orford, 1999). He noted that although polycentric models may depict an urban area as having several centres, each centre may have a different function, and as such, a varying degree of influence on the urban area. This is, of course, different from the monocentric model that has a single centre, where it is assumed *a priori* that all economic activities take place at the CBD. Moreover, the definition of sub-centres is not clearly expressed in the literature. The literature shows that the most fundamental attribute of the emergence of polycentric urban model is the concentration of employment in sub-centres. However, other urban amenity centres have also been considered. These include shopping centres, hospitals, airports, and cultural centres such as universities (see for example, Hoch and Waddell, 1993). For instance, Hoch and Waddell (1993) found that distance to the airport had a much greater impact on house rent than distance to the CBD. It is also difficult to determine how the traditional concept of accessibility and the measurement of the bid-rent curve can be applied to some of these proposed secondary centres.

Two methods of measuring accessibility within a polycentric model are recognised and demonstrated in the literature. The first is by estimating an accessibility trend surface of the effects of multiple centres as proposed by Jackson (1979). Following this method, housing attributes is constant across an urban area, but allows the price of land to vary spatially as a result of demand for more accessible sites. The most fundamental reason for the existence of accessibility surface is due to the power of the polynomial of the trend surface. For example, a quadratic approximation represents a surface with a single maximum value for accessibility; that is a monocentric city. It is noted that more complex surfaces with multiple local peaks can be represented by increasing the degree of the polynomial. To determine which degree of polynomial estimates the accessibility surface the best, Jackson (1979) calculated an estimate for it using a combination of $R^2$ and F-test. Consequently, the result of the surface can then be mapped. It is interesting to note that the advantage of this kind of approach is that the secondary centres that have a significant influence on house prices do not have to be specified *a priori.*

Conversely, the second method of measuring accessibility within a polycentric model is to identify secondary employment centres *a priori.* Following this method, the housing price gradient can be estimated by using traditional accessibility measures. In general, this method divides into two stages. The first stage was to experiment with various hypothesised secondary centres. In other words, in a two-dimensional urban context, one might hypothesise that the value of a house is determined in part by its distance to each of the several centres (such as employment centres, shopping centres, hospitals, airports and universities).

The second stage was selecting those that produced the optimal results based on $R^2$ values and statistical tests (see for example, Dubin and Sung, 1987; Heikkila, 1988; Heikkila et al., 1989; Waddel et al., 1993). However, one statistical problem with which the researchers were concerned was the existence of multicollinearity. Heikkila (1988: pp. 345) has argued that 'intuition tells us that three distance variables will be collinear when confined to a plane. Thus, three distance measures maybe redundant in a two-dimensional space, even though the three urban nodes are not redundant in terms of their influence on urban land rents'. The results of these studies show the failure of the CBD to exert a dominant influence on the house price gradient. In the case of Baltimore however, the polycentric models statistically explain house price gradient better than monocentric models. Dubin and Sung (1987) concluded that in Baltimore the CBD appears to behave much like the other centres. In other words, the CBD has an impact on rents, but this effect is limited to a relatively small area.

In this subsection, the accessibility of fixed locational attributes and how they have been presented and measured in the context of monocentric and polycentric urban models has been discussed. It began with measuring the accessibility of fixed locational attributes in monocentric models. The discussion was then followed by the measuring accessibility of fixed locational attributes in polycentric models. The next subsection discusses how neighbourhood quality (such as racial composition, socio-economic status, public amenities and environmental quality) has been presented and measured in the hedonic house price models.

### 5.3.3.2 Measuring Neighbourhood Quality for Relative Locational Attributes

As has been discussed in the previous section, each residential unit has a unique bundle of attributes. Within this unique bundle of attributes is the *neighbourhood quality* in which the dwelling is located. Neighbourhood quality represents the influential factors affecting house prices. Most studies have acknowledged that house prices are determined not only by the structural attributes of the dwelling units themselves, but also by neighbourhood quality in which the dwelling units are located. Census data is a good indicator of these attributes. Economists argue that the value of a desirable item can be measured by looking at how much an individual is willing to pay for it (Turner et al., 1994). By regressing the attributes of the purchased goods (dwelling unit), including neighbourhood quality on the observed price of the purchased goods, the contribution of neighbourhood quality to the price of the marketed goods can be extracted. In relation to this point, this subsection focuses on how neighbourhood quality has been presented and measured in the hedonic house price models.

Several major and interlinked strands of theory and econometric studies have explored the relationship between neighbourhood quality and house prices (see for example, Ridker and Henning, 1967; Muth, 1969; Evans, 1973). As with accessibility, there are debates relating to how the relationship between neighbourhood quality and house prices can be measured. Davies (1974) argued that neighbourhood quality is a subjective attribute evaluated in the mind of the buyer and it is not traded in the market. In other words, there is no tangible manifestation of its worth for empirical analysis. Therefore, it can only be measured indirectly by the use of proxy measures. Orford (1999) correctly highlighted that not until recently, many aspects of neighbourhood quality are tangible and have been quantified, such as in The English Housing Condition Survey and The American Housing Survey (AHS).

As shown in the literature, a variety of approaches have been used to measure the relationship between neighbourhood quality and house prices. Dubin and Sung (1990) have classified measures of neighbourhood quality included in the hedonic models into three distinct groups; measures of local public amenities, measures of the socio-economic status of the neighbourhood, and measures of neighbourhood racial composition. In comparison, Mingche and Brown (1980) argued that many studies have included few, if any, location-specific attributes or proposed measures of the micro-neighbourhood. They have classified micro-neighbourhood measures into three types; measures of aesthetic, measures of pollution levels and measures of proximity, by which they mean accessibility to local amenities. These classifications can be regarded as direct measures of neighbourhood quality.

However, as has been argued by Fujita (1989) and Mingche and Brown (1980), neighbourhood quality can also play a role as an indirect measure of environmental quality. For example, as the density of households in a neighbourhood increases, the environmental quality tends to diminish partly because of an increase in noise, littering and crime. In addition, residential density (number of dwelling units per square mile) can also be used as a proxy for open space or green areas in a neighbourhood. Nonetheless, in the context of environmental quality, Boyle and Kiel (2001) have classified measures used in the previous research into three distinct groups; measures of air quality, measures of water quality, and measures of undesirable land uses. These three distinct groups can be classified as a measure of pollution levels.

## (a) Measurement of Neighbourhood Quality

Let us first discuss *local public amenities* and how they have been measured in the previous study. Since the early 1980s, there has been considerable number of studies on the subject of the relationship between local public amenities and house prices. The literature clearly captures that local public amenities are generally the most straightforward to measure and interpret since they are principally regarded as direct measures of neighbourhood quality. The better the quality of the service, the more highly valued it is and so is positively capitalised into house prices. Cheshire and Sheppard (2004) argued that most of the value in the market price of urban land is in fact represented by the capitalised value of such local public amenities. These include the quality of local schools, the existence of public parks (McLeod, 1984; Orford, 1999), golf courses (Do and Grunditski, 1995) and the availability of local shops (Powe et al., 1995; Orford, 1999).

In the case of relationship between the quality of local schools and house prices, a large number of studies have found a positive relationship; recent examples include Gibbons and Machin (2003; 2006), Briggs et al. (2004), Cheshire and Sheppard (2004), Clapp and Ross (2004), Weimer and Wolkoff (2001), Bogart and Cromwell (2000), Black (1999), Orford (1999), Fortney (1996), Haurin and Brasington (1996), and Hayes and Taylor (1996). As indicated in the literature, various approaches have been adopted to measure the quality of local schools; performance of its pupils on the examination for example performance in English, Mathematics, and Science, pupil/teacher ratio and school demographic composition. It must be noted that in some models, it is appropriate to view the property tax rates and local government jurisdictions as local public amenities. Ross and Yinger (1999) argued that the process of household sorting across jurisdictions can lead to the capitalisation of local public amenities into house prices.

In the case of *socio-economic status* however, the situation is more difficult. Powe et al. (1995) argued that measures of the socio-economic status of a neighbourhood are less tangible, and have been classified as doubtful variables. It must be noted that the determinants of socio-economic status in house prices relate to income levels, age, education and car ownership. Commonly high socio-economic groups tend to have much higher levels of home ownership than those with lower incomes. Also, members of high socio-economic groups are thought to be more desirable neighbours since they value the quality of the local environment greater than those in lower social groups. Therefore, they are perhaps better prepared to make larger investments to maintain neighbourhood quality such as investments in exterior maintenance and landscape (Dubin and Sung, 1987).

Higher residential density areas are viewed as less desirable among high socio-economic groups than less dense areas. As the residential density of a neighbourhood increases, the environmental quality tends to diminish partly because of an increase in noise, littering, crime and a decrease in the open space and green areas in a neighbourhood. Thus, high socio-economic groups tend to live in low residential density and are prepared to pay a higher price for that. The socio-economic status represents a proxy for other attributes of neighbourhood quality such as low levels of noise pollution, a low crime rate, high aesthetic surroundings and more open space and green areas.

Next, in the case of *racial composition*, as has been seen in the case of socio-economic status, there is a disagreement over whether racial composition is a direct measure or proxy for neighbourhood quality. In the former case, the argument was economic theory predicts that discrimination can produce price differentials within a neighbourhood, while prejudice and segregation produce house price differentials between neighbourhoods (see for example, King and Mieszkowski, 1973; Daniels, 1975; Yinger, 1975; Schnare, 1976; Follain and Malpezzi, 1981; Cutler et al., 1999; Myers, 2004). Myers (2004) argued that racial housing price differentials occur due to discrimination, prejudice and segregation against racial minorities such as black communities in the US.

As indicated by Myers, price differentials could result from supplier price discrimination. If suppliers such as landlords, real estate agents and owners dislike dealing with black people and will do so only if they receive a premium, then one would expect this discriminatory behaviour to result in black people paying more for a comparable unit of housing than white people. Fujita (1989) has arrived at a similar conclusion regarding prejudices among some groups of people against other groups. In a city with more than one racial or ethnic composition, there may be case of prejudice whereby one racial group may feel intimidated by the presence of the other in the neighbourhood they belong to. For instance, some white people may have a prejudice against living near black communities. Hence, the intimidation is being felt by the black communities.

As a result, it may affect the city's structure of housing prices. However, in the case for a proxy measure of neighbourhood quality the argument was that if the racial composition of a neighbourhood reflects other attributes such as socio-economic status, income and depressed surroundings, then racial composition is merely a proxy for neighbourhood quality. For example, evidence suggests that black neighbourhoods tend to have relatively higher crime rates, lower wealth, poorer provision of public goods and other negative characteristics (see for example, Harris, 1999).

## (b) Measurement of Environmental Quality

The discussion now turns from the measurement of neighbourhood quality to the *measurement of environmental quality*. The next discussion is focused on the measures of environmental quality such as aesthetic, pollution levels and proximity to local amenities as classified by Mingche and Brown (1980).

Let us first discuss *aesthetic measures* and how they have been measured in previous studies. Aesthetic can be defined as sensory-emotional values or judgements of taste on environmental features such as fields, rivers, lakes, mountain and beaches. The presence of such features in the neighbourhood will be capitalised into the price of a house. Generally, properties adjacent or close to such features often command a premium over and above that of equivalent properties elsewhere (Willis and Garrod, 1992). These include river/canal views (McLeod, 1984; Willis and Garrod, 1992; Landsford and Jones, 1995), forestry (Garrod and Willis, 1992; Tyrvainen, 1997), shoreline (Brown and Pollakowski, 1977), lake recreation (Lansford and Jones, 1995), harbour (Jim and Chen, 2009) and mountain (Jim and Chen, 2009). In the case of river/canal views, Willis and Garrod (1992) classified measures of waterside frontage into three categories; measures of a canal-side location, measures of a location adjacent to a canal and measures of no proximity to a canal. However, it has been argued by Bourassa et al. (2003) that the analysis of aesthetic externalities should not be limited to the examination of the views on a specific feature. The quality of the landscaping in the neighbourhood should be taken into account when analysing the relationship between environmental quality and house prices.

*Pollution measures* in the previous studies can be classified into three distinct groups; measures of air pollution, measures of water pollution and measures of undesirable land uses (Boyle and Kiel, 2001). However, much attention has been given to the role and contribution of air pollution on house prices (see for example, Ridker and Henning, 1967; Harrison and Rubinfeld, 1978; Nelson, 1978; Palmquist, 1982; Graves et al., 1988). In most of these studies, Harrison and Rubinfeld's study of air pollution in Boston caused by traffic and industry has been considered as the most influential study (Orford, 1999). However, it has been argued by Willis and Garrod (1992) that the impact of air pollution on house prices is more difficult to estimate through hedonic price models due to multicollinearity between air pollution attributes.

Other important pollution measures have been water pollution (see for example, Mendelsohn et al., 1992;), undesirable land use (see for example, Nelson, 1981; Kiel, 1995; Kiel and McClain, 1996; Carroll et al., 1996) and noise pollution particularly with respect to aircraft noise (see for example, Collins and Evans, 1994; Levesque, 1994; McMillen, 2004) and, highway and road noise (see for example Nelson, 1978; Soguel, 1991; Lake et al., 2000b; Anderson et al., 2009) . It has must be noted that the effect of aircraft noise on house prices has been of interest since the first wave of hedonic house price studies during the 1970s. The results of these early studies reviewed by Nelson (1980: pp. 46) as 'a survey of evidence from thirteen studies suggests noise discounts in the range of 0.4 to 1.1 per cent per decibel'.

As noted above, the effects of local amenities such as schools, shops, sport centres, religious centres, universities, airports, shopping centres, hospitals and open spaces on house prices can be measured using *proximity measures*. Since externality can be positive (beneficial) and negative (harmful) and local in their impacts on residents with a distance decay effect in their extent and intensity, the method that has been used in the previous studies was non-monotonic distance function (see for example, Tu, 2005; Paterson and Boyle, 2002; Orford, 1999; Powe et al., 1997; Waddell et al., 1993; Mingche and Brown, 1980). Perhaps, the most fundamental reason for using non-monotonic proximity measures to estimate the externality effect of local amenities is due largely to its capability in showing the magnitude and range of values.

Waddell and Berry (1993) and Orford (1999) have demonstrated different shaped distance decay functions in estimating the effects of local amenities on house prices. In a study of the housing price gradients (the intersection of space and built form in Dallas, US), Waddell and Berry (1993) concluded that the local amenities such as major and minor shopping centres, universities, hospitals and airports vary in their range and magnitude on property prices. Orford (1999) has arrived at a similar conclusion in a study of Cardiff, UK where local amenities included non-residential land use, Bute Park, parks, industrial, hospitals, sport centres, community centres, institutional centres, local shops, schools and parks/open space affected house prices. He concluded that the effects of different local amenities vary in their range and magnitude on house prices in Cardiff (see Table 5.2). For instance, Table 5.2 shows the importance of proximity to parks (see variables Parks and Bute Park) on house prices in the immediate vicinity, with the distance decay of the effect diminishing by half within a few streets distance. In the case of proximity to heavy industries on house prices, the t-values suggest that only those houses within visible distance of the sites are significantly affected.

**Table 5.2**: T-statistics for non-residential land use proximity estimates

| β-values | 0.25 | 0.5 | 1.0 | 2.0 | 3.0 |
|---|---|---|---|---|---|
| Non-residential Land Use | 0.37 | 0.09 | 0.36 | 0.96 | 1.74 |
| Bute Park | 3.86 | 3.60 | 2.93 | 2.00 | 1.69 |
| Parks | 3.32 | 2.78 | 2.24 | 1.06 | 0.68 |
| Industrial | 0.02 | 0.05 | 0.05 | 1.11 | 0.80 |
| Industrial: Heavy | 2.01 | 2.27 | 1.51 | 0.48 | 0.11 |
| Industrial: Light | 0.30 | 0.47 | 0.28 | 1.03 | 0.76 |
| Community | 0.90 | 1.59 | 1.97 | 1.94 | 1.96 |
| Institutional | 0.22 | 0.668 | 0.23 | 0.13 | 0.01 |
| Hospital | 1.18 | 0.98 | 0.61 | 0.26 | 0.29 |
| Sports | 0.88 | 0.016 | 1.21 | 2.09 | 2.06 |
| Shops | 0.29 | 0.27 | 0.02 | 0.121 | 0.01 |
| Primary School | 1.83 | 1.76 | 1.77 | 2.03 | 2.14 |
| Secondary School | 1.66 | 1.56 | 1.30 | 0.88 | 0.69 |

*Note*: β-values, ranging from 0.25-3.0, were used to calibrate five distance decay functions. A small β-value represents a gentle distance decay curve and therefore, the greater the extent of the effect. A large β-value represents a steep distance decay curve, and the externality only has an influence over a short distance.
*Source*: Adapted from Orford (1999: pp. 162)

In a study of proximity to woodland and its effects on the house prices of Southampton, Powe et al. (1997) found that house value increase is associated both with locating in close proximity to woodland and within easy access of larger areas of woodland. However, a study conducted by Tu (2005) assessing the effects of the proximity of new sports stadiums on house values in Washington found that properties located in close proximity to sports stadiums sell at a discount relative to those with comparable housing attributes but distant to the stadium. The magnitude of the parameter estimates reveals that the closer the property is to the stadium, the larger the price discount. For instance, Tu (2005) discovered that the value of a single-family home located less than three miles but more than two miles from the stadium is not significantly affected, whereas properties within a one mile radius of the stadium are priced approximately 10.06 per cent lower than comparable units outside the impact area. He attributed this to negative externalities related with congestion.

However, the study conducted by Davies (2005) in Manchester and Cardiff, UK found a positive relationship between the existence of sport facilities and residential value in the surrounding area. Davies clearly argues that the City of Manchester stadium and Millennium stadium of Cardiff have positively improved the image of the areas where they are located. Davies further suggested that the existence of stadiums in those two cities helped promote the cities through media exposure and coverage of major sport events that were held at the venues. In short, it has positively affected people's perception towards the neighbourhood. As a result, residential property has increased in value by approximately 12.5 per cent within two kilometres of the Manchester stadium and 2.92 per cent within one kilometre of the Millennium stadium. It has been acknowledged that proximity measures have traditionally caused debate within hedonic studies, due to contradicting results in both general and specific studies into its effects (Orford, 1999).

## 5.4 Geographic Information Systems and Spatial Statistics in Hedonic House Price Study

### 5.4.1 Introduction

In preceding sections, the discussion has focused on the importance of spatial data/locational data in hedonic house price study. It has been highlighted that one of the main problems with hedonic house price models is the treatment of locational data, in particular for the purpose of modelling and measurement of locational attributes, and specifically the measurement of proximity variable. Our attention now turns from the problem of locational data to its solution. The discussion will be focused on the benefits of closer linkages between geographic information systems (GIS) and spatial analysis. However, before starting the discussion of closer linkages between GIS and spatial analysis in the next section, section 5.4.2 will introduce various kinds of theme related to GIS; the definition of GIS, its applications in various fields and the basic functionalities of GIS. Note that emphasis will be placed upon the application and advantages of using GIS in hedonic house price study.

### 5.4.2 The Definition of GIS

Since the development of GIS forty years ago, a number of attempts have been made by many GIS practictioners to define what GIS is. However, it remains difficult to precisely define what GIS is. Yet, most of the definitions provided by GIS practictioners contain a number of common elements. Broadly, GIS can be defined as a branch of computer technology that deals with geographical information (Maguire, 1991); or alternatively as the set of computer-based decision support systems containing data, hardware, software and organisational for capturing, storing, managing, manipulating, analysing and visualising a special type of information, namely spatially referenced data (for alternative definitions of GIS, see Dueker, 1979; Burrough, 1986; Smith et al., 1987; Cowen, 1988; Parker, 1988; Aronoff, 1989; Carter, 1989; Koshkariov et al., 1989; Delaney, 1999; Demers, 2000). Studies have shown GIS have proven to be useful in many areas. Traditional GIS application fields include military, government, education and utilities.

The developing GIS application fields of the mid 1990s included general business uses such as banking and financial services, transportation logistics and, real estate and market analysis. Longley et al. (1999) have categorised the applications of GIS into two major groups; operational applications and social and environmental applications. Operational applications of GIS are those that are being used on a daily basis to record the location of features (for example land parcels, network devices and highways signs), to perform update transactions (for example the acquisition and disposal of properties and changes to telecommunication devices) and to calculate delivery routes. Social and environmental applications are those that have been used in planning, decision support and modelling environmental and social problems.

The question is, what makes the above mentioned applications are possible? Basically, contemporary commercial GIS contain several functionalities/capabilities which are input, output, manipulation, analysis and display of spatial or non-spatial information (Maguire and Dangermond, 1991). In the case of input function, there are two main methods involved, namely data capture and data transfer. Data capture represented by raster and vector data types, whilst data transfer involves importing data from other sources. Note that all these data will be stored in the database. The database is the basis of all analysis and decision-making. All large GIS implementations store data in a database management system (DBMS), a specialist piece of software designed to handle multi-user access to an integrated set of data (Longley et al. 2001). In addition, the database of many GIS explicitly contains the topological relationships between various spatial features (Ungerer and Goodchild, 2002). Nonetheless, a wealth of spatial data exists in GIS databases and it is convenient to be able to perform the analysis from within the software in which the data are typically accessed. In the case of output function, the paper map is the most established and conventional means of displaying data, yet GIS provides a far richer and more flexible medium for portraying attributes distributions and transforming spatial objects. There are two ways of displaying data in GIS; standard cartographic conventions and graphic symbology.

### 5.4.3 GIS and Hedonic House Price Research

Having understood the functionalities of GIS, it is appropriate to incorporate GIS in hedonic house price study. Incorporation of GIS in hedonic house price study brings about a number of technical advantages. Note that in the hedonic price model the data with which relationships between house prices and its structural and locational attributes are to be examined, are gathered manually from maps or from photographs, and these methods are highly time-consuming even with the used of GIS (Lake et al. 1998; Powe et al. 1995). As suggested by Lake et al. (2009) and Lake et al. (1998) the main limitation to the use of GIS in any studies such as hedonic house price study was the time and effort required to collect and input data into the system. However, this may become less of a problem as more organisations store data in digital format. As Lake et al. (2009: pp. 65) noted ' research into more efficient ways of joining such data or convincing data providers to provide such comprehensive land use maps would be helpful'.

In addition, through the integration of GIS and large-scale digital data, the process to derive structural, locational and socio-economic attributes together with accessibility analysis associating to individual properties is possible to be carried out. This is due to the fact that GIS provides a simple means of defining the locations of locational attributes precisely. Thus, the locational attributes which may have an impact on house prices can be measured accurately. In addition, GIS gives the most flexibility in measuring and modifying variables that will be used for analysis. Nonetheless, the speed and accuracy with which the variables can be generated using GIS permits a greater variety of locational attributes to be generated. GIS also has tremendous advantages in the sense that it can be used to organise and manage large spatial datasets such as those used in hedonic house price studies, that is unit of houses and of course its structural and locational attributes too. Most importantly, GIS can be used to position each observation and locational attribute on a local map by using their geographical coordinates. Furthermore, a GIS can handle these data at different spatial resolutions for example at the level of the individual house and neighbourhood.

A GIS also yields a precious platform for spatial analysis. This is particularly useful in measuring the distance and proximity that have caused controversy in preceding work. In order to obtain the results that could represent reality, network analysis can be used (Hess and Almeida, 2007). Network analysis can measure road network-distance between two points. For example, the travel time that people take to reach rail transit stations can be measured accurately. Ford and Barr (2009) have conducted a study on developing a set of spatial accessibility measures for transport throughout London by a number of different modes. They have employed ArcGIS Network Analyst to construct representations of the four modes of transport such as heavy rail, light rail, bus and private car. As they stated by using network analysis, the shortest paths between each pair of origin and destination zones in terms of time can be obtained. In the contex of this study, measures of accessibility and proximity will be calculated from each house to rail transit stations, the CBD, shops, parks, schools, universities, lake recreation and places of worship by employing network and eucludian measures. Apart from that, a GIS can assist the visualisation of the spatial data and map the results of the modelling (Orford, 1999: pp. 68). For instance, we will be able to visualise OLS residuals and GWR results on the map – this enables a graphical analysis to identify any systematic pattern of residuals that can indicate the existence of spatial variation of house prices and its determinants' interactions.

### 5.4.4 The Nature of Spatial Data in GIS

In the study of the relationship between house prices and its structural and locational attributes using GIS, it is essential to know the nature of spatial data in GIS, particularly with respect to spatial analytical issues and their relevance to hedonic house price study. Thus, in this subsection the nature of spatial data in GIS and spatial analytical issues will be discussed. As has been mentioned in the literature, there are several major spatial analytical issues relevant to spatial data; spatial heterogeneity (as has been discussed extensively in the preceding chapter) and modifiable area unit problem (the focus of the discussion in this subsection). The discussion will begin with the nature of spatial data in GIS.

In the previous sections, the determinants of house prices in hedonic house price study related to the structural and locational attributes of housing have been discussed. It must be noted that these attributes of data are available at different resolutions; structural attributes data are generally available for the individual house, whereas locational attributes data are to be aggregated at a higher level for example census area. The different resolutions between structural and locational attributes data can be solved by using GIS. As mentioned earlier, GIS provides special facilities for storing and manipulating spatial data in a database management system.

GIS also provides an opportunity to integrate the structural and locational attributes data sets because it treats the attribute of an object and its location in geographic space as two separate entities. For example, in ARC/INFO GIS software, the non-spatial attribute information is stored in a relational database management system and the spatial information in a separate subsystem which enables dealings with spatial data and spatial queries. By storing these two types of information separately in a database management system and allowing interaction between them, the data can be manipulated on the basis of either geographic location or attribute value. Since a GIS is capable of storing these data at different scales, data can be geo-referenced and aggregated at various spatial levels such as street level or the neighbourhood level. But this situation is not as simple as this, since it is important to appreciate the nature of the data within the GIS, particularly with respect to areal data (Orford, 1999).

### 5.4.5 Spatial Analysis and GIS

'The true potential value of GIS lies in their ability to analyse spatial data using the techniques of spatial analysis' (Goodchild, 1988: pp. 76). Within the same context of hedonic house price study, discussion on the closer linkages between spatial analysis and GIS will be provided in this subsection. At the outset, it must be noted that GIS and spatial analysis are inextricably linked, and spatial analysis has benefited from advances in GIS in recent years. Note that both GIS and spatial analysis can benefit from greater integration and interaction between them (see Figure 5.2) (Fisher and Nijkamp, 1992).

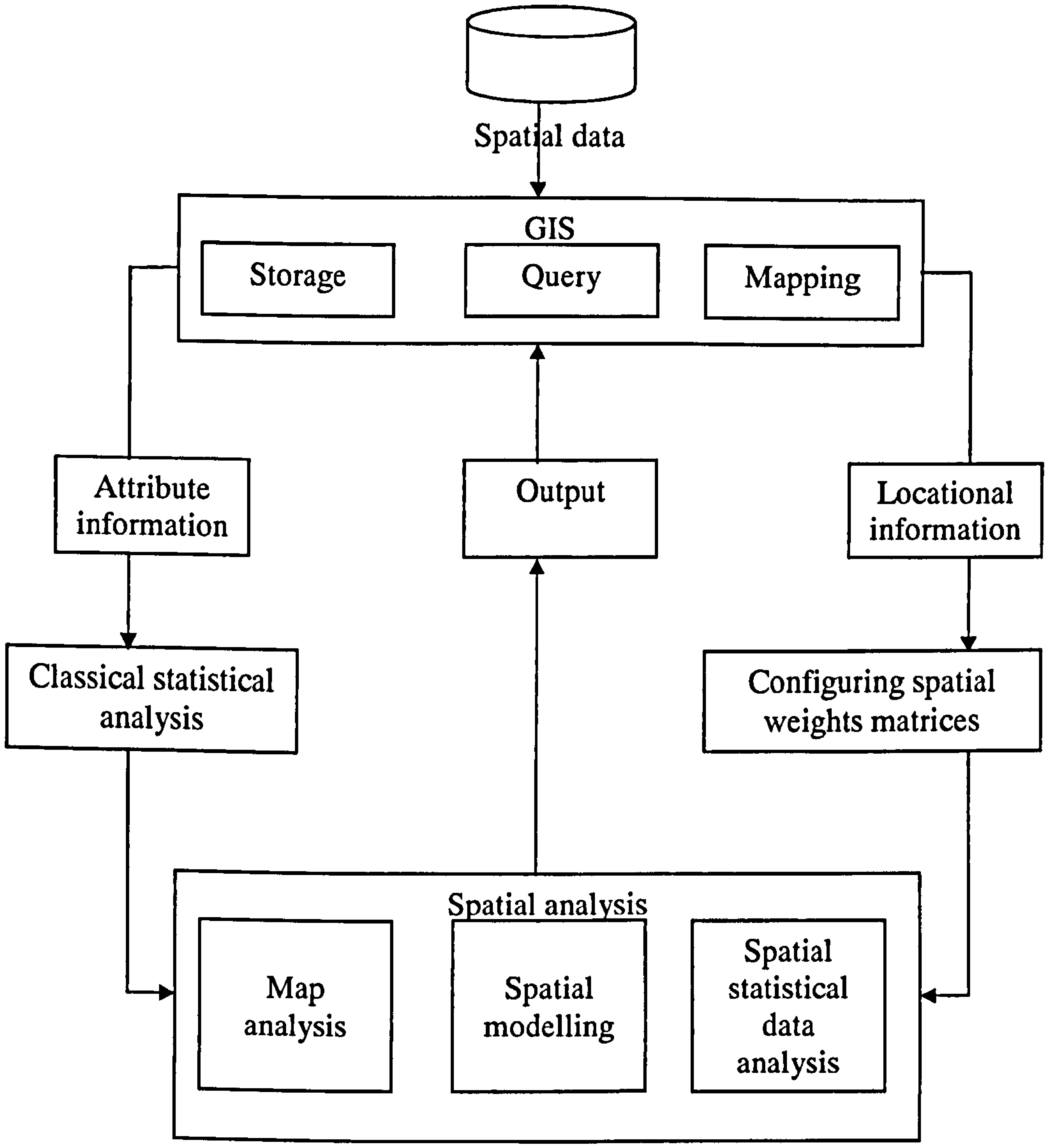



**Figure 5.2**: Linkages between GIS and spatial analysis
*Source*: Adapted from Zhang and Griffith (2000)

Spatial analysis techniques have been defined as those 'whose results are dependent on the locations of the objects or events being analysed' (Goodchild et al., 1992). Bailey (1994) noted that spatial analysis is a general ability to manipulate spatial data into different forms and extract additional meaning as a result. Most importantly, spatial analysis involves the analysis of patterns in spatial data, relationships between patterns and other attributes, or the modelling of such relationships for the purpose of the understanding or prediction of certain phenomenon within the study region. As noted in the previous subsection, GIS has a capability of storing rich amounts of spatial data in its database management system – spatial analysis might take advantage of it.

In the context of this study, by integrating spatial analysis techniques into GIS, it would seem that a GIS would be an effective tool for estimating hedonic house price models. Arguably, GIS were initially developed as tools for storage, retrieval and display of geographic information. Therefore, its functionalities for the geographic analysis of spatial data, specifically the spatial analytical and modelling functionality were either poor or lacking, particularly in the early systems (Rogerson and Fotheringham, 1994). As has been argued by Fisher and Nijkamp (1992), GIS technology has been commonly used for visualising information into a map and answering simple spatial queries. In other words, the spatial analytical and modelling functionalities of GIS are limited and it would seem that a GIS is only appropriate for simple analysis. In relation to this point, Fischer and Nijkamp (1992: pp. 8) have summarised the basic spatial analytical of GIS technology as follows:

- geometric calculation operators such as distance, length, perimeter, area, closest intersection and union,
- topological operators such as neighbourhood, next link in a polyline network, left and right polygons of a polyline, start and end nodes of polylines,
- spatial comparison operators such as intersects, inside, larger than, outside, neighbour of, etc.,
- multilayer spatial overlay involving the integration of nodal, linear and polygon layers, and
- restricted forms of network analysis.

It is widely acknowledged that the lack of spatial analytical functionalities is a major deficiency of GIS. Hence, Openshaw (1994a) argued that attention needs to be moved away from the view of GIS as solely one of Geographic Information Handling to one of Geographic Information Using. The concept that has been developed by Openshaw and his colleagues is that of 'GISable' spatial analysis. Orford (1999) and Lake et al. (1998) have arrived at a similar conclusion in the context of GIS functionalities. They noted that GIS have been used extensively for storing, manipulating, transforming and visualising spatial data, however, its spatial analysis potential has been under utilised. According to Lake et al. (1998) in most of the hedonic house price studies relatively simple GIS techniques are used, hence, the true potential of a GIS is not fully exploited. Moreover, there is an increasing demand for GIS that 'do something' other than display and organise data.

In order to achieve this, Openshaw (1994b) has proposed ten basic rules for identifying 'GISable' spatial analysis technologies (see Table 5.3).

**Table 5.3**: Ten rules for developing 'GISable' spatial analysis

| | |
|---|---|
| Rule 1 | A GISable spatial analysis method should be able to handle large and very large N values |
| Rule 2 | Useful GISable analysis and modelling tools are study region independent |
| Rule 3 | GIS relevant methods need to be sensitive to the special nature of spatial information |
| Rule 4 | The results should be mappable |
| Rule 5 | GISable spatial analysis is generic |
| Rule 6 | GISable spatial analysis methods should be useful and valuable |
| Rule 7 | Interfacing issues are initially irrelevant and subsequently a problem for others to solve |
| Rule 8 | Ease of use and understandability are very important |
| Rule 9 | GISable analysis should be safe technology |
| Rule 10 | GIS methods should be useful in an applied sense |

*Source*: Adapted from Openshaw and Clarke (1996)

The next logical question that could be asked is; what is the best way to link GIS and spatial analysis? In answering that, the discussion will refer to the suggestions provided by Goodchild (1987; 1991) and Openshaw (1990b). They have characterised the general ways of linking GIS and spatial analysis; full integration of spatial analysis tools into GIS, 'loose coupling' of GIS and spatial analysis, 'close coupling' of GIS and spatial analysis, and full integration of GIS procedures into spatial analysis and modelling frameworks.

A full integration of spatial analysis tools into GIS occurs when statistical spatial analysis software is incorporated into the GIS package. In the case of 'loose coupling', user-friendly interfaces need to be written to special statistical software packages for spatial data, whilst for the 'close coupling', a basic spatial tool box needs to be developed for inclusion in standard statistical packages or graphics software usually achieved through ASCII files exported from GIS. A full integration of GIS procedures into spatial analysis and modelling framework attempts to exploit the unique functionalities of GIS to devise new and more relevant analytical procedures.

Following Fisher and Nijkamp (2005) attention also needs to be given to the issue of identifying GIS-relevant spatial analysis functions. In relation to this point, different researchers have different opinions concerning it. As has been noted by Goodchild (1987), an ideal GIS should include at least six classes of spatial analysis. Openshaw (1991) recommends eight spatial analysis techniques that might be regarded as 'GIS appropriate generic'. Haining (1994) identifies three fundamental types of spatial operations for a spatial data analysis module in GIS. Finally, Bailey (1994) lists more than ten methods of potentially useful spatial analysis techniques. As Bailey noted GIS has indeed provides a suitable environment for application of spatial statistics and other forms of spatial analysis. In response to this, much attention has been given recently to the role and contribution of GIS in spatial analysis and much progress has been made in the last decade in improving the spatial analytical functionalities of GIS (Zhang and Griffith, 2000). For example, a feature of the GIS research agendas of both the UK Regional Research Laboratories and the American National Centre for Geographic Information Systems and Analysis was the perceived need for GIS users to have access to a greater range of facilities for undertaking spatial analysis. In addition, the University Consortium for Geographic Information Systems (UCGIA) identifies spatial analysis in a GIS environment as one of its top research priorities.

In the context of house price study, for instance, empirical studies in the 1970s and 1980s used very simplistic measures of locational attributes such as straight-line distance to CBD. However, the rapid development in GIS is driving recent study towards more sophisticated way of capturing the characteristics of the environment in which the property is located (Wu, 2002). For instance, Lake et al. (1998) used GIS viewshed analysis to include the visual impact of various land uses on property prices. As they highlighted (pp. 125) 'GIS allows us not only to determine whether the river can be seen in a fraction of the time, but also permits more sophisticated measures of visual impact to be considered'. Orford (1999) developed explicit measures of the attributes at the levels of property, street and community. Moreover, Lake et al. (2000b), Orford (1999), Hess and Almieda (2007) and Poudyal et al. (2009) utilised the capabilities of GIS by using it to measure the proximity from each property to locational attributes by employing network analysis. Poudyal et al. (2009) for instance used the capabilities in ArcGIS 9.2 to measure network distance from each observation to airport, schools, railroad, rivers, urban parks and CBD. Orford (1999) and, Du and Mulley (2006) integrated GIS with the advanced data analysis techniques such as Multilevel modelling approach and GWR models to be applied to the house price analysis, respectively. In other words, analytical GIS techniques that integrated to spatial modelling such as Multilevel modelling approach and GWR models can provide clues to previously unreported non-stationary of spatial relationships between house prices and its determinants and can serve a useful starting point and a guide for future investigations. García et al. (2008) constructed of an automated valuation system through the combination of an artificial neural network (ANN) and GIS. They concluded that the integration between ANN and GIS has proved to be a very powerful and useful tool for house price studies, and therefore other researchers may consider this approach heavily in carrying their research.

It is worth noting that, the process of integrating GIS and spatial analysis is more convenient since we are now be able to access to the user friendly of GIS software package such as ArcView and ArcGIS. Furthermore, the ability of GIS to perform network analysis has given us opportunity to carry out accessibility analysis which is somewhat important in measuring the effects of locational attributes on house prices. As Zhu and Liu (2004: pp. 91) pointed out 'GIS has become a useful tool for accessibility analysis, which provides capabilities for data collection, data management and manipulation, spatial analysis, network analysis and cartographical presentation of accessibility measures'. In the case of the role of GIS as a powerful visualisation tool, many efforts have taken place in order to improve the capability of GIS in visualising spatial data such as through new developments within framework of wearable computing and augmented reality. Pundt and Brinkkötter-Runde (2000) stated research and development in visualisation will have impacts on GIS, in particular on field based GIS. In addition, the problems associated to visual information management have been solved due to the existence of new concepts and techniques in computer science that can be employed.

### 5.4.6 GIS in Previous Hedonic House Price Study

An attempt to employ GIS in hedonic house price study has started in the US, but in the late 1990s, much attention has been given by UK researchers in employing GIS for the purpose of their research and now GIS has widely been employed in hedonic house price study. GIS has obtained greater attention from researchers because of its capabilities, particularly in handling and organising large spatial datasets from various sources. A review of the literature indicates that GIS has previously been used by a large number of researchers (see for example Bateman et al. 2001; Des Rosiers et al. 2001; Mikelbank, 2000; Lake et al. 2000a; 2000b; Orford, 1999; Powe et al. 1997; Kennedy et al. 1996; Waddell and Berry, 1993; Waddell et al. 1993; Sanchez, 1993), to name a few. In most of these studies, GIS has been used to prepare spatial datasets and conduct several functions such as calculate distance and proximity measures from residential properties to the CBD, roads network and rail stations and amenities. In addition, GIS has also been use to calculate lot-size from digitised boundary data and the mapping of the error terms to determine the existence of spatial autocorrelation.

For instance, Mikelbank (2004) has carried out research on the spatial relationship between house price and investment in road-based transportation infrastructure. He has analysed single-family detached residential properties sold in the Ohio counties of Franklin and Delaware during 1990. GIS has been used to prepare the dataset for the analysis, the analysis itself made extensive use of GIS in the geocoding of the housing transactions, the geocoding of the transportation investments and the creation of the spatial variables. Finally, GIS has also been used in the process of building the spatial regression model. Meanwhile, research carried out by Song and Knapp (2004) has focused on the impact of mixed land used on the prices of single-family houses in Portland, US. In this work, GIS has been used to develop several quantitative measures of mixed land uses. In addition, accessibility to the nearest non-residential land uses can be measured accurately due to the existence of GIS technology.

Lake et al. (2000b) have carried out a study on the determinants of house prices in Glasgow, Scotland. They used GIS to derive the variables which impact on house prices. For instance, GIS has been used to determine the ground floor area of a property. Moreover, GIS has been used to position each observation on a local map by using ADDRESS-POINT. They also utilised the capabilities of GIS by using it to measure the accessibility from each property to shops, parks, railway stations, schools, bus routes and the CBD. For this, two types of measures have been employed; Euclidian distance and car travel time. In the case of car travel time, it was calculated by extracting a road network and estimating the likely vehicle speed along each road. The network modelling capabilities of a GIS were then utilised to calculate the time it would take a car to travel between each observation and the nearest facilities. Furthermore, GIS has also been used to create measures of visual impact for each property and for each land use. Using a similar approach, Bateman et al. (2001) have carried out a study on the effect of road traffic on residential property values in Glasgow, Scotland. In this work, GIS has been used to derive structural and neighbourhood variables which are believed to have an impact on house prices. In the case of structural variables, factors such as floor area, plot area, slope and property type were derived using GIS. Similarly to the neighbourhood variables, GIS has been used to calculate neighbourhood variables at variety of different spatial scales. GIS has also been used to calculate three different measures of accessibility from each property to each amenity (Euclidian distance, car travel time and walking distance). Finally, GIS has been used to calculate viewsheds for each property. The results from this analysis have showed the area of land that was visible from each property by taking into account the height of the land and the height of features such as buildings.

Orford (1999) used GIS to value the built environment in Cardiff, Wales. He used GIS for the construction of coverage which contained four spatial levels of resolution; the property, the street, the HSC area and the ward. Other coverages were also constructed in an attempt to quantify the major locational externalities. GIS has also been used to generate locational externality measures. For instance, GIS has been used to measure the straight-line distance between two points and for a more accurate measurement of accessibility, the underlying typology of the road network. In his study, ARC/INFO programme has been used to measure accessibility along the street network using the NETWORK module within the ARC/INFO programme. In addition, GIS has also been used to visualise locational externalities and the estimated parameters that have been used to calculate the effects of these externalities on each property in monetary terms. These values have also been visualised within the GRID module of ARC/INFO.

A study carried out by Powe et al. (1997) on the benefits created by improving access to woodland in Southampton, England have used GIS for several purposes. Firstly, maps which contain land use data and land parcels were digitised onto a computerised data file and the ARC/INFO programme was used to generate accurate data on the level of environmental and service variables. Secondly, GIS has been used to measure the extent of access to woodland and other amenities from each observation. Finally, GIS has been used to measure how far away a house is from woodland sites and also to estimate the area of those sites. Note that the information obtained from this analysis was used to construct a forest index measuring the woodland access potential of a given property. This study has demonstrated that GIS provides clear advantages over manual methods of data collection, and the speed and accuracy with which the variables can be generated using GIS permits a greater variety of spatial variables to be generated.

It should be clear from the above discussion that a GIS is an ideal medium to approach hedonic house price research. Therefore, GIS will be employed in this study to organise and manage spatial datasets, perform spatial analysis (particularly with respect to the distance and proximity measures) and finally visualise the spatial data and map the results of the modelling.

## 5.5 Conclusion

This chapter has described the types of housing attributes that influence house prices. These housing attributes have been classified into two categories; structural and locational attributes. The discussion on the effect of locational attributes on house prices led to the concept of locational externalities. It has been suggested in the above discussion that the effects of locational attributes on house prices are determined primarily by the magnitude of the attribute and proximity to the residential property. However, as mentioned earlier, most externalities are local in their impact, with a distance decay effect in their extent and intensity. The discussion is continued by focusing on how these attributes have been presented and measured in the previous studies. Yet, it has been highlighted above that one of the main problems with hedonic house price models is the treatment of locational data, for example, for the purpose of modelling and measurement of locational attributes, in particular the measurement of proximity variable. This problem has been addressed by combining GIS together with spatial analysis as a powerful tool that can be used to measure the proximity from a unit of house to various locational attributes which always caused problems in the previous studies. Finally note that the information given in this chapter on the types of housing attributes that need to be considered in determining house prices, as well as on how these attributes has to be measured in order to capture its effects, will be used as guidelines in the next chapter.

# CHAPTER 6

## Measuring the Effects of Rail Transit Systems on House Prices: Research Methodology

### 6.1 Introduction

Based on the discussion in previous chapters, it can be appreciated that measuring the effects of rail transit systems on house prices is a demanding exercise. It requires appropriate methods that are capable of measuring the changes in house prices following the construction of rail transit systems accurately. As has extensively been discussed in Chapter one and three, the ideal method for measuring these effects is by measuring accessibility as the distance of a house from the rail transit stations.

The next question is; how to measure the distance of a house from the rail transit stations and also from other amenities? Is a straight-line-distance measure an appropriate measurement for capturing those effects on house prices? Do we have other types of measurements that can be used, so that it could capture much more accurate effects? In order to answer these questions, various types of measurements that have been proposed by previous studies will be examined. In addition, as has been pointed out in Chapter three, the overall effect on house prices can be measured accurately by taking into account changes in the prices of all housing attributes (structural and locational attributes).

Measuring these effects also requires good quality data of a high spatial resolution, econometric techniques and the use of appropriate methods that are able to identify and determine all factors that contribute to house prices. Hence, this chapter intends to answer the questions highlighted earlier. The aim of this chapter is to outline the appropriate methods for measuring the effects of rail transit systems on house prices. Furthermore, this chapter will also outline the case study and identify suitable datasets.

## 6.2 Research Methodology

### 6.2.1 Introduction

The aim of this study is to measure the effects of rail transit systems on house prices. The methodological framework of this study is shown in Figure 6.1. The research procedures of measuring the effects of the rail transit systems on house prices can be described in six stages. These six stages are research approach, selection of study area and rail transit systems, data collection (this includes identifying data requirements and investigating their availability), preparing the data, an overview of house prices and the LRT relationship, and final dataset for principal analysis.

The first stage involves a **research approach.** It aims to find the appropriate approach to measure the effects that has been previously mentioned. This stage examines two areas; first is the approaches that have been used and suggested by other researchers, and second is the selection of the approach that will be applied in this study.

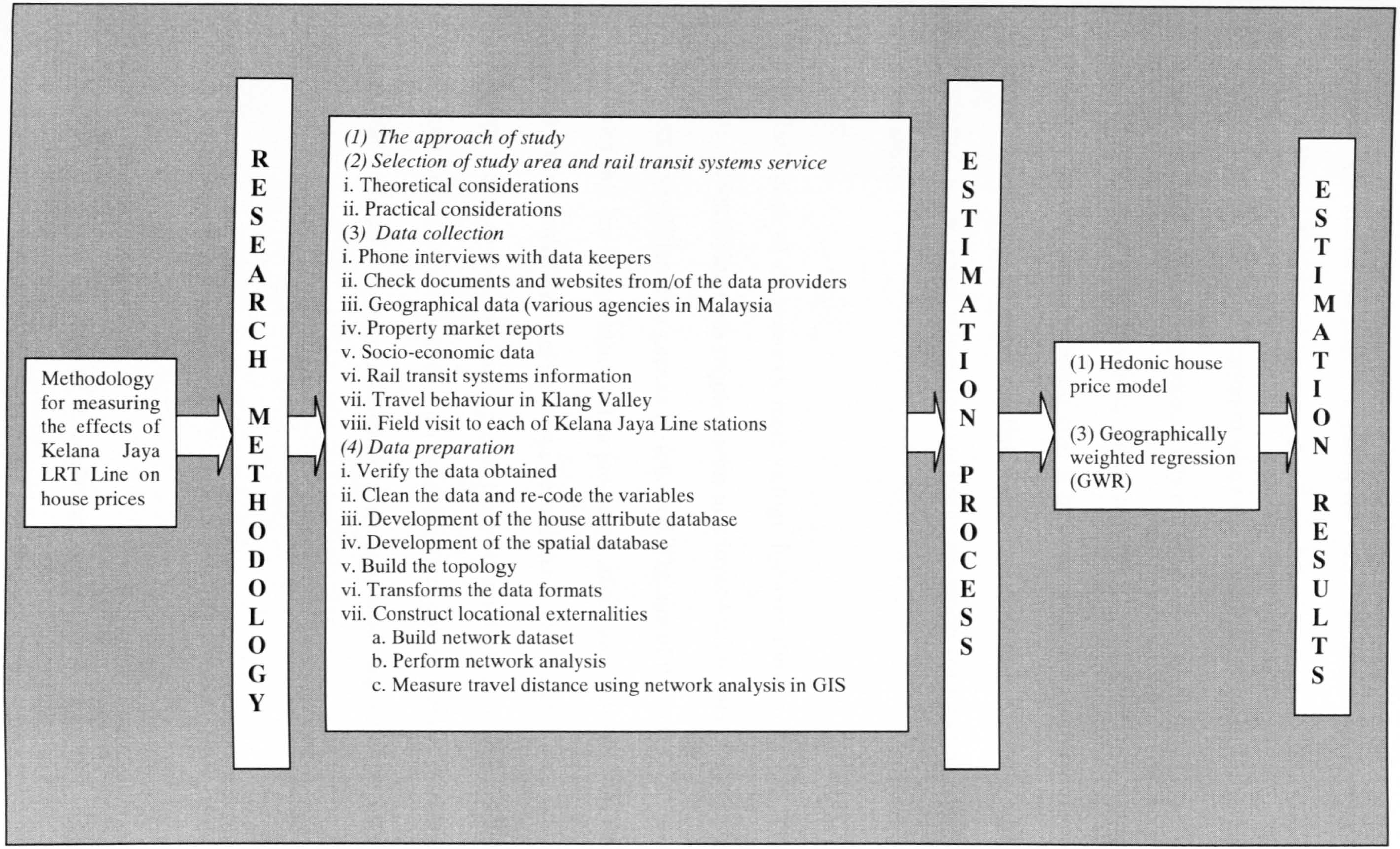



**Figure 6.1**: The framework of the methodology

The second stage of the research discusses the **selection of the study area and rail transit systems**. The aim of this stage is to justify the use of the Klang Valley region as a study area, and the Kelana Jaya Line as the line that is needed to measure the effects of light rail transit on house prices. The justification of using the Klang Valley region as a study area as been argued in Chapter four is that accessibility of rail transit systems may have a different impact in different cities – as has been mentioned earlier that there is a debate between the monocentric city and polycentric city. It has also been argued that different types of rail transit systems such as heavy and light rail transit systems may have a different impact on house prices. Therefore, it is essential to justify the process of selecting rail transit systems as a case study.

The final stage of the research methodology involves **data collection**. This includes the process of **identifying data requirements and investigating their availability**. This process involves several steps that need to be followed. The aim of this stage is to make sure that the variables that have been identified in preceding stages are available. It is also important to identify their availability before it can be collected. This stage is very crucial because the researcher need to deal with many people from various agencies in order to obtain all the data and information that is required for this study. Thus, this process is both highly demanding and time and cost consuming. All of the aforementioned stages will be discussed in greater detail in the next subsections.

### 6.2.2 Research Approach

This subsection will identify the research approach that will be applied in this study. In the literature, several approaches have been proposed on how to measure the effects of rail transit systems on property values such as house prices. In most studies, a cross-sectional approach was employed in measuring the effect of rail transit systems on property values. A cross-sectional approach is a method that compares conditions in one area with a given transportation investment to a similar area without such an investment. For example, rail transit systems can be reached by accessing its transit stations. Therefore, the ability to access transit stations conveniently and quickly should be capitalised property values. In other words, higher property values are expected in places with superior access to stations. Property values changes within certain distances of transit stations are compared to those in similar areas before rail transit systems were constructed. However, the changes in property values can only be expected if accessibility to and from the CBD has improved due to the existence of rail transit systems. When rail transit system facilities influence travel times for households, it is reasonable to expect property values to be affected. However, in studies that do not accurately measure the changes in travel time (usually properties located too far away to enjoy travel time savings) are included in the analysis, results tend to show insignificant property value changes (Ryan, 1999). Therefore, areas within walking distance of the station are typically considered as the catchment areas.

The other method that can also be found in the literature is by implementing a "test" group and a "control" group, each monitored before and after the "treatment". However, it has been argued by Giuliano (2004) that it is nearly impossible to implement such an approach in the context of transportation effects on property values. He explained further that with enough lead time in which a before and after study can be done, there is no control group with which to compare the before and after results. There are two main problems with this method; transportation changes that take place in a highly dynamic system and the interaction of property values and transportation takes place over time. This method requires transportation investment to be identified as a major effect on property values, but this is problematic due to a change in the transportation system which is just one of many changes occurring at the same time with other developments. In addition, changes continue after investment takes place, making it difficult to attribute observed changes correctly (Giuliano, 2004). Also, the interaction of the property values and transportation in an urban area may take place over time. As a result, the market response to changes in transportation may take place only several years after of implementation.

In several other studies, the method known as longitudinal was applied to measure the effect of rail transit systems on property values. A longitudinal approach is a method that compares conditions before and after a given transportation investment. The main focus of a longitudinal approach is on one area and studies the changes that take place over a given period of time. Note that if lead time is sufficient and the data is available, property values change within the area of effect are traced from before the project took place to a period of time after its completion. Giuliano (2004) suggests that in order to isolate transportation-related effects, all other factors thought to be relevant should be incorporated into the analysis. However, the major limitation with this method is a need to have a large sample size and accurate sampling to reach representativness. In other words, this method is extremely time consuming and the readily available data (house price transactions and land use changes over certain period of time) is the crucial one. This is due to the fact that the robustness of the estimation is relying heavily upon the quality of data that has been prepared.

Based on the discussion of the aforementioned approaches, the cross-sectional method has been identified as an appropriate approach in measuring the effect of LRT on house prices for this study. The selling price for each of the individual houses located within two kilometres of the rail transit station will be collected before the construction of the rail transit system and after its completion. Further discussion on the use of the two kilometres radius buffer areas surrounding LRT stations will be given in the subsection of the data collection. In the context of this study, residential parcels that were sold during the years of 2004/05 (after opening) will be selected. The justification of selecting these two periods will be provided in subsequent sections. As has also been highlighted above, the ideal method for measuring rail transit effects on house prices is by measuring accessibility as the travel time savings provided by the service. It is because straight-line-distance from residential parcels to rail transit stations may not always be correlated with travel time.

The most commonly used measures in accessibility studies are gravity potential, average distance between each origin and all amenities and other facilities, minimum distance (the distance from an origin to the nearest amenities and other facilities) and the number of amenities and other facilities within *n* meters (Appraricio and Sequin, 2006). Three types of distance can be used to calculate these four measures of accessibility; Euclidean distance (straight-line), network-distance and network-time (easy walking and driving distance to LRT stations, and other amenities and facilities). In the case of this study, two methods will be tested for measuring the distance between a residential property and an LRT station; straight-line-distance and network-distance. It is noted that the primary objective of accessibility measures is to describe the proximity of housing buildings to LRT stations and other amenities and facilities, in the process of identifying the determinants of house prices, particularly those located near to LRT stations and to other amenities and facilities.

### 6.2.3 The Study Area: Klang Valley

#### 6.2.3.1 Introduction

The chosen area of study is the Klang Valley region, Malaysia. The Klang Valley region consists of five administrative units which include the Federal Territory of Kuala Lumpur (the capital and financial and commercial centre of Malaysia), and four other districts of the state of Selangor; Klang, Petaling, Hulu Langat and Gombak. Being situated between the northern and southern regions has made the Klang Valley the core of the larger planning entity of the Peninsular Malaysia (see Figures 6.2 and 6.3). The Klang Valley region encompasses an area of 2,843.42 square kilometres or 1,097 square miles and, as of the year 2000, it had a population of about 4.5 million (about 20.4 per cent of the total population of Malaysia). The selection of the Klang Valley as a study area relies principally on several considerations.

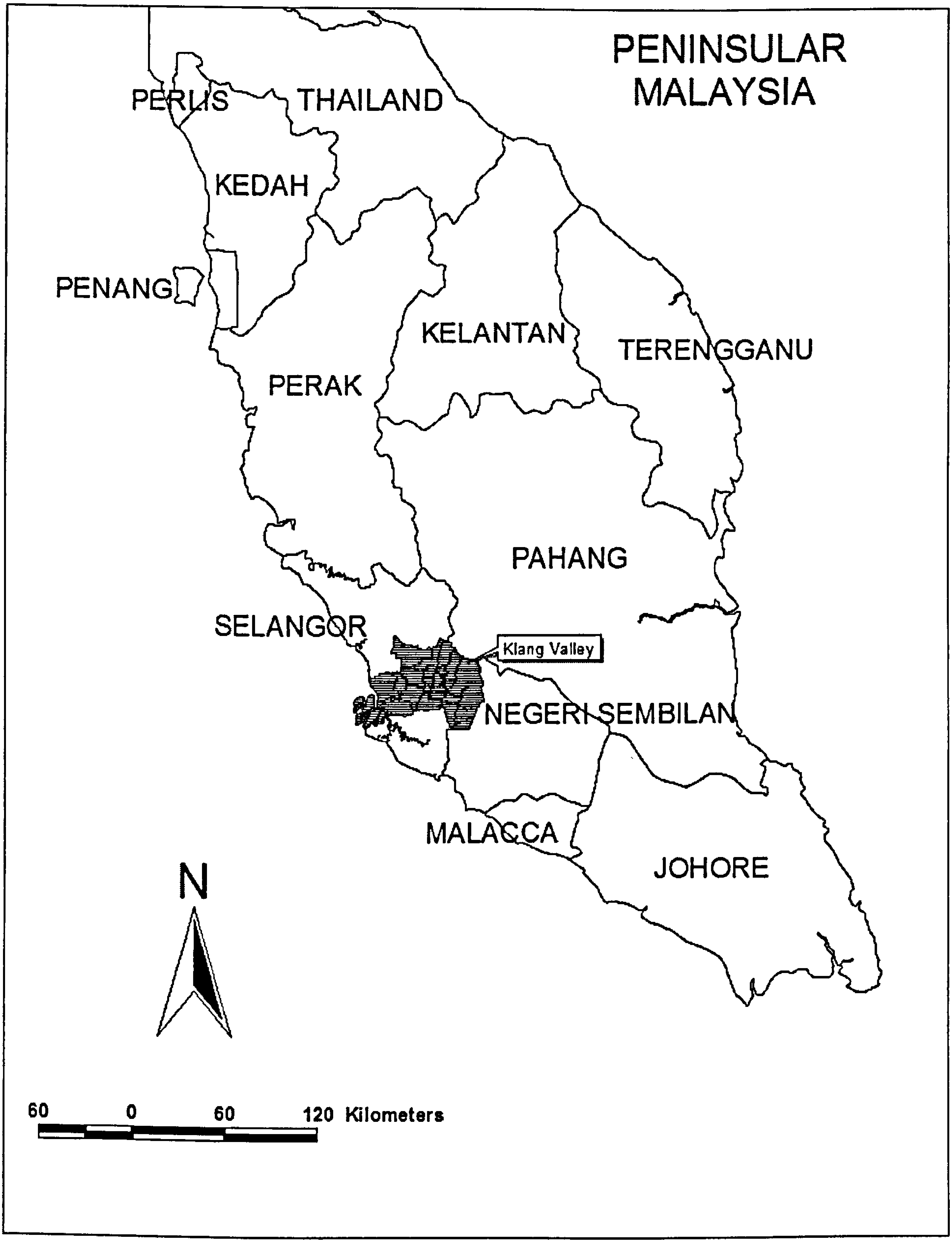



**Figure 6.2**: The location of the Klang Valley in Peninsular Malaysia
*Source*: The Federal Territory Development and the Klang Valley Planning Division (2004)

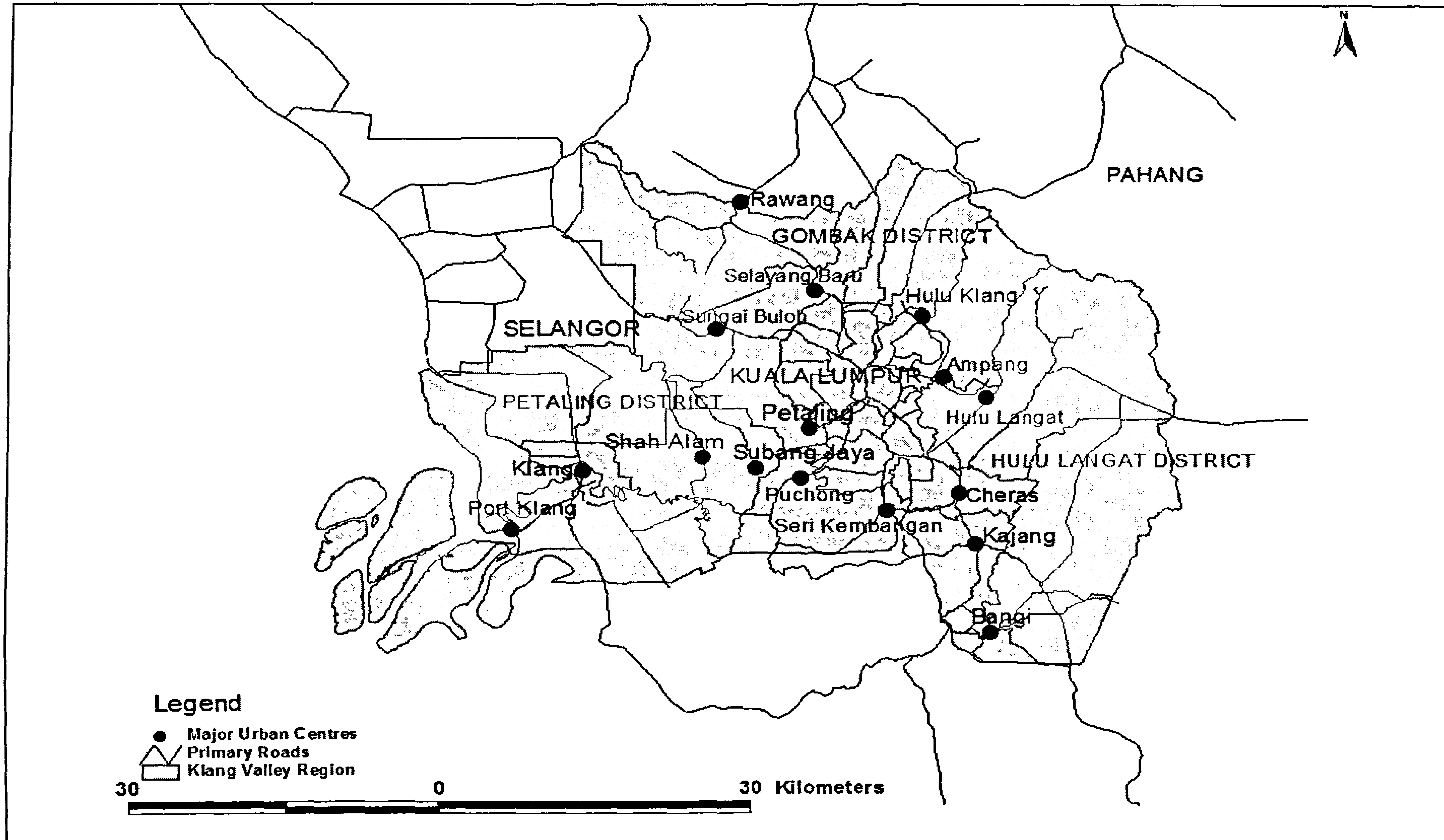



**Figure 6.3**: The Klang Valley and its conurbation
*Source*: The Federal Territory Developnment and the Klang Valley Planning Devision (2004)

The first consideration is that the Klang Valley region has been the most rapidly growing region in Malaysia during the past few decades. The early growth of this region concentrated primarily in the Federal Territory of Kuala Lumpur. Kuala Lumpur is the major financial and commercial centre of Malaysia and it encompasses an area of 243 square kilometres and had a population of about 1.4 million in 2000 (about 31 per cent and 7 per cent of the total population of the Klang Valley and Malaysia, respectively). Figure 6.4 shows the built environment of the Klang Valley. According to Sirat (2000), there are various criteria that are required to be fulfilled before any city can be identified as world city of a particular rank and, evidently, Kuala Lumpur has fulfilled some of these criteria. It has been argued further by Beaverstock et al. (1999) that Kuala Lumpur also plays a major role as a 'major global banking service centre' and a 'minor global accountancy and advertising service centre'. Kuala Lumpur can be illustrated as a monocentric city, where all job opportunities are located in the CBD. This is opposed to the role of Kuala Lumpur in the 1960s and 1970s where it was primarily focused on manufacturing production. In other words, there has been a rapid transition of Kuala Lumpur's economy from manufacturing production to tertiary production – this transition can be seen clearly in the 1980s. As a result, gross domestic product (GDP) per capita of Kuala Lumpur and incomes have continuously been higher than in the rest of the country (Sirat, 2000).

The rapid growth of the population, employment, economic activities and services, particularly in Kuala Lumpur and the Klang Valley in general has resulted in a demand boom for housing, primarily within easy commuting distance to and from Kuala Lumpur such as in Petaling Jaya, Klang, Ulu Langat and Gombak. In addition, the rapid growth of the population often creates structural challenges and problems (Hirschman, 1980).

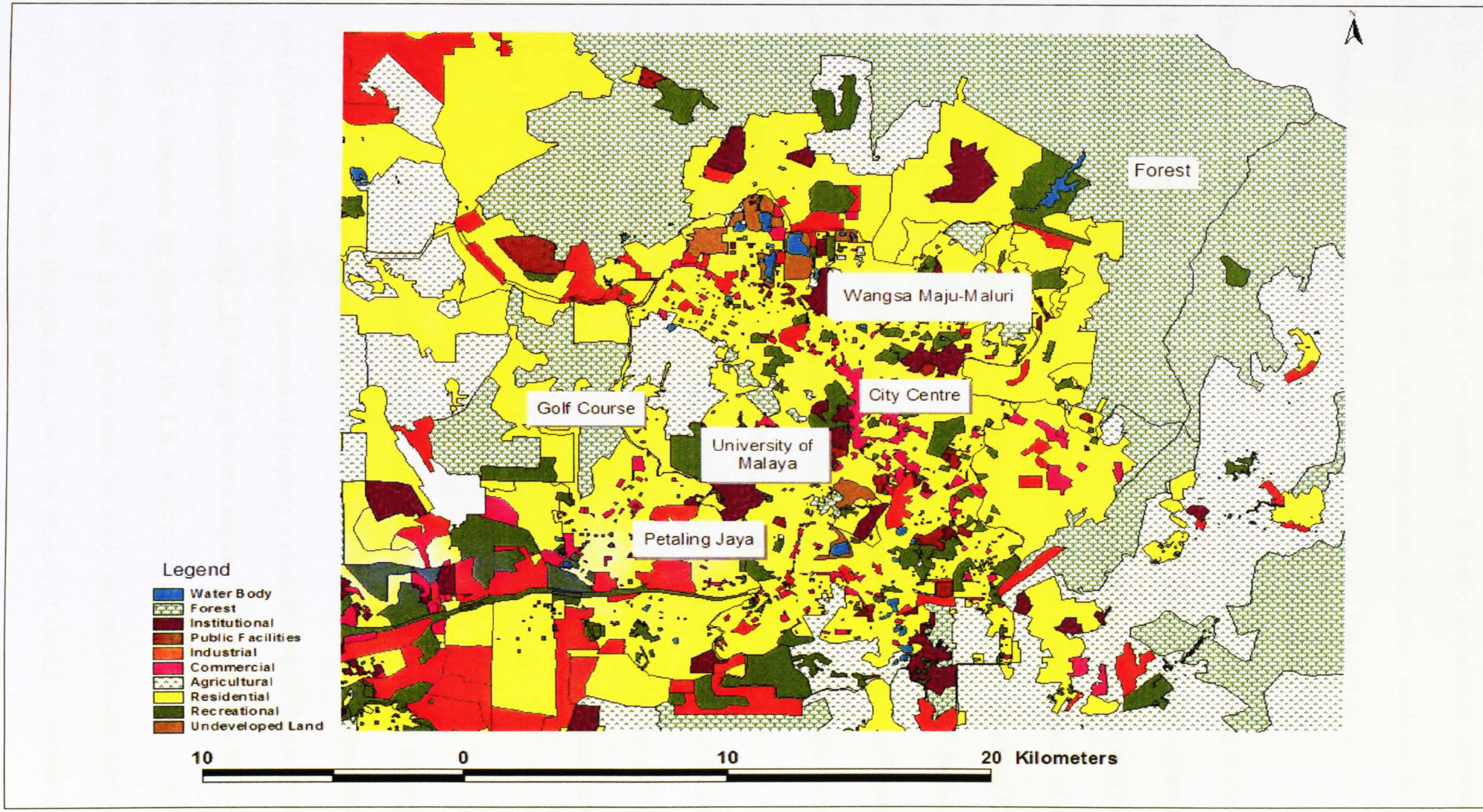



**Figure 6.4**: The built environment of the Klang Valley

In the case of the Klang Valley for example, its rapid population growth has created a number of problems such as traffic congestion, squatter settlements, pollution and environmental quality which tends to diminish (Aiken and Leigh, 1975).

Therefore, in the presence of these problems, comprehensive planning is essential to ensure that new development does not generate a negative impact on the society, economy and environment (Samat, 2001). The Klang Valley Planning Secretariat (KVPS) was established in 1981 under the Prime Minister's Department. The establishment of this secretariat coincides with the formation of two committees; the Klang Valley Planning Council (KVPC) and the Klang Valley Working Committee (KVWC) through the Federal Government Circular dated 9th March 1981. Moreover, Kuala Lumpur's Master Plan Transportation Study was undertaken and one the recommendations of this study was 'the need to achieve the best possible physical structure and arrangement for Kuala Lumpur which is supported by an efficient transportation system' (Kuala Lumpur City Hall, 1984). The efficient transportation system was translated into constructing an LRT system as part of the public transportation system in the Klang Valley region – to handle future traffic demands and, of course, to reduce traffic congestion, particularly in Kuala Lumpur.

The Klang Valley LRT system is the first LRT system that has been implemented in Malaysia. The reason for selecting this area as the study area can be associated with this point. Thirdly, no empirical research of property values effects has been conducted following the implementation of the LRT system in this region. This study can be considered the first attempt to measure the effects of the LRT system on property values. Fourthly, as has been mentioned above, this area is appropriate to apply the well-known monocentric model of urban land use. Thus, the task to measure the effects of the LRT system on house prices is less complicated compared to a polycentric city that can be found in most of US cities. In addition, the availability of land parcels and land use digital data is another consideration in selecting this area. As has been noted earlier, GIS will be employed in preparing and analysing the data for hedonic price models. Thus, the basic map for this study namely land parcels, have to be digitised before any further analysis can be performed.

The process of digitising the land parcel map can be time intensive before it is ready to use. But, this is not the case of this study since land parcel and land use data in digital format were obtained from the Centre of Spatial Analysis, University Science of Malaysia. Once the spatial data is ready and in a usable format, it is a simple task for the GIS package to derive spatial variables for each house (Powe et al., 1995). Finally, the familiarity of the researcher with the study area also needs to be considered as a significant factor in choosing the study area. It has been argued in the literature that familiarity with the study area could help the researcher to verify the results and findings. In addition, familiarity with the study area is important because the researcher has to visit the place several times and collect secondary data from various government agencies for the purpose of this study. Therefore, familiarity with the study area could make this task much easier. The discussion now is extended from the study area into several essential attributes, particularly in understanding the contributory factors of the rapid growth of this region.

### 6.2.3.2 Historical Background

As noted in the preceding subsection, the rapid growth of the Klang Valley region was concentrated primarily in the Federal Territory of Kuala Lumpur. Geographically, Kuala

Lumpur is located at the confluence of the Klang and Gombak rivers (over a hundred years ago this was the farthest point that could be reached by cargo-boats) (Daly, 1882). Kuala Lumpur has long been the centre of trade and commerce of this region (Aiken, 1981). The major contributions of the early rapid growth of the town included agricultural, tin mining and rubber plantation industries in the early nineteenth century, and it later became the most prominent mining and plantation centre in the state. It must be noted that agricultural, tin mining and rubber plantation industries depended heavily on foreign immigrants who came from Indonesia, China and India. For example, in 1887, 4,438ha of land in the state were opened for agricultural purposes. Note that the development of agricultural activities led to a greater population increase. As Lee (1994) noted, in 1886, 8,000 migrants from China and 12,000 migrants from Indonesia entered Selangor.

In 1880 when the British Resident and staff were transferred from Klang to Kuala Lumpur, its administrative role began, and 1896 Kuala Lumpur was chosen by the British as the capital of the Federated Malay States (Selangor, Perak, Pahang and Negeri Sembilan). Since the British were established in Kuala Lumpur, the jungle tracks were transformed into road and rail networks. The construction of road and rail networks produced a number of benefits – the town began to emerge as a major centre of commerce and services, particularly for the developed west-coast lowlands (Aiken, 1981). Its rapid development during the First World War and Second World War period was closely related to the varied fortunes of tin and rubber production. The rapid growth of this town created employment opportunities and further attracted people to work in these industries, in particular immigrants from China and India. According to Aiken and Leigh (1975) the most rapid urban growth of this region occurred between 1947 and 1957.

After achieving independence from the British in 1957, many areas in the Klang Valley joined the rapid growth of greater Kuala Lumpur through industrialisation to form a huge conurbation. Thus, many employment opportunities were offered by this region. Interestingly, there are perceptions among people in rural areas about better opportunities in this region to improve their lives. Therefore, it has made the Klang Valley in general, and Kuala Lumpur in particular the main attraction of people from the rural areas in the State of Selangor itself and other parts of Malaysia, especially from the neighbouring states of Negeri Sembilan and Perak, and the east-coast which faced slower economic development. In 1970, greater Kuala Lumpur had 43 per cent of the population of the State of Selangor and 8 per cent of the population of Peninsular Malaysia. Indeed, rural-urban migration has significantly contributed to the transformation of many areas in the Klang Valley into new towns. These new towns encompass the satellite town of Petaling Jaya (the first new town in Malaysia), Ulu Klang/Ampang, Subang Jaya, Shah Alam, Batu Tiga and more recently Bangi and Selayang (Aiken and Leigh, 1975; Aiken, 1981; Ithnin, 2001). In February 1974 the city of Kuala Lumpur was declared the Federal Territory of Kuala Lumpur. The state of Selangor gave up her legislative power and control of Kuala Lumpur to the Federal Government.

In the next subsection, detailed discussion is primarily focused on various aspects that have been associated with the rapid growth of the Klang Valley region such as demographic trends, jobs and employment, and transportation development. Note that in the case of transportation development, the focus will be given to the construction of rail transit systems as an effort made by the government to improve public transportation in the densest urban areas such as the Kuala Lumpur metropolitan area.

### 6.2.3.3 Patterns of Population Growth

The discussion in this subsection will be focused on the patterns of population growth in the Klang Valley since World War II. Table 6.1 shows the patterns of population growth of the Klang Valley between 1947 and 2000. As noted in the literature, the most rapid population growth of this region occurred after World War II, shown in Table 6.1, and was entirely attributable to natural increase, namely the surplus of births over deaths and the migration of people from rural areas to the towns. Note that the rapid population growth between 1947 and 1957 during the Emergency resulted from the migration of people from dangerous isolated rural areas to the relative security of towns (Aiken and Leigh, 1975). However, the rates of rural-urban migration probably decreased in the period of stability the end of the Emergency. As a result, between 1957 and 1970 the population growth of the Klang Valley was at a slightly slower rate compared to the previous period of time. Between 1970 and 1980, rapid population growth occurred, primarily due to the rural-urban migration from the State of Selangor and other parts of the country, and was of course also contributed to by natural increase. It must be noted that 1970 is a year after the May 13 Tragedy – race riots between the Malay (indigenous people) and Chinese in Kuala Lumpur on 13$^{th}$ of May, 1969. During this period, the population growth rate increased tremendously for several areas in the Klang Valley region, particularly in Petaling, Kuala Lumpur and Klang. These three areas have been dominated by the Chinese for about a hundred years.

**Table 6.1:** Patterns of population growth in the Klang Valley, 1947-2000

| *State and Administrative District* | Population | | | | | | Percentage annual growth rate | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1947 | 1957 | 1970 | 1980 | 1991 | 2000 | 1947-1957 | 1957-1970 | 1970-1980 | 1980-1991 | 1991-2000 |
| **KLANG VALLEY** | **374,245** | **576,065** | **874,646** | **1,902,951** | **2,952,050** | **4,546,402** | | | | | |
| Kuala Lumpur | 175,961 | 316,230 | 451,810 | 919,610 | 1,145,342 | 1,297,526 | 8.0 | 2.8 | 10.4 | 2.2 | 1.4 |
| Klang | 105,044 | 149,957 | 233,524 | 279,349 | 406,994 | 648,918 | 12.6 | 3.1 | 14.5 | 4.1 | 5.2 |
| Petaling | 29,352 | 41,664 | 93,447 | 360,056 | 633,165 | 1,181,034 | | 14.1 | 28.5 | 5.1 | 6.9 |
| Gombak | - | - | - | 166,059 | 352,649 | 553,410 | | | | 6.9 | 5.0 |
| Ulu Langat | 63,888 | 68,214 | 95,865 | 177,877 | 413,900 | 865,514 | | | | 7.7 | 8.2 |
| **SELANGOR** | **710,788** | **1,012,891** | **1,625,625** | **1,426,250** | **2,297,159** | **3,947,527** | | | | | |
| **MALAYSIA** | **4,908,086** | **6,278,758** | **8,780,728** | **13,136,109** | **17,563,420** | **22,202,614** | | | | | |

*Source*: 1947, 1957, 1970, 1980, 1991 and 2000 Population and Housing Census of Malaysia.

The rapid population growth between 1970 and 1980 can be classified as a manifestation of the race riots of 1969. Since then, the migration inclinations of the three major racial groups in Peninsular Malaysia have changed significantly. The main reason for the migration of huge numbers of Malays from other parts of Peninsular Malaysia to the Klang Valley is due largely to employment opportunities and promises of government assistance. It is important to note that the promises of government assistance were due significantly to the introduction of the Malaysian New Economic Policy (NEP) in 1971.

This policy was an affirmative action programme launched by the government for the purpose of reducing the socio-economic inequality between the minority of Chinese and the majority of Malays by 1990. The most fundamental idea of this policy was to create new economic opportunities for Malays without taking what belongs to the Chinese. Yet, it has been argued by some critics that the implementation of the NEP has it weaknesses and was not immune from corruption.

Between 1980 and 1991, the population of the Klang Valley grew at an average rate of 5.0 per cent per annum. The highest average annual growth rate in the Klang Valley region was recorded in Ulu Langat (7.7 per cent), Gombak (6.9 per cent), Petaling (5.1 per cent) and Kelang (4.1 per cent). However, between 1991 and 2000, this rate increased to 6.0 per cent per annum. The high growth rate of the Klang Valley has been accompanied by an increase in the birth rate and a reduction in mortality levels. In addition, the continued increase of the population in the Klang Valley region was due to a migration of people from other parts of Malaysia, particularly from the less developed area of the east coast and the northern part of the country (Department of Statistics Malaysia, 1980; 1991; 2000).

For example, in 1985 the total number of migrants to the Klang Valley was 215,425 people, which was almost 8.5 per cent of the total population in the Klang Valley. Nearly 60 per cent of them chose Kuala Lumpur as their destination followed by Ulu Langat, Petaling and Gombak and other districts (Department of Statistics Malaysia, 1986). However, this does not include the illegal immigrants from the various neighbouring countries such as Indonesia, Philippines and Thailand. Besides those neighbouring countries mentioned, the illegal immigrants also comprised people from Bangladesh and India. The exact number could not be obtained, yet it has been estimated that the total number of illegal immigrants in the Klang Valley is 1.5 million people.

### 6.2.3.4 Background Economic Indicators

In order to understand the housing market in the Klang Valley, it is essential to know the economic growth of this region. Thus, in this subsection we discuss the economic growth of the Klang Valley between 1990 and 2000. The selection of the period 1990 to 2000 is due predominantly to the availability of the data. It is noted that a gross domestic product (GDP) of Kuala Lumpur and Selangor can be used as a proxy to indicate a GDP of the Klang Valley since there is no direct GDP for the Klang Valley region. The economic growth of the Federal Territory of Kuala Lumpur and Selangor is largely determined by the performance of Malaysia's economy. It suffered several economic problems during the economic recession between 1985 and 1986 and the financial crisis between 1997 and 1998. Prior to the financial crisis, Malaysia maintained its growth rates averaging 8.9 per cent during the period 1990-96. However, from July 1997 the Malaysia economy took a severe blow after currency speculators successfully targeted the Malaysia Ringgit (MYR). As a result, the Malaysian currency was devalued by half. Since the financial crisis hit Malaysia in July 1997, it had created a crisis in confidence which led to an economic downturn.

However in general, Kuala Lumpur and Selangor's economic performance between 1990-2000 has been impressive – making it one of the fastest growing states in Malaysia. This is due largely to a very good performance of Malaysia's economy and its help to create good economic environments for the whole country, particularly in these two states. Between 1990 and 2000, the Malaysian economy was governed by the National Development Policy (NDP). In addition, Vision 2020 (Malaysia: The Way Forward) was launched in 1991 to reflect on a fully developed nation by the year 2020 – a thirty year plan between 1991 and 2020 containing broad policy directions encompassing various dimensions (Okposin and Yu, 2000). Between 1990-2000, the GDP of Kuala Lumpur and Selangor grew at an average rate of 12 per cent per annum and 10 per cent to 14 per cent per annum respectively. In addition, the per capita GDP for Kuala Lumpur and Selangor between 1990 and 2000 increased from MYR 10,329 to MYR 21,827 and MYR 14,690 to MYR 36,476, respectively. The high growth rate of Kuala Lumpur and Selangor's economy between 1990-2000 has been accompanied by generally low rates of inflation.

The healthy growth of Kuala Lumpur and Selangor's economies in general and the Klang Valley region in particular have created plenty of job opportunities. For instance, total employment in Kuala Lumpur and Selangor between 1990 and 2000 increased from 530,200 to 696,100 and 945,600 and 1,291,300, respectively. Note that the services sector has been identified as the major contributor for Kuala Lumpur, especially in creating job opportunities. It also contributes towards the country's GDP. According to Sirat (2000) the services sector such as finance, insurance, real estate and business services (wholesale and retail trade, hotels and restaurants, and transport, storage and communications) has created approximately 60 per cent of all new jobs in the region.

### 6.2.3.5 Transportation Development

The discussion in this subsection highlights the prominent attributes of transportation systems in the Klang Valley. Note that the focus will be given to two important parts of the systems; transportation infrastructure and transportation services. The discussion begins by concentrating on the road system and road based transportation system in the region and the emphasis of the government on further road infrastructure development. This is followed by discussing the trend of vehicle ownership as well as the effect on travel demands. Also, the discussion briefly reviews several issues and problems that are consistently associated with the rapid growth of the region such as low public transport modal share resulting in high demand on road infrastructure and traffic congestion, and high travel demand to and from the city centre during peak hours (Kuala Lumpur City Hall, 2000).

As mentioned earlier, it has been established that public transportation is an extremely prominent mode of travel from one place to another, particularly in the larger and more dense metropolitan areas such as Kuala Lumpur in particular and the Klang Valley in general. Therefore, the discussion will focus on the prominent role public transportation has played in the region. Finally, the section discusses the construction of rail transit systems as part of the public transportation system in order to reduce traffic congestion that was highlighted earlier. In other words, the discussion focuses on the direct benefits from the opening of the light rail transit system in the Klang Valley.

*The Road System*: It has been established that road transport plays a significant role in shaping the urban pattern of the Klang Valley – the town began to emerge as a major centre of commerce and services, particularly for the developed west-coast lowlands. As has been noted in previous sections, the early roads were constructed around 1880 and 1890 when the British were established in Kuala Lumpur; the jungle track has been transformed into road and rail networks. Today, all major roads in Peninsular Malaysia converge in the Klang Valley – five main roads radiate from the city of Kuala Lumpur. The main road system of the Klang Valley is shown in Figure 6.5. As can be seen from Figure 6.5, the five main roads are the Federal Route 1 running from the North-West to South-East Peninsular Malaysia, the Federal Highway from Klang to Kuala Lumpur, the Karak Highway connecting Kuala Lumpur to the East Coast and Kuala Lumpur-Seremban Highway to the south and the North-South Highway.

The pattern of road networks in the Klang Valley could be divided into several forms; a grid network, a ladder network or concentric ring and radial network. Note that there are several characteristics that can be found at the road network in the Klang Valley. For example, the road network configuration in Kuala Lumpur was developed partially in the form of a ring and radial, consisting of two completed inner ring and middle ring roads. The middle ring road is connected to four major expressways radiating from Kuala Lumpur. However, the road network in Petaling Jaya has a complete and inter-connected pattern. This pattern of road network is different from other parts of the Klang Valley (Kuala Lumpur City Hall, 2000; Shah Alam City Hall, 2000).

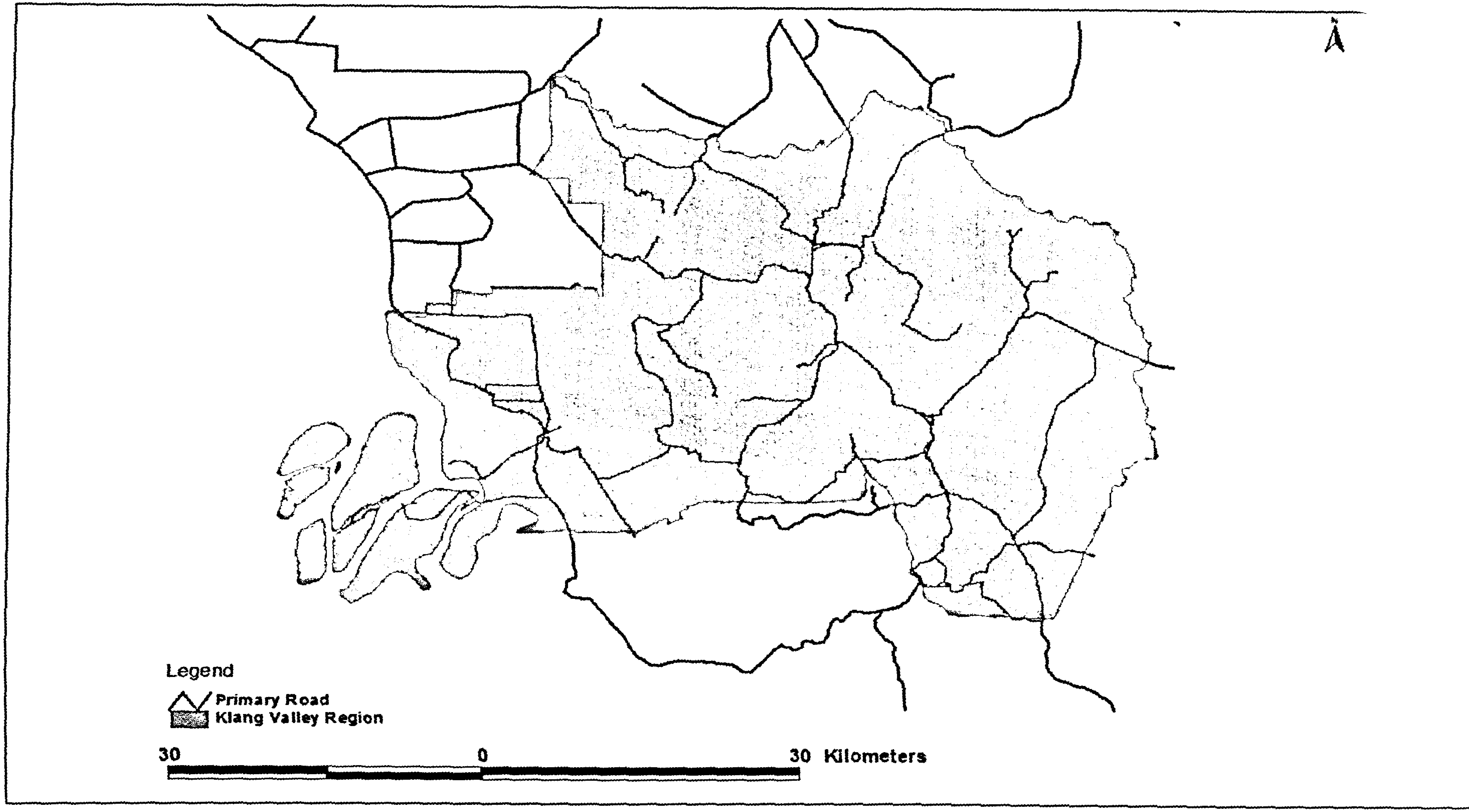



**Figure 6.5**: Main roads of the Klang Valley, 2004
*Source*: The Federal Territory Development and the Klang Valley Planning Devision (2004)

The emphasis on the improvement of transportation in the Klang Valley by the government was mostly concentrated on constructing further road networks. For example, under the privatisation policy that has been implemented in Malaysia, the road construction programme for the Klang Valley set out in the Kuala Lumpur Structure Plan 1984 comprised twenty-three new roads and twenty-one major road improvement projects has been mostly completed, together with some additional toll highways. The road network now in place has succeeded in its primary purposes of eliminating through traffic from the city centre, reducing congestion on minor roads and efficiently dispersing traffic from the city centre. The construction of road and highway projects is shown in Table 6.2 (Kuala Lumpur City Hall, 2000).

The cost of implementing the aforementioned projects was enormous. For example, a total of nearly RM2.5 billion (£0.625 billion) has been spent on the construction of road networks alone. The question is; how does the improvement in the transportation network in the Klang Valley affect the pattern of travel demand? It has been argued that the improvement in the transportation network through the construction of the highway system permits workers to live at greater distances from their work places. Evidently, in the context of the Klang Valley, areas around seventy kilometres radius from the Kuala Lumpur Metropolitan Area were becoming increasingly attractive due to several factors including cheaper house prices and house rent, spacious living and a pleasant suburban environment. Based on the statistics of 1995, there are approximately 1.4 million motor vehicles (particularly cars and motorcycles) using the Kuala Lumpur city roads each working day and most of these vehicles are from outside Kuala Lumpur.

**Table 6.2**: Road and Highway Construction Projects, 2000

| Road Projects | Status |
|---|---|
| 1. Middle Ring Road 2 | Completed |
| 2. New Pantai Highway | Under construction |
| 3. Western Kuala Lumpur Traffic Dispersal Scheme (Damansara, Kerinchi and Penchala Link) | Under construction |
| 4. Sungai Besi Highway | Completed |
| 5. Ampang Elevated Highway | Completed |
| 6. New Klang Valley Expressway (NKVE) – North Link | Completed |
| 7. Salak Expressway | Completed |
| 8. East-West Link | Completed |
| 9. Middle Ring Road 1 | Completed |
| 10. Inner Ring Road | Completed |
| 11. Puchong-Sungai Besi Road | Completed |
| 12. Jalan Pahang | Completed |
| 13. Jalan Genting Klang (upgrading) | Planning stage |
| 14. Jalan Gombak (upgrading) | Planning stage |
| 15. Kuala Lumpur Karak Highway (upgrading) | Planning stage |

*Source*: Kuala Lumpur City Hall, 2000

*Private Transportation*: At the outset, it must be noted that the level of private transportation in the Klang Valley is the highest in the country. In 1985 for example, the number of registered motor vehicles in the Federal Territory of Kuala Lumpur and the state of Selangor was only 1,084,573. However between 1985 and 1995, the figure increased to 2,248,914 – an increase of 107 per cent in ten years compared with only 60 per cent for the whole country. The high level of private transportation between 1985 and 1995 has been contributed to by private cars and motorcycles. Evidently, in Kuala Lumpur and Selangor the total number of registered cars and motorcycles was 1,960,415 or 87.2 per cent. Since then the number of registered cars and motorcycles has increased tremendously. Following the Road Transport Department of Malaysia's report, the ratio of registered cars and motorcycles in Kuala

Lumpur alone was 985.7 per 1,000 populations in 2000. Moreover, based on the statistics revealed by the Road Transport Department of the Federal Territory of Kuala Lumpur (see Figure 6.6), the number of motor vehicles registered in Kuala Lumpur have shown impressive increases between 1983 and 2004 except after the recession periods of 1985-1986 (electronic crisis) and 1997-1998 (financial crisis).

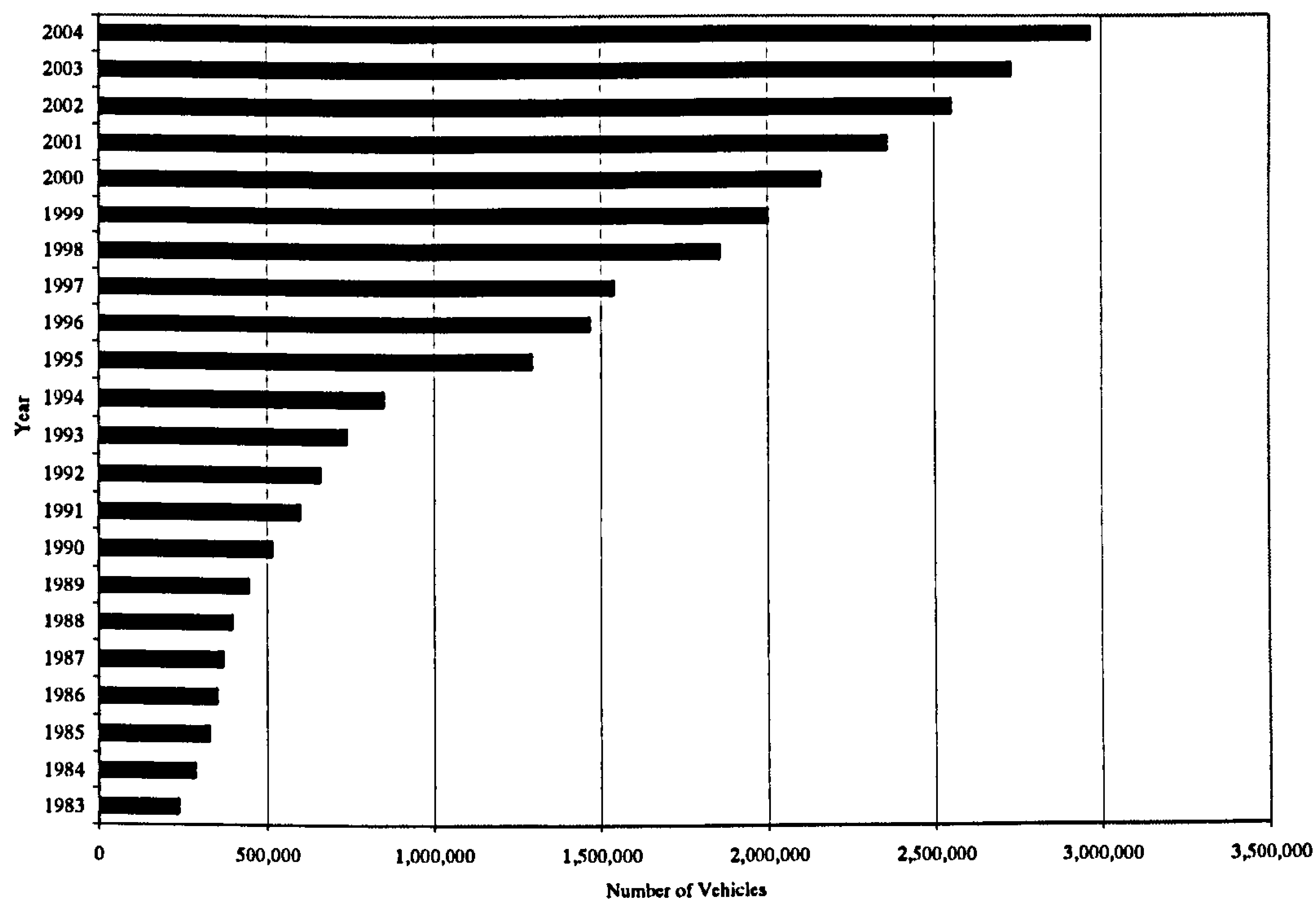



**Figure 6.6**: Number of motor vehicles registered in Kuala Lumpur, 1983-2004
*Source*: Mohamad and Kiggundu (2007, Table 1). The rise of private cars in Kuala Lumpur, Malaysia

In the context of the Klang Valley, following the Home Interview Survey carried out by Japan International Cooperation Agency (JICA) in 1998, the estimated possession ratio of vehicles represents approximately 211 cars per 1,000 population and 164 motorcycles per 1,000 populations. Private cars account for 56.6 per cent of all motorised trips in Kuala Lumpur (Kuala Lumpur City Hall, 2000). It should be noted that the increase in vehicle ownership in the Klang Valley is caused by a number of factors. These factors can be summarised as follows; rising per capita incomes, reduced price of cars since the involvement of Malaysia in car manufacturing and road network has expended rapidly.

As the number of private cars and motorcycles in the Klang Valley increases, the demand for commuting to and from the city centre tends to increase far beyond the capacity of the road network, even after upgrading to an existing road and the construction of new roads has taken place. As a result, traffic congestion has become the serious problem for the Klang Valley, particularly in Kuala Lumpur Metropolitan Centre. According to Mohamad and Kiggundu (2007) the average number of vehicles entering Kuala Lumpur City Centre in 1995 was estimated at about 740,000 per day – after more than ten years since 1995 this number has increased enormously. Note that each car on the road or highway adds to the congestion and therefore increases travel time from one place to another. For instance, during peak-hour periods the average travel speed in the CBD of Kuala Lumpur is 28 km/h. The average travel speed in the major routes of Kuala Lumpur can be seen on Table 6.3. In addition, traffic congestion would also cause other serious problems such as accidents and air pollution in an urban area. In the case of road accidents, statistics have shown that road accidents in Kuala Lumpur alone increased from 20,104 cases in 1987 to 33,375 cases in 1996 (Figure 6.7).

**Table 6.3**: Average travel speed in the CBD of Kuala Lumpur

| Route name | Average route travel speed (km/h) Inbound A.M. Peak 1986 | Inbound A.M. Peak 1997 | Outbound A.M. Peak 1986 | Outbound A.M. Peak 1997 |
|---|---|---|---|---|
| 1. Inner Ring Road | 26.7 | 15.0 | 21.2 | 17.3 |
| 2. Middle Ring Road | 23.6 | 17.1 | 33.4 | 13.6 |
| 3. Ipoh Road, Kuching Road | 32.3 | 35.6 | 25.5 | 67.3 |
| 4. Kepong Road, Ipoh Road | 25.6 | 19.3 | 17.2 | 28.2 |
| 5. Karak Highway, Sentul Road | 23.7 | 26.4 | 37.0 | 45.0 |
| 6. Gombak Road, Pahang Road | 10.3 | 12.4 | 36.6 | 27.0 |
| 7. Ampang Road | 19.5 | 10.4 | 24.9 | 19.5 |
| 8. Cheras Road, Pudu Road | 15.8 | 14.0 | 34.8 | 22.8 |
| 9. Seremban Highway | 38.8 | 20.3 | 68.7 | 60.6 |
| 10. Federal Highway II | 39.9 | 21.7 | 45.7 | 26.9 |
| 11. Pantai Road | 24.3 | 13.4 | 32.7 | 19.6 |

*Source*: Mohamad and Kiggundu (2007). The rise of private cars in Kuala Lumpur, Malaysia

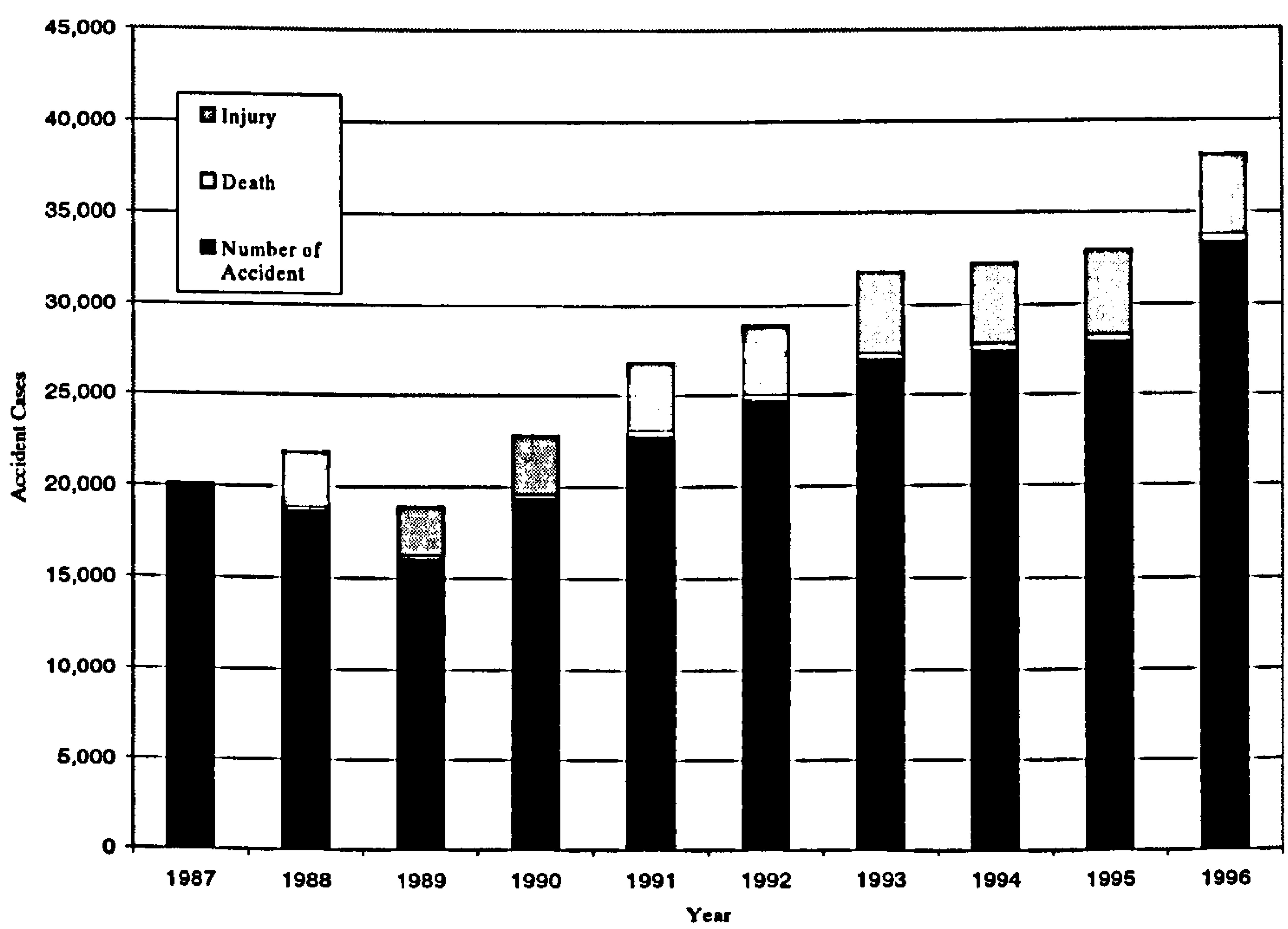



**Figure 6.7**: Total road accidents in Kuala Lumpur, 1987-1996
*Source*: Mohamad and Kiggundu (2007, Table 3). The rise of private cars in Kuala Lumpur, Malaysia

The problem of traffic congestion can be reduced through the improvement of public transportation to the city centre such as by improving bus services, introducing rail transit systems and expanding road lanes and networks. Yet, it has been argued further that the expanding road lanes and networks alone are not adequate enough to overcome traffic congestion in the Klang Valley. Hence, policy measures such as high parking charges, strict enforcement of parking and traffic regulations, encouraging transit use, walking and cycling that have successfully been implemented in most European countries, should be taken into consideration. In addition, by improving public transportation in the Klang Valley we may encourage people to use public transport rather than their own vehicles. However, it has been argued that good public transportation depends on its ability to provide various requirements of users such as improved accessibility, continuity and punctuality. The question here is; does public transportation in the Klang Valley fulfil these requirements?

In the case of the Klang Valley, various efforts have been made in order to improve public transportation systems. As mentioned earlier, in 1981 the Kuala Lumpur Master Plan Transportation Study was undertaken in order to assist the formulation of a set of transport programmes. Yet, the performance of public transportation in the Klang Valley was still below the level of satisfactory due to the inefficient services especially during peak periods – this is a common problem in most developing countries. As a result, only a small percentage of the Klang Valley residents use public transportation as a mode of travel on a regular basis. According to Sharifi et al. (2006) the present modal split of public to private transportation is about 20:80. In other words, only 20 per cent of the Klang Valley residents commute using public transportation. Realising that this issue needs to be addressed, recently through the Federal Territory Ministry, the Malaysian government has started on the Integrated Public Transport System Plan for the Klang Valley. This plan would be the holistic solution to improve public transportation in the Klang Valley. The next discussion will be focused on public transportation in the Klang Valley.

*Public Transportation*: Public transportation consists of a wide range of travel modes and it can be differentiated based on various attributes; technology, cost, operating, geographical context, market share and the socio-economic makeup of their users (Pucher, 2004). In the Klang Valley, the most common form of public transportation is bus (stage bus, minibus, express bus, school bus and factory bus) and is followed by several other modes such as taxis, the commuter train system (also called "heavy rail transit") and the LRT system.

In the thirty year period, public transportation in the Klang Valley experienced various stages of improvement. This improvement is essential since it plays a significant role in the movement of people. Thus, public transportation needs to be efficient and able to cater for the demand from people, especially at peak periods. As noted above, the bus service is the most common form of public transportation. In the case of the Klang Valley, stage bus services play a dominant role. There were ten companies who were responsible for providing the service with the total fleet of nearly 1500 buses. The operation of stage buses in the Klang Valley could be divided into two types. First, the stage bus operates within the city centre such as Kuala Lumpur, Petaling Jaya, Klang, Shah Alam and Bangi. Secondly, those that operate inter-regional by within the Klang Valley are called express buses (Mohamad, 1994). However, the services provided by the stage bus have been greatly criticised by the public. The main criticism of the stage bus service was associated with inefficiency and not being on time.

Another type of bus service that can be found in the Klang Valley is minibuses. A minibus service was first introduced in Kuala Lumpur in 1975. The introduction of this service was to supplement and to provide additional capacity for the stage bus services (Mohamad, 1994). In 1978, 400 minibuses were operating and connected several areas in Kuala Lumpur. After more than a decade operating in Kuala Lumpur, minibuses were introduced to other parts of the Klang Valley; Shah Alam, Klang, Bangi and Petaling. The service provided by minibuses has proven to be significant among commuters compared to stage buses – accessibility from one place to another has improved notably. Yet, after providing good service for the urban residents for many years, minibus services could not maintain their performance – poor management by the operators from small private companies and individual owners, over crowding and deviation from designated routes are some of the causes. In addition, some of the drivers did not stop at the bus stops and the competition from various operators has resulted in aggressive and dangerous driving by the drivers. Hence, in 1996 nearly 90 per cent of the minibus services in Kuala Lumpur were terminated.

As highlighted earlier, the main problem with the bus services in the Klang Valley was its operation by small private companies and individual owners. Thus in 1993, the former Prime Minister Dr. Mahathir Mohamad suggested merging bus companies into one consortium (Mohamad, 1994). The purpose of this consortium was to integrate bus and rail services in the region. As a result, in September 1993, a company known as Diversified Resources Bhd (DRB) was given approval to organise a consortium to streamline the bus services in Kuala Lumpur – there were also some problems faced by this company in providing efficient services. Thus in 2004, a company known as Rangkaian Pengangkutan Integrasi Deras Sdn Bhd (RapidKL), wholly owned by the government, took the role of providing an integrated public transport system in the Klang Valley incorporating rail and bus services. RapidKL transports approximately four million passengers per week; 2.1 million on the Ampang Line (formerly known as STAR) and Kelana Jaya Line (formerly known as PUTRA) and 1.9 million on the bus system, previously Intrakota and Cityliner. RapidKL provides services across fourty-eight rail stations and 165 bus routes. It should be noted that, RapidKL has covered about 65 per cent of public transportation in the Klang Valley since it was formed in 2004.

Besides stage buses and minibuses, another popular mode of public transportation in the region is the taxi. Taxis are operated either by the individual, co-operative agencies or by private companies. Presently, there are approximately 24,721 taxis licensed in Kuala Lumpur alone and are run by 4,183 operators (Mohamad and Kiggundu, 2007).

Rail transit services are another mode of public transportation in the region. Rail transit service in the Klang Valley can be divided into two; heavy and light rail transit service. Heavy and light rail transit service was the outcome of the privatisation policy introduced by the government in the 1980s. One of the main objectives of the new transit plan was to encourage faster growth in the railway system and to handle future traffic demands in the region by diverting part of the road traffic to the railway (Mohamad, 1994). First, let us discuss the construction of the heavy rail transit system in the Klang Valley.

The heavy rail transit system in the Klang Valley was constructed and operated by a company called the Malayan Railway Limited or KTM Berhad. The KTM commuter system was the first of the new generation rail transit systems to be constructed in the Klang Valley. The first line began operating in 1995, connecting Kuala Lumpur-Port Klang in the Klang Valley and Seremban (in the state of Negeri Sembilan) and Kuala Lumpur. An additional line to Rawang and Kuala Kubu Bahru was constructed and opened in 2000 and 2007 respectively. The KTM commuter system, with 175 kilometres of total length of network has fourty-five stations. It should be noted that several prominent shopping complexes and recreational centres became more accessible after the opening of the KTM commuter service. For example, the Mid Valley station (which was opened in 2004) made the Mid Valley Megamall easily accessible. Several other shopping complexes that can be reached by the KTM commuter service are Subang Parade and Carrefour Subang in Subang Jaya, and The MINES in Seri Kembangan Town. In addition, the KTM commuter system has improved accessibility for commuters from suburban areas who work in Kuala Lumpur City Centre, as they can travel without being caught in the traffic congestion. Table 6.4 shows the number of passengers who have travelled on the KTM commuter system between 1995 and 2005. Within a decade of operation, the KTM commuter has transported over 200 million people; of these, annual passenger trips have increased by 14 per cent, from 2,817,443 in 1995 to 30,934,51 in 2005.

**Table 6.4**: Number of KTM Commuter Passengers, 1995-2005

| **Year** | **Number of Passengers** | **Percentage** | **Growth Rate** |
|---|---:|---:|---:|
| 1995 | 2,817,443 | 1.33 | - |
| 1996 | 11,094,551 | 5.24 | +3.91 |
| 1997 | 14,578,704 | 6.89 | +1.65 |
| 1998 | 20,803,363 | 9.83 | +2.94 |
| 1999 | 17,168,074 | 8.11 | -1.72 |
| 2000 | 19,154,197 | 9.05 | +0.94 |
| 2001 | 20,928,816 | 9.89 | +0.84 |
| 2002 | 22,084,124 | 10.44 | +0.55 |
| 2003 | 24,645,493 | 11.65 | +1.21 |
| 2004 | 27,380,423 | 12.94 | +1.29 |
| 2005 | 30,934,651 | 14.62 | +1.68 |
| Total | 211,589,839 | 100.00 | |

*Source*: The Malayan Railway Berhad Annual Report (2005)

The construction of the LRT system in the Klang Valley was first proposed in early 1980s through the Kuala Lumpur Master Plan Transportation Study to improve accessibility in an urban area and to handle future traffic demands in the Klang Valley. The proposed idea was then incorporated into the Kuala Lumpur Structure Plan of 1984. However, due to the 1985-1986 economic crisis, the construction of the LRT system was delayed. In 1987, the Klang Valley Transportation Study was conducted and it confirmed the proposed idea; the urgent need of the LRT system in the region.

Several major conferences on improving the transportation system in the Klang Valley were held and the importance and advantages of having the LRT system was stressed by several researchers. Finally, in 1990 the government formed a consortium of companies to examine the feasibility of implementing the system on a privatised basis. In mid 1991, the government concluded that the LRT system was an appropriate system that could be implemented in the Klang Valley. Thus, the proposal submitted by the consortium named STAR-LRT1 and PUTRA-LRT2 was finally approved by the government. The STAR-LRT1 offered services from the east to the south of the Klang Valley, whilst PUTRA-LRT2 served from the north to the west of the Klang Valley.

It should be noted that the construction of the LRT system in the Klang Valley involved several phases. The first phase of the LRT system in the Klang Valley under Sistem Transit Aliran Ringan (STAR), stretches for twelth kilometres over thirteen stations between Ampang and Jalan Sultan Ismail, linking the northern and southern suburbs of Kuala Lumpur. This section began operating in April 1997. However, the section between Ampang and Plaza Rakyat began operating during the first quarter of 1996. The second section of the

STAR LRT system project was completed on 30 June 1998 – extending southwards to the Commonwealth Games complex in Bukit Jalil.

The second phase of the LRT system in the Klang Valley was under Projek Usahasama Transit Ringan Automatik (PUTRA). PUTRA LRT was incorporated on 15 February 1994 to design, construct, operate and maintain the LRT System Two for the Klang Valley, and is a wholly owned subsidiary of Renong Berhad. The LRT System Two, known as the PUTRA line, covers the eastern and western suburbs of Kuala Lumpur. The line services some of Kuala Lumpur's most affluent and heavily populated areas. The total alignment of the line, which starts from the depot in Subang and ends at Terminal Putra in Gombak is twenty-nine kilometres in length. The construction is divided into two sections.

The first section, which is from Subang Depot to Pasar Seni station, commenced operation on 1 September 1998. The second section, which is from Pasar Seni station to Terminal Putra, began operating in June 1999. The total cost of the STAR and PUTRA LRT system was MYR8.62 billion. However in 2004, the operation of this service was taken over by Rangkaian Pengangkutan Integrasi Deras Sdn Bhd (RapidKL). Since then, the name of PUTRA LRT has been changed to Kelana Jaya Line LRT system. In addition to the Ampang Line and Kelana Jaya Line, the Kuala Lumpur monorail system was constructed to serve downtown Kuala Lumpur with its 8.6 kilometres route with eleven stations. The Express Rail Link (ERL) provides two rail services; the KLIA Express and KLIA Transit which opened in 2002 and provided service to the Kuala Lumpur International Airport (KLIA) and the Multimedia Super Corridor (MSC), respectively. Figure 6.8 shows the number of passengers who used the LRT system over the period 2000-2003, the most recent years for which data is available. Total daily passenger trips for the Kelana Jaya Line and Ampang Line rose from only 199,753 in 2000 to 244,960 in 2003 – an increase of 18.45 per cent. According to RapidKL, presently Kelana Jaya Line LRT carries over 170,000 passengers a day, and over 350,000 passengers a day during national events such as Independence Day and New Year celebrations.

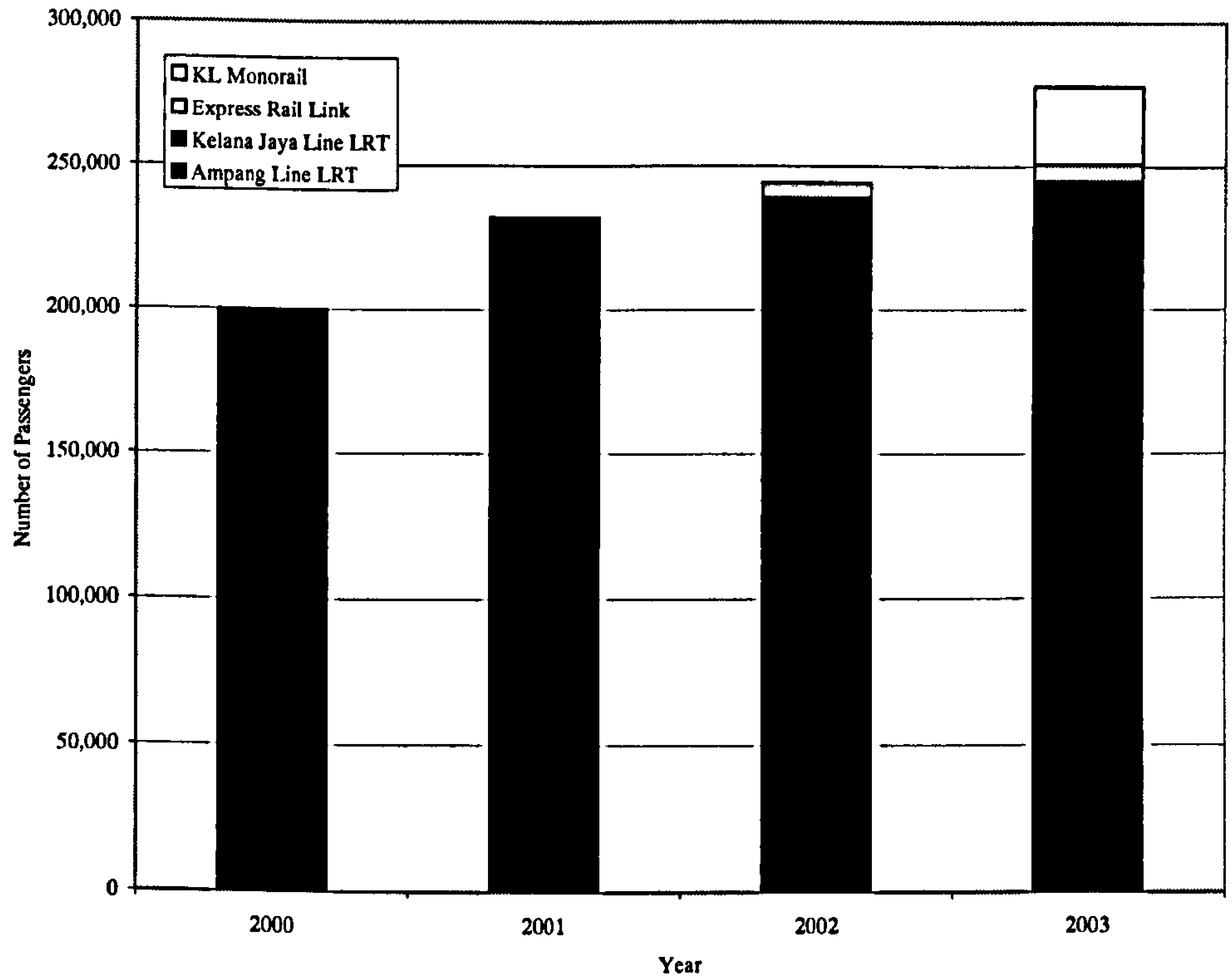



**Figure 6.8**: Passenger journey per day on Ampang Line LRT, Klana Jaya Line LRT, KLIA Express and KLIA Transit, 2000-2003
*Source*: Rancangan Pengangkutan Deras Kuala Lumpur (RapidKL), 2006

The increase in usage of heavy and LRT systems in the Klang Valley can be attributed to a number of factors. Firstly, the rail transit system has improved accessibility from residential areas to the city centre, work places and other areas (particularly at peak periods). This leads towards time and cost savings. In other words a rail transit system is a solution to commuters rather than facing the potential traffic congestion delays. Therefore, by using rail transit services, people are able to plan their journey since they know how long it will take to reach their desired destination. Table 6.5 shows travel time to the CBD using the Kelana Jaya Line.

**Table 6.5**: Travel time from one station to the next station of the Kelana Jaya Line LRT system

| LRT Station From/To | Kelana Jaya | Taman Bahagia | Taman Paramouth | Asia Jaya | Taman Jaya | University | Kerinchi | Abdullah Hukum | Bangsar | KL Sentral | Pasar Seni | Masjid Jamek | Dang Wangi | Kpg. Baru | KLCC | Ampang Park | Damai | Dato Keramat | Jelatek | Setiawangsa | Wangsa Maju | Taman Melati | Terminal Putera |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Kelana Jaya | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 | 20.68 | 22.56 | 24.44 | 26.32 | 28.20 | 30.08 | 31.96 | 33.84 | 35.72 | 41.36 | 43.24 | 45.12 |
| Taman Bahagia | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 | 20.68 | 22.56 | 24.44 | 26.32 | 28.20 | 30.08 | 31.96 | 33.84 | 35.72 | 41.36 | 43.24 |
| Taman Paramouth | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 | 20.68 | 22.56 | 24.44 | 26.32 | 28.20 | 30.08 | 31.96 | 33.84 | 35.72 | 41.36 |
| Asia Jaya | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 | 20.68 | 22.56 | 24.44 | 26.32 | 28.20 | 30.08 | 31.96 | 33.84 | 35.72 |
| Taman Jaya | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 | 20.68 | 22.56 | 24.44 | 26.32 | 28.20 | 30.08 | 31.96 | 33.84 |
| University | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 | 20.68 | 22.56 | 24.44 | 26.32 | 28.20 | 30.08 | 31.96 |
| Kerinchi | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 | 20.68 | 22.56 | 24.44 | 26.32 | 28.20 | 30.08 |
| Abdullah Hukum | | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 | 20.68 | 22.56 | 24.44 | 26.32 | 28.20 |
| Bangsar | | | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 | 20.68 | 22.56 | 24.44 | 26.32 |
| KL Sentral | | | | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 | 20.68 | 22.56 | 24.44 |
| Pasar Seni | | | | | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 | 20.68 | 22.56 |
| Masjid Jamek | | | | | | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 | 20.68 |
| Dang Wangi | | | | | | | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 |
| Kpg Baru | | | | | | | | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 |
| KLCC | | | | | | | | | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 |
| Ampang Park | | | | | | | | | | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 |
| Damai | | | | | | | | | | | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 |
| Dato Keramat | | | | | | | | | | | | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 |
| Jelatek | | | | | | | | | | | | | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 |
| Setiawangsa | | | | | | | | | | | | | | | | | | | | - | 1.88 | 3.76 | 5.64 |
| Wangsa Maju | | | | | | | | | | | | | | | | | | | | | - | 1.88 | 3.76 |
| Taman Melati | | | | | | | | | | | | | | | | | | | | | | - | 1.88 |
| Terminal Putera | | | | | | | | | | | | | | | | | | | | | | | - |

*Source*: RapidKL (2007)

**Table 6.5:** (continued)

| LRT Station From/To | Terminal Putera | Taman Melati | Wangsa Maju | Setiawangsa | Jelatek | Dato Keramat | Damai | Ampang Park | KLCC | Kpg Baru | Dang Wangi | Masjid Jamek | Pasar Seni | KL Sentral | Bangsar | Abdullulah Hukum | Kerinchi | University | Taman Jaya | Asia Jaya | Taman Paramouth | Taman Bahagia | Kelana Jaya |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Terminal Putera | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 | 20.68 | 22.56 | 24.44 | 26.32 | 28.20 | 30.08 | 31.96 | 33.84 | 35.72 | 41.36 | 43.24 | 45.12 |
| Taman Melati | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 | 20.68 | 22.56 | 24.44 | 26.32 | 28.20 | 30.08 | 31.96 | 33.84 | 35.72 | 41.36 | 43.24 |
| Wangsa Maju | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 | 20.68 | 22.56 | 24.44 | 26.32 | 28.20 | 30.08 | 31.96 | 33.84 | 35.72 | 41.36 |
| Setiawangsa | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 | 20.68 | 22.56 | 24.44 | 26.32 | 28.20 | 30.08 | 31.96 | 33.84 | 35.72 |
| Jelatek | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 | 20.68 | 22.56 | 24.44 | 26.32 | 28.20 | 30.08 | 31.96 | 33.84 |
| Dato Keramat | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 | 20.68 | 22.56 | 24.44 | 26.32 | 28.20 | 30.08 | 31.96 |
| Damai | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 | 20.68 | 22.56 | 24.44 | 26.32 | 28.20 | 30.08 |
| Ampang Park | | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 | 20.68 | 22.56 | 24.44 | 26.32 | 28.20 |
| KLCC | | | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 | 20.68 | 22.56 | 24.44 | 26.32 |
| Kpg. Baru | | | | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 | 20.68 | 22.56 | 24.44 |
| Dang Wangi | | | | | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 | 20.68 | 22.56 |
| Masjid Jamek | | | | | | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 | 20.68 |
| Pasar Seni | | | | | | | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 | 18.8 |
| KL Sentral | | | | | | | | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 | 16.92 |
| Bangsar | | | | | | | | | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 | 15.04 |
| Abdullulah Hukum | | | | | | | | | | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 | 13.16 |
| Kerinchi | | | | | | | | | | | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 | 11.28 |
| University | | | | | | | | | | | | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 | 9.40 |
| Taman Jaya | | | | | | | | | | | | | | | | | | | - | 1.88 | 3.76 | 5.64 | 7.52 |
| Asia Jaya | | | | | | | | | | | | | | | | | | | | - | 1.88 | 3.76 | 5.64 |
| Taman Paramouth | | | | | | | | | | | | | | | | | | | | | - | 1.88 | 3.76 |
| Taman Bahagia | | | | | | | | | | | | | | | | | | | | | | - | 1.88 |
| Kelana Jaya | | | | | | | | | | | | | | | | | | | | | | | - |

*Source*: RapidKL (2007)

As has been highlighted above, traffic congestion in the Klang Valley has been a major issue since the mid 1990s – the improvement of public transportation through the construction of a rail transit system has provided an option for people to travel using the system rather than using their own vehicles.

Based on the statistics presented above, the number of passengers using rail transit systems has increased since the day operations began. Hence, there was a plan from the government to extend the current heavy and LRT systems to other parts of the region. In the case of the Kelana Jaya Line LRT system for instance, the current line which stops at Kelana Jaya would be extended to the suburbs of Sunway Town, Subang Jaya and UEP Subang Jaya (USJ), which are located to the south-west of Kuala Lumpur, whilst the Ampang Line LRT system would be extended to Puchong. The extension will be part of a MYR10 billion plan to expand Kuala Lumpur's public transport network (The Star Newspaper, 2007).

Secondly, the rail transit system serves the most of the prominent areas in the region. The construction of the rail transit system in the Klang Valley has made major financial and commercial centres accessible to the people. For example, the Kelana Jaya Line LRT stations are strategically located at major financial and commercial centres such as PETRONAS Twin Towers (KLCC), Ampang Park, Petaling Jaya town centre and central market. In the case of the KTM commuter, it serves several shopping complexes such as Mid Valley Megamall (one of the largest shopping malls in south-east Asia), Subang Parade and Carrefour Subang. In addition, the rail transit system was built for the purpose of connecting major transit points. Thus, it is convenient to travel by rail transit systems rather than using other modes of transport. Obviously, being strategically located in these areas has made rail transit systems become an increasingly famous mode of travel compared to the other modes such as buses and taxis.

Thirdly, in order to promote greater usage of the system, both the Ampang Line and Kelana Jaya Line LRT system has reduced its fare over a series of promotional drives – by April 2001, the discount was 53 per cent of the government approved rate (Abdul Aziz, 2007). The fare reduction has led to an increase in passengers using the LRT system daily as a mode of transport in the region.

Finally, the increase in the usage of rail transit systems in the Klang Valley can be associated with the condition of the trains and stations. In terms of the condition of the trains, they have air-conditioning which is very important for the hot and humid weather of Malaysia and they also provide comfortable seats for passengers. In addition, the stations were built to support disabled passengers – Kelana Jaya Line LRT system for example, provides elevators and wheelchair lifts alongside escalators and stairways between various levels of the stations. The stations were also designed to have platform gaps of five centimetres in order to allow easy access for disabled passengers.

In the case of the Ampang Line and Kelana Jaya Line LRT system, although the number of passengers who travel with the system has increased since it was opened, in reality it suffered below-expectation ridership, particularly for the Ampang Line (see Figure 6.7 above). Low ridership may indicate that the system has improved accessibility for a limited population. Therefore, we will not expect a greater impact on house prices for larger areas. Yet, when the construction of the LRT system was announced to the public, service expectations were heightened and house prices were significantly affected. In addition, since the LRT system has improved accessibility from the residential location to other destinations, prices of residential properties that are located near the LRT stations would also be significantly affected. Evidence of these two expectations will be measured in this study.

As previously advocated, the Kelana Jaya Line LRT system is the line that has been identified for this research in observing the effects on house prices that may be impacted by this line. Hence, the justification of using this line as a case study will be given in the next subsection.

#### 6.2.3.6 The Kelana Jaya Line LRT System: A Case Study

Why must the Kelana Jaya Line LRT system be chosen as a case study for this research? As has been mentioned earlier, there are several other rail transit systems that operate in the region; Ampang Line, KL Monorail, Express Rail Link (KLIA Express and KLIA Transit) and the KTM commuter. The KLIA Express Line had to be eliminated since it is a non-stop transit system to the Kuala Lumpur International Airport (KLIA). In the case of KLIA Transit, it also had to be set aside since there were only three stations on this line; these three stations were quite far apart from the residential areas. This is because the main purpose of constructing this service was to connect between Kuala Lumpur-Putrajaya-KLIA. Note that Putrajaya is a new centre in the Malaysian government administration. The KL Monorail had to be eliminated from this study due to the area in which it provides its service, namely it only serves the city centre.

The KTM commuter had also to be disqualified due to the problems of data availability (especially land parcel data) for those areas that were served by the system. With respect to land parcel data availability, it is argued that in the process of preparing land parcel maps in digital format using GIS tools, the process of digitising land parcel maps can be time intensive before they are ready to use, hence unavailability of land parcel maps in digital format need to be given greater attention before deciding which area to be selected as a case study. It has also been mentioned that the KTM commuter was built to serve suburban areas of the Klang Valley and the connecting states. If the KTM commuter is chosen for this study, a very large area will need to be covered and a single researcher is not able to do that especially within a very limited period of time. Thus, the researcher was left with two lines to choose from as a case study; the Kelana Jaya Line LRT system and the Ampang Line LRT system.

Between these two lines, the Kelana Jaya Line LRT system was finally selected as a case study (see Figure 6.9) for several reasons. Firstly, as has been mentioned in the preceding discussion, the Kelana Jaya Line LRT system has served prominent commercial and service centres, and heavily populated areas in the Klang Valley. Therefore, it offers a greater opportunity and is an appropriate area to measure the effect of the LRT system on house prices. Secondly, the number of commuters who travel with the Kelana Jaya Line LRT system is much greater compared to the Ampang Line LRT system – it provides a clear indication of the differing importance of these two lines. Hence we could expect a positive relationship between the existence of the LRT system and the house prices by selecting an appropriate line to be studied. Finally, more data is available (house price transactions) for residential areas that were served by the Kelana Jaya Line compared to the Ampang Line.

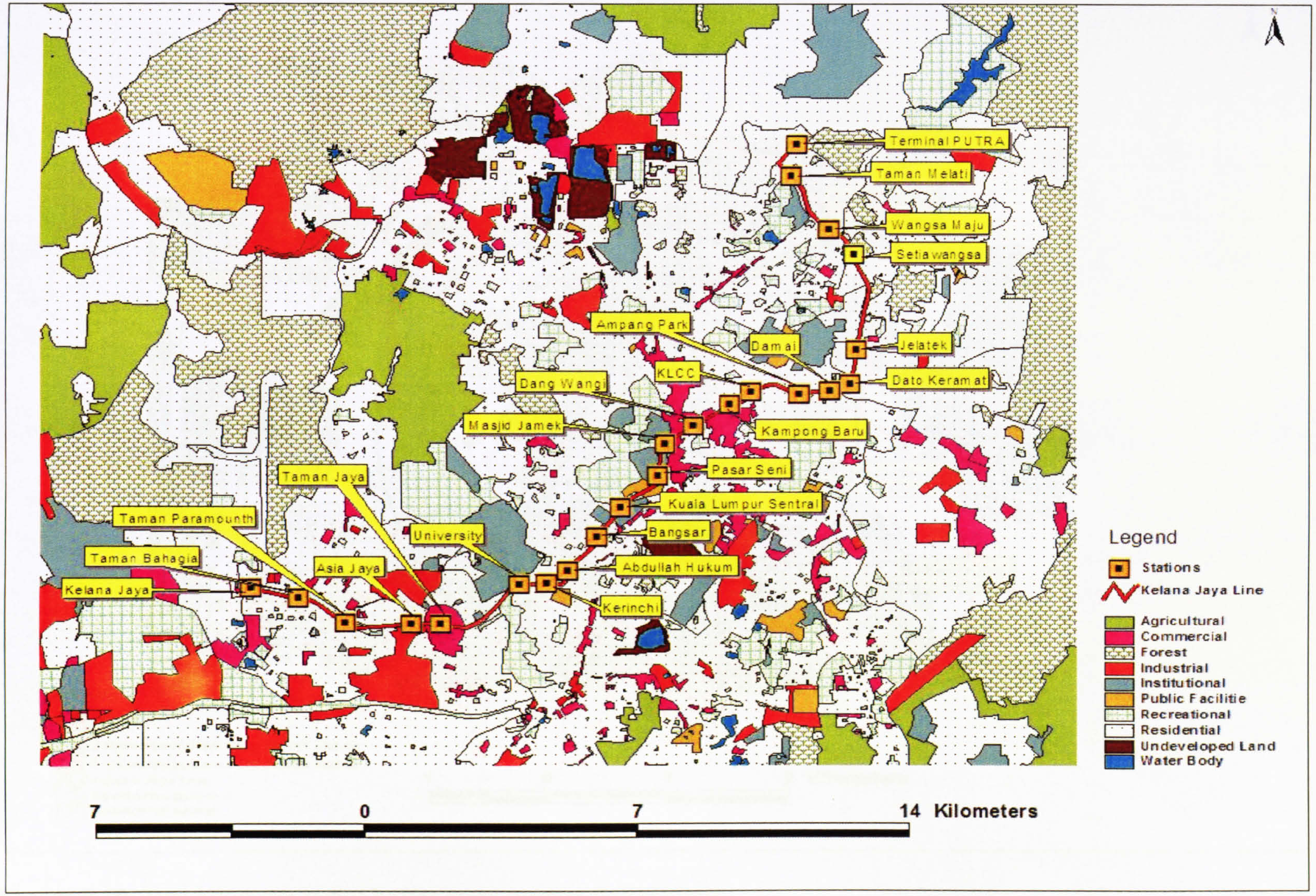



**Figure 6.9**: Case study: the Kelana Jaya Line LRT system

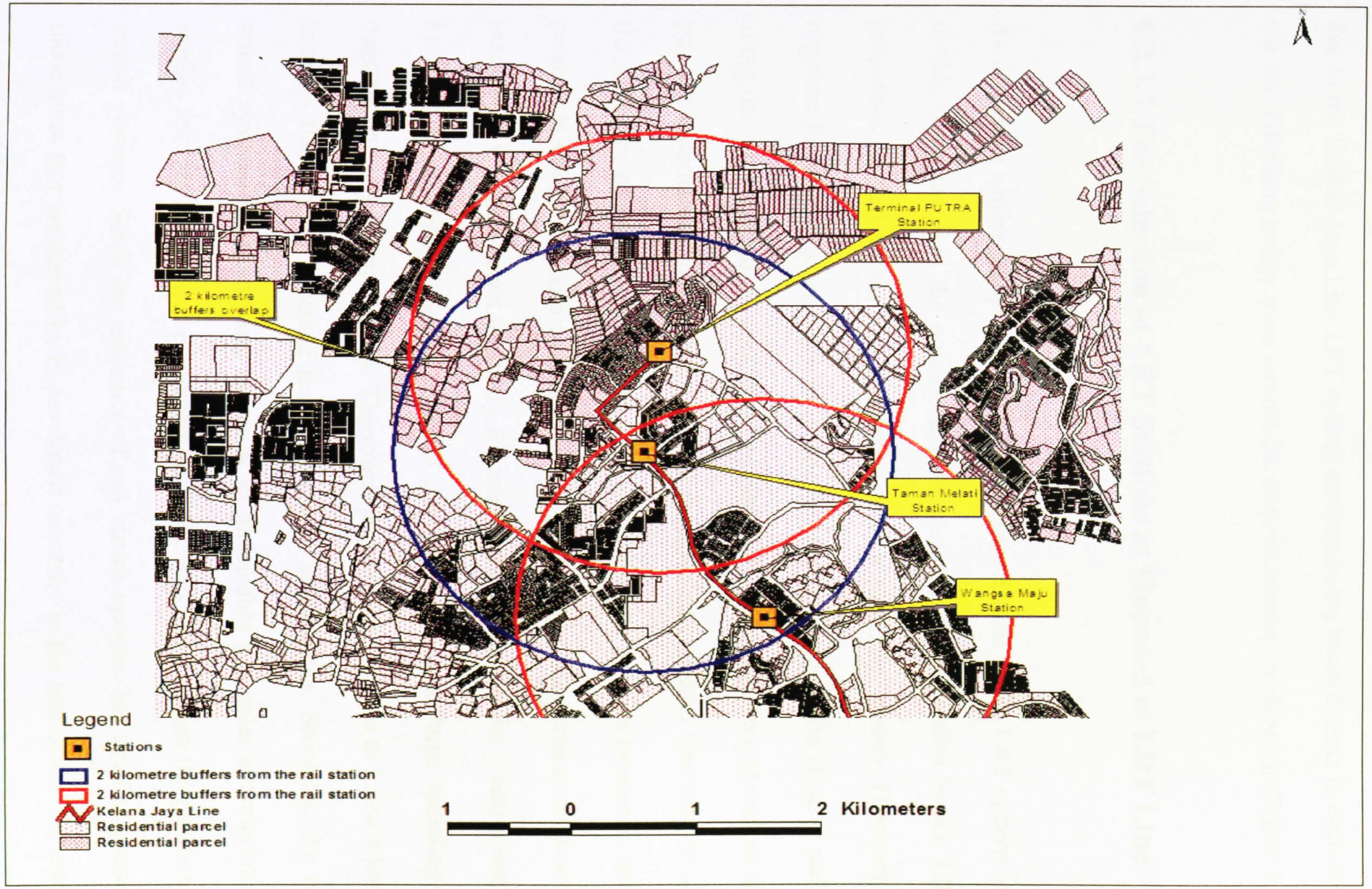



**Figure 6.10**: Two kilometre radius buffer areas surrounding stations

Thus the effect of the LRT system on house prices can be measured. Figure 6.10 above shows a two kilometre radius buffer surrounding the Kelana Jaya Line stations. However, due to the Kelana Jaya Line LRT system stations being located close to each other means that the two kilometre buffer areas around the stations overlap as shown in Figure 6.10.

#### 6.2.3.7 The Selection of LRT Stations as Opposed to LRT Line

As discussed earlier, the process of measuring the effects of the LRT system on house prices in this study involves the positive externalities that are generated by the LRT system for properties located within two kilometres from a particular station. However, the potential negative locational externalities for properties that are located too close to rail transit line or along the route will not be considered in this study. There are several reasons in selecting the positive externalities rather than potential negative externalities that may be associated with the existence of rail transit systems. First, measuring the positive economic impacts of transit projects is one of the main considerations in planning practice around the world. This can be associated with the needs to justify for large expenditure for the construction of rail transit systems. In addition, it is also of great public interest since large spending is incurred in constructing rail transit systems. Therefore, people are interested to know what other indirect benefits that can be expected from rail transit investments. Secondly, the notion that rail transit systems uplift property values is an undeniably a popular assumption. Hence, many studies that are carried out previously have focused mainly upon the positive effects of rail transit systems. Since the existence of rail transit systems has uplifted property values for those areas that are served by it, developed countries in the like of the UK and US have even promoted LVC policy – a framework collating results and observations supporting how property value is affected from improving the accessibility provided by transport facilities. The positive results of LVC have been captured by the local government and exercised as a policy that contains various taxes. Thirdly, most of the researches' objectives that have been carried out for the past forty years were to provide an empirical evidence for the basic urban economic theory which suggests that any improvement in transportation infrastructure is capitalised into the land values (a more in-depth discussion on this theory can be found in the previous chapters). Hence, the theory assumes that savings generated via the use of transportation and access to transportation services may be capitalised into property prices. In other words, there is positive correlation between rail transit systems and property values. Thus, the study in the Klang Valley will be carried out in order to provide an empirical evidence for the estimation of the negative rent gradient with respect to the trade-off between the improvement of accessibility to the CBD and house prices. Finally, as far as the Kelana Jaya Line LRT system and its effects on house prices are concerned, the system itself is free from noise along the line due to the cutting-edge technology used. The service provider has carefully chosen the technology from Germany which is considered to be one of the best in the world, in particular with regards to the issue of nuisance that may generated by the system. Additionally, it is important to note that the route to construct the track for the LRT system is carefully considered in order to avoid the potential negative effects such as nuisance and other effects along the route. For instance, some parts of the LRT line and station are constructed underground, in particular when it passes through the denser residential areas.

### 6.2.4 Data Collection

Thus far the research approach and study area of this study have been examined. The discussion now is extended by asking what type of empirical data needs to be collected once a hedonic house price study has been formulated. In order to collect the empirical data for this study, which hedonic data is required should be known beforehand. In general, this process could be done by extensively reviewing the literature and discussing with the supervisor. It should be noted that the identification process might produce a long list of data. Yet, it is data availability that determines what data one can realistically use to develop a hedonic model. Therefore, the next process in the data collection stage is the investigation of data availability and quality. In the following subsections, the discussion is focused on the research activities related to the identification of data requirement, data availability and data quality carried out in this study.

#### 6.2.4.1 Identifications of Data Requirement

It was pointed out in the previous discussion (Chapter four) that in order to measure the effects of rail transit systems on house prices, the changes in the prices of all housing attributes need to be taken into consideration. In our attempt to measure the effects of the LRT system on house prices in this study, sixty seven types of variables were selected and grouped into five main categories; focused variables, structural attributes of the house, locational attributes and socio-economic attributes and selling price of each individual house (see Table 6.6). The identification of these variables is guided by the literature review (the detailed discussion on this can be found in section 5.2), discussion with supervisors, the appropriateness of the study area and the availability of the data.

#### 6.2.4.2 Data Sources and Data Availability

The main purpose of this subsection is to discuss the data sources for this study. The literature has shown that hedonic data can be obtained from two sources; primary data and secondary data sources. Before discussing data sources further however, it is helpful to describe both primary and secondary data. Primary data are data collected primarily for the research project by the individual researcher of the research team. In practice however, there are three basic means of obtaining primary data; observations, survey and experiment.

Conversely, secondary data is data that has been collected by someone else and which is available for the researcher to use – normally secondary data is publicly available even if not already published. Secondary data that can be accessible to the public are the major government surveys such as the censuses of population (in most countries), the statistics on human resource development, key economic indicators, health, crime, environment, housing, transport, employment, and agriculture and production.

In the case of this study, most of the data were collected from secondary data sources. This is not an issue because the literature suggests that previous hedonic house price studies have relied primarily on secondary data, particularly for information on selling price. The secondary data were collected during fieldwork in the Klang Valley. The fieldwork consisted of several phases, spread over a period of five months from July to September 2006 and July to August 2007.

**Table 6.6:** List of explanatory variables available to the model

*A. Focus (light rail transit system) variables*

*Straight-line-distance measures*

1. Proximity to LRT stations
2. Location within 500 metres
3. Location within 501-1,000 metres
4. Location within 1,001-1,500 metres
5. Location within 1,501-2,000 metres

*Network-distance measures*

6. Proximity to LRT stations
7. Location within 500 metres
8. Location within 501-1,000 metres
9. Location within 1,001-1,500 metres
10. Location within 1,501-2,000 metre
11. Location beyond 2,001 metres
12. Travel time savings to CBD

*B. Structural attributes of the house*

13. Floor area
14. Number of bedrooms
15. Number of bathrooms
16. Apartment
17. Cluster house
18. Condominium
19. Detached house
20. Flat
21. Semi-detached house
22. Terraced house
23. The availability of parking space
24. The availability of swimming pool
25. The availability of sauna
26. The availability of café
27. The availability of gymnasium
28. The availability of sport facilities
29. The availability of laundry
30. The availability of security
31. The availability of shop
32. The availability of landscaping

*C. Locational variables*

33. Accessibility to the city centre
34. Proximity to major roads
35. Proximity to highways

**Table 6.6**: (continued)

36. Proximity to primary schools
37. Proximity to secondary schools
38. Proximity to universities
39. Proximity to hospitals
40. Proximity to institutions
41. Proximity to commercial areas
42. Proximity to worship places
43. Proximity to green areas
44. Proximity to parks
45. Proximity to recreational areas
46. Proximity to industrial areas
47. Proximity to cemeteries
48. Proximity to forests

*D. 1991-2000 census enumeration district-level socio-economic variables*

49. Proportion of elderly (age above 60)
50. Proportion of young (age 25-34)
51. Rate of employment
52. Proportion of Malays
53. Proportion of Chinese
54. Proportion of Indians

*E. Other variables*

55. 1994 Purchase (MYR) before opening LRT service
56. 1995 Purchase (MYR) before opening LRT service
57. 2004 Purchase (MYR) after opening LRT service
58. 2005 Purchase (MYR) after opening LRT service

In the first fieldwork, data on several categories were collected from various agencies in Malaysia. However, after completing the first fieldwork and returning to the UK, the researcher identified several other relevant data that are still needed for this study. Thus, the second fieldwork need had to be carried out in order to the fill gaps. As noted earlier, the second fieldwork was completed in August 2007. Several categories of data have been identified with regard to this study. These categories of data can be grouped into five; the selling price of individual houses and its structural attributes, locational attributes, socio-economic attributes, property market and transportation access variables. Table 6.7 provides a list of explanatory variables that will be used in this study, along with the data element, definition, unit of measurement and data sources for each variable.

The question here is whether all these fifty four explanatory variables should be included in the model. For the purpose of avoiding multicollinearity for this study, the explanatory variables that will be used to measure the LRT-house price relationship are selected using step-wise regression. By using step-wise regression, the researcher would be able to identify the highly correlated explanatory variables with the dependent variable (house prices).

*The Klang Valley House Price Survey*: As has been noted in preceding section, two samples of data on housing units were taken from the population of houses sold before and after the opening of the LRT system. As has been noted by Du (2006), choosing the right time period is essential in order to measure accurate effects on house prices. She explained further that there are three different periods of time which should be considered; before the decision to build, immediately after opening and several years after its completion. In the context of this study, data on house prices for two points in time were chosen. It must be noted that the year immediately after it was opened has to be eliminated due to the condition of the housing market during that time. As mentioned previously, the first phase of the LRT system in the Klang Valley was opened in September 1998 – a year after financial crisis hit several South-East Asian countries.

**Table 6.7**: List of explanatory variables and data elements

| Explanatory variables | Data elements |
|---|---|
| 1. Proximity to LRT stations (straight-line-distance) | LRT station and land parcel |
| 2. Location within 500 metres | LRT station and land parcel |
| 3. Location within 501-1,000 metres | LRT station and land parcel |
| 4. Location within 1,001-1,500 metres | LRT station and land parcel |
| 5. Location within 1,501-2000 metres | LRT station and land parcel |
| 6. Proximity to LRT station (network-distance) | roads, LRT station and land parcel |
| 7. Location within 500 metres | roads, LRT station and land parcel |
| 8. Location within 501-1,000 metres | roads, LRT station and land parcel |
| 9. Location within 1,001-1,500 metres | roads, LRT station and land parcel |
| 10. Location within 1,501-2000 metres | roads, LRT station and land parcel |
| 11. Location beyond 2,000 metres | roads, LRT station and land parcel |
| 12. Travel time savings | LRT station, LRT route and land parcel |
| 13. Floor area | land parcel and floor area |
| 14. Number bedrooms | land parcel and number of bedrooms |
| 15. Number of bathrooms | land parcel and number of bathrooms |
| 16. Apartment | land parcel and housing type |
| 17. Cluster house | land parcel and housing type |
| 18. Condominium | land parcel and housing type |
| 19. Detached house | land parcel and housing type |
| 20. Flat | land parcel and housing type |
| 21. Semi-detached house | land parcel and housing type |
| 22. Terraced house | land parcel and housing type |
| 23. The availability of parking space | land parcel and car parking |
| 24. The availability of swimming pool | land parcel and swimming pool |
| 25. The availability of sauna | land parcel and sauna |
| 26. The availability of café | land parcel and cafeteria |
| 27. The availability of gymnasium | land parcel and gymnasium |
| 28. The availability of sport facilities | land parcel and sport facilities |
| 29. The availability of laundry | land parcel and laundry |
| 30. The availability of security | land parcel and security |
| 31. The availability of shop | land parcel and shop |
| 32. The availability of landscaping | land parcel and landscaping |
| 33. Accessibility to city centre | land use, roads and land parcel |
| 34. Proximity to major roads | major roads and land parcel |
| 35. Proximity to highways | highways and land parcel |
| 36. Proximity to primary schools | land use, roads and land parcel |
| 37. Proximity to secondary schools | land use, roads and land parcel |
| 38. Proximity to universities | land use, roads and land parcel |
| 39. Proximity to hospitals | land use, roads and land parcel |
| 40. Proximity to institutions | land use, roads and land parcel |
| 41. Proximity to commercial areas | land use, roads and land parcel |
| 42. Proximity to worship places | land use, roads and land parcel |
| 43. Proximity to green areas | land use, roads and land parcel |

**Table 6.7**: (continued)

| | |
|---|---|
| 44. Proximity to parks | land use, roads and land parcel |
| 45. Proximity to industrial areas | land use, roads and land parcel |
| 46. Proximity to recreational areas | land use, roads and land parcel |
| 47. Proximity to cemeteries | land use, roads and land parcel |
| 48. Proximity to forests | land use, roads and land parcel |
| 49. Proportion of elderly (age above 60) | mukim and proportion of elderly |
| 50. Proportion of young (age 25-34) | mukim and proportion of young adults |
| 51. Rate of employment | mukim and employment rate |
| 52. Proportion of Malays | mukim and proportion of Malays |
| 53. Proportion of Chinese | mukim and proportion of Chinese |
| 54. Proportion of Indians | mukim and proportion of Indians |
| 55. Selling price of 1994 | land parcel and selling price |
| 56. Selling price of 1995 | land parcel and selling price |
| 57. Selling price 2004 | land parcel and selling price |
| 58. Selling price of 2005 | land parcel and selling price |

As widely recognised, property sectors was among the sectors that were impacted by the financial crisis due to the increased interest rate. During that period, the interest rate for mortgages was as high as 14 per cent. In addition, the demand for housing decreased and the market was facing over supplied housing units. As a result, house prices in the Klang Valley fell precipitously compared to previous years. Therefore, it needs several years to recover after it was blown up by the serious financial crisis of 1997 and 1998. Based on this condition, the year after the opening of the LRT system has to be eliminated.

However, after examining the condition of the housing market in the study area, house price transactions for 2004/05 were chosen to be a sample. This marked a period after several years of rail transit systems operated in the Klang Valley. In total, 2338 units of housing selling prices were collected. This cross-sectional data refers to the residential property located within two kilometres (straight-line-distance) of LRT stations. The selection procedure for residential property area is based on two considerations; the ease of the residents to either walk or drive from their houses to the LRT stations. The question is how far are people willing to walk from their house to a particular LRT station? According to Untermann (1984), planners typically assume that people will comfortably walk approximately one-quarter of a mile to reach the transit stations. However, one-quarter of a mile to walk is considered distant especially for countries such as Malaysia which has a tropical and humid climate with temperatures averaging $30^0$C ($86^0$F).

In the context of this study, we refer to the recent guidelines provided by O'Sullivan and Morrall (1996). O'Sullivan and Morrall have summarised the guidelines of walking distance to the LRT station based on two countries; Canada and the US (see Table 6.8). They noted that the willingness of people to walk from their house to the rail station depends primarily on various factors; trip purpose, available time and walking environment. They also illustrated further that the walking environment has proved to be an important factor in influencing people to walk to the rail stations.

For instance, inconveniences such as lack of sidewalks, inadequate signage, dangerous walkways and poor appearance can cause potential passengers to choose their own vehicles as a mode of travel. In addition, a study conducted by Olszewski and Wibowo (2006) on the walking distance to the MRT station in Singapore (Malaysia's neighbour) have arrived at the conclusion that nearly 60 per cent of MRT passengers walked to the stations and the average walking distance was 608 metres. Based on the guidelines given above and the study conducted in Singapore, the UK and the US; five minutes (400 metres), ten minutes (800 metres) and fifteen minutes (1200 metres) walking time to LRT stations were considered as appropriate walking time for this study – after assuming a walking speed of 80m/min. The selling price of an individual house and its structural attributes were collected from the Department of Valuation and Property Services, Malaysia (hereafter referred to as DVPS).

**Table 6.8**: Recent LRT walking distance guidelines

| Country | Walking Distance Guidelines |
|---|---|
| *Canadian Cities* | |
| 1. Calgary Transit, Calgary | 1. General guideline is 400m |
| 2. B.C. Transit, Vancouver | 2. Guideline for LRT is 900m |
| 3. Societe de Transport de la Communaute Urbaine de Montreal, Montreal | 3. General guideline is 400-500m |
| 4. Ottawa-Carleton Regional Transit Commision, Ottawa | 4. General guideline is 400-600m |
| 5. Toronto Transit Commision, Toronto | 5. General guideline for surface transit is 300m |
| 6. Edmonton Transportation, Edmonton | 6. General guideline is 400m |
| *American Cities* | |
| 7. Maryland Mass Transit Administration, Baltimore | 7. Use guideline of the American Association of State Highway and Transportation Officials |
| 8. Niagra Frontier Transportation Authority, Buffalo | 8. General guideline is 457m |
| 9. Regional Transportation District, Denver | 9. General guideline is 536m |
| 10. New Jersey Transit, Newark | 10. General guideline is 804m |
| 11. Southern Pennsylvania Transportation Authority, Philadelphia | 11. An area is considered 'well served' if a stop is less than 402m (5-minute walking time) from passenger's origin and is considered 'served' if a stop is less than 804m (10-minute walking time) from a passenger's origin. |
| 12. Port Authority of Allegheny County, Pittsburgh | 12. No guideline available |
| 13. Sacramento Regional Transit District, Sacramento | 13. A 1992 study found that 64% of transit passengers walk less than 403m and 90% walk less than 804m. Regional transit's guideline is 609m |
| 14. Bi-state Development Agency, St. Louis | 14. No guideline available |
| 15. Metropolitan Transit Development Board, San Diego | 15. General guideline is 538m |
| 16. San Jose Trolley Corp. San Jose | 16. Average walking distance from LRT to a commercial destination is 30-60m. A one block walk is necessary for 42% of LRT passengers in the five block long core area |
| 17. Greater Cleveland Regional Transit Authority, Cleveland | 17. No guideline available. |

*Source*: O'Sullivan and Morrall (1996).

The sample of data refers to 2004/05 (six years after the Kelana Jaya Line was opened). The sample of data thus includes the residential properties in the study area, whilst house price transactions would only have included properties that changed hands. Unfortunately, these data are made available only to valuers, appraisers and estate agents who are registered with the Board of Valuers, Appraisers and Estate Agents, Malaysia. For researchers or those parties who are not associated with the aforementioned board, but are interested to obtain these data have to purchase them from DVPS. After discussing with the officer who is responsible for managing these data, the researcher managed to obtain these data without have to purchase them. This is due to the policy of the Malaysian government in encouraging students to do research related to real estate, in particular at the doctorate level. In return the researcher has to submit a copy of his thesis from this study to the DVPS. However, not all structural attributes of the condominiums and apartments are available in the dataset. Thus, a field survey to locate identified condominiums and apartments was carried out. Face-to-face interviews were carried out with the condominium and apartment management in order to elicit available facilities. Table 6.9 shows a summary of the information that we obtained from DVPS and the field survey. In the case of data quality, the selling price and structural attributes of the house that have been received can be trusted. It has undergone some 'cleaning' as mentioned by the data provider, and it was also used by the data provider for their own research, as well as producing a property market report for the government. It should be noted that these data came from the government agency which obtained the information from the consortium of solicitors directly involved with particular property sales.

*Base Map, Land Parcel and Locational Attributes Data Survey*: The data on the base map, land parcel and locational attributes (type of land use) were obtained from the Centre of Spatial Analysis, University Science of Malaysia, Kuala Lumpur City Hall and Department of Agriculture. Land use or locational attributes data were collected for two different periods of time; 2004 and 2005. The purpose of dividing these data was based on different time periods because we need to see the land use changes during these two periods of time. Thus, we would be able to measure how these attributes could affect house prices in the study area. The data was believed to be of high quality and reliability as these come from the centre that is involved in the GIS application of the Klang Valley project for the Prime Minister's Department of Malaysia. Table 6.10 is a summary of the land parcel and the locational attributes data that has been obtained from the Centre of Spatial Analysis, University Science of Malaysia and Kuala Lumpur City Hall.

**Table 6.9**: Data obtained in the house price survey

| | |
|---|---|
| Selling price (MYR) | Age |
| Land parcel number | Swimming pool |
| Total floor area (sq-ft) | Balcony |
| Total property area (sq-ft) | Cafeteria |
| Dwelling type | Club house |
| Number of bedrooms | Gymnasium |
| Number of bathrooms | Children playground |
| Parking space | Sport facilities |
| Mini shop | Sauna |
| Security | Laundrette |
| Landscaping | |

*Source*: Adopted from the Department of Valuation and Property Services, Malaysia and Researcher's Survey (2006 and 2007)

*Socio-Economic Data*: Studies of the determinants of house prices using hedonic house price models have highlighted that it is essential to construct indices of deprivation and socio-economic classification at Mukim level for the whole of the Klang Valley housing market.

Therefore, the 2000 population census was used to construct these indices. Orford (1999, pp. 83) notes that it is important to choose the appropriate variables used to construct these indices, since they can determine the results of the analysis. Moreover, the selected variables could also represent the factors considered to influence housing supply and demand, and residential differentiation. From this viewpoint, the selected variables can be grouped into two general categories; socio-economic and ethnicity – these two are close coupling (Orford, 1999). Table 6.11 shows the variables constructed from 1991 and 2000 census population data. As for growth domestic product (GDP) information for Malaysia, the state of Selangor and Federal Territory of Kuala Lumpur, it was obtained from the financial report and Five Year Malaysia Plan published by the Ministry of Finance and Economic Planning Unit, respectively.

**Table 6.10**: Data obtained for base map, land parcel and land use types

| | |
|---|---|
| Base map | Hospitals/clinics |
| Land parcel | Open space/parks & sport facilities |
| Land parcel number | Parks |
| Area | Forest |
| Residential | Squatters |
| Commercial | Undeveloped land |
| Industrial | Cemetery |
| Institutional | Worship places |
| Roads network | River |
| Schools | LRT network |
| Community centres | |

*Source*: Centre of Spatial Analysis, University Science of Malaysia and Kuala Lumpur City Hall (2006)

**Table 6.11:** Variables constructed from 1991 and 2000 census population data

| | |
|---|---|
| Socio-economic dimension | Proportion of young (age 26-34) |
| | Proportion of elderly (age above 60) |
| | Proportion of professionals |
| | Rate of male employment |
| | Rate of female employment |
| | Rate of male unemployment |
| | Rate of female unemployment |
| Ethnic dimension | Proportion of Malays |
| | Proportion of Chinese |
| | Proportion of Indians |

*Source*: Department of Statistics (1991 and 2000)

*The Klang Valley Housing Market Data*: Two major sources of relevant data for the Klang Valley housing market were obtained from the property market report of Malaysia and the Malaysian house price index, annually published by DVPS. Data from these two sources would provide a general picture of the housing market and price range, as well as the housing stock in a particular district/mukim. These reports were collected from the library at University Malaya and the National Institute of Valuation, Malaysia. The information received from this source is highly reliable as it comes from the government agency, the DVPS. The information from the property market report and house price index could help in gaining a better understanding of the Klang Valley housing market to help verify the results of the analysis. Table 6.12 is a summary of some of the data in the property market report and Malaysian house price index report.

**Table 6.12**: Data obtained for housing market and house prices

| | |
|---|---|
| Sales of residential properties | Selangor house price index |
| Stocks of residential properties | House price index for growth region |
| Median house prices | All houses price index |
| The Malaysian house price index | Terraced house price index |
| Kuala Lumpur house price index | High-rise unit price index |

*Source*: Property Market Report and Malaysian House Price Index Report

*Kelana Jaya Line LRT System Information*: The information of the Kelana Jaya Line LRT system was obtained from the company who operated this service. A company known as Rangkaian Pegangkutan Integrasi Deras Sdn. Bhd. (RapidKL) was given approval to operate the Kelana Jaya Line LRT system. There was a great deal of important information with regards to the Kelana Jaya Line LRT system that this study managed to obtain. This information is important because it provides us with relevant statistics of the LRT line that we are interested in to measure its effects on house prices. The type of information that we obtained from RapidKL is shown in Table 6.13.

**Table 6.13**: Information on the Kelana Jaya Line LRT system

| | |
|---|---|
| Travel time from one station to another | Number of passengers per day |
| Travel time from one station to CBD | Map of LRT service |
| Frequency of trains | History of Kelana Jaya Line LRT system |

*Source*: RapidKL (2006)

## 6.3 Conclusion

The aim of this chapter was to describe the method that has been employed in measuring the effect of Kelana Jaya Line LRT system on house prices. Specifically, it has discussed the research approach, the Klang Valley as a study area and selling price of an individual house, together with the structural attributes associated with it. It must be noted that a long list of the required data could be identified but it was the data availability that would determine the final dataset for the principal analysis. In the next chapter, the discussion will continue by discussing the process of developing the database and performing the analysis.

# CHAPTER 7

## THE DEVELOPMENT OF THE DATABASE AND GIS ANALYSIS

### 7.1 Introduction

Having collected all the empirical data available from the secondary sources (as extensively discussed in the previous chapter), it is essential now to prepare the data before it can be used to measure the effects of the LRT system on house prices. For this, all the empirical data that have been collected needs to stored in a database. The development of the database is a process to prepare and manipulate the attribute data and coverages of map that can be used to estimate the effects of the LRT system on house prices. The coverages of map that will be prepared and manipulated in this study are a base map of the study area, residential property coverage, land use coverage and, socio-economic and population coverage. Note that GIS will be used to prepare the data for hedonic price models, particularly in the process of constructing locational externalities. In addition, it could also be used in addressing the issue of accessibility in a case of measuring the effects of rail transit systems on house prices – all of these issues will be discussed in section 7.2. Then in section 7.3, the discussion will go on to discuss final dataset that has been prepared for principal analysis. Finally, the chapter will be concluded by summarising the process of preparing the data for this study (section 7.4).

## 7.2 Data Preparation

This subsection is structured as follows. First, the selling price and housing structural attributes data need to be verified. It then proceeds with the data cleaning. Thirdly it discusses the data conversion. Fourthly, the discussion continues with the process of constructing residential property coverage. The discussion then proceeds with the process of constructing land use coverage. Finally, the process of generating locational externalities is discussed.

### 7.2.1 Selling Price Data Verification

The purpose of selling price verification in this study is twofold. Firstly, it is necessary to remove unsuitable selling prices for this study so that we can examine the effect of LRT on house prices based on accurate data. Secondly, it is important to identify data that needs format conversion. This data should be prepared in the appropriate format for application using ArcView, SPSS and GWR.

As noted in the previous section, this study relies primarily on the selling price and structural attributes obtained from DVPS. Table 7.1 shows the characteristics of the available data obtained from DVPS. Evidently, this study was able to obtain the data on most of the important structural attributes of housing for hedonic house price models.

**Table 7.1**: The characteristics of the available data from DVPS sales dataset

| | |
|---|---|
| Mukim name | Bedrooms |
| Section | Bathrooms |
| Land parcel number | Housing address |
| Selling date | Selling price (MYR) |
| Area size | Housing types |

### 7.2.2 Data Cleaning

Several steps were taken to clean the sample dataset by eliminating the unsuitable data and updating the unavailable data. The purpose of this process therefore is to ensure that only reliable datasets will be ready to be presented for further analysis. This process can be done by examining the dataset with simple descriptive statistics which can be found in SPSS. The results of this analysis are shown in Table 7.2.

**Table 7.2**: Sales transactions from sample dataset of 2004/05

| **Year** | **Number of sales** | **Percentages** |
|---|---|---|
| *Purchase (MYR) after opening LRT service* | | |
| 2004 | 1042 | 50.58 |
| 2005 | 1018 | 49.42 |
| **Total** | 2060 | 100 |

Out of the total samples, 50.58 per cent of the samples were representative of sales transactions for 2004 and 49.42 per cent were sales transactions for 2005. This implies that the highest sales transactions occurred in 2004. The selection of the study period has been governed by a research approach in measuring the effects of rail transit systems on house prices that were discussed in the preceding section, and also by the objective of the study; that is to identify the effects of the LRT system on house prices in the Klang Valley. Thirdly, it is of course influenced by the availability of land use data, census data and house price transactions data.

Discussion continues with the process of cleaning based on the above presented samples of sales transactions. The following criteria have been implemented for the purpose of sales transactions data cleaning; non year 2004 and 2005 transactions, non residential property use, incomplete information and suspected error in data entry. The cleaning process has left this study with 2060 observations. These observations represented several areas that have been served by the LRT system such as Petaling Jaya, Kuala Lumpur, Hulu Klang, Setapak and Gombak.

After completing the cleaning process, data updating was then undertaken by inputting several data on structural attributes for condominiums and apartments. These structural attributes are believed to be highly significant in influencing each unit of the condominium and apartment prices. As mentioned earlier, data on these structural attributes were obtained via face-to-face interviews with the condominium and apartment management during fieldwork. These data include car parking, swimming pool, sauna, cafeteria, club house, gymnasium, childrens' playground, sport facilities, launderette, security, mini market shops and landscaping. The process of updating structural attributes has given dummies of 1 for "yes" and 0 for "no". Yet, it has been argued by Powe et al. (1995) that dummy variables should only be employed to estimate individual amenity effects if they are uncorrelated with other physical, locational or environmental variables. Hence, it is essential to examine the correlation between dummy variables and other variables. For this, the correlation analysis that can be found in SPSS was used to examine the relationship between dummy variables and other variables (see Table A7.2 of Appendix B).

### 7.2.3 Data Format Conversion

The next stage of data preparation is the data format conversation. As has been discussed earlier, this study specifically uses various computer programmes. These computer programmes are ArcInfo and ArcGIS to build the road network, ArcView 3.2 to prepare the database, as well as for measuring straight-line and network distances, SPSS to implement the classical regressions and heteroscedasticity testing and GWR for spatial regressions and to examine heterogeneity of spatial process.

### 7.2.4 Constructing Residential Property Coverage

In order to measure the effects of LRT on house prices, it is important to input the selling price and its structural attributes that are obtained from DVPS to the matched land parcel in the GIS database. The effects of LRT and other locational attributes on house prices could not be assessed accurately if the most important data are input incorrectly. As has been shown in previous research conducted in the UK and North America, each property is geo-referenced using its postcode. For example, Orford (1999) has employed two procedures in constructing residential property coverage; the matching of ADDRESS-POINT and the datasets by text-strings and the matching of ADDRESS-POINT and the datasets by a mixture of postcodes and addresses. However, this method cannot be employed in the Malaysian context since it does not have a geo-referenced system. After examining the selling price of each residential parcel dataset, the DVPS sales dataset was inputted manually to a land parcel database which relies primarily on the following criteria:

1. Land parcel number
2. Housing address
3. Size of land parcel

Figure 7.1 shows the process of manually inputting the selling prices and its structural attributes to a land parcel database. It should be noted that any land parcel number missing in either the DVPS or land parcel database was subsequently eliminated from the samples.

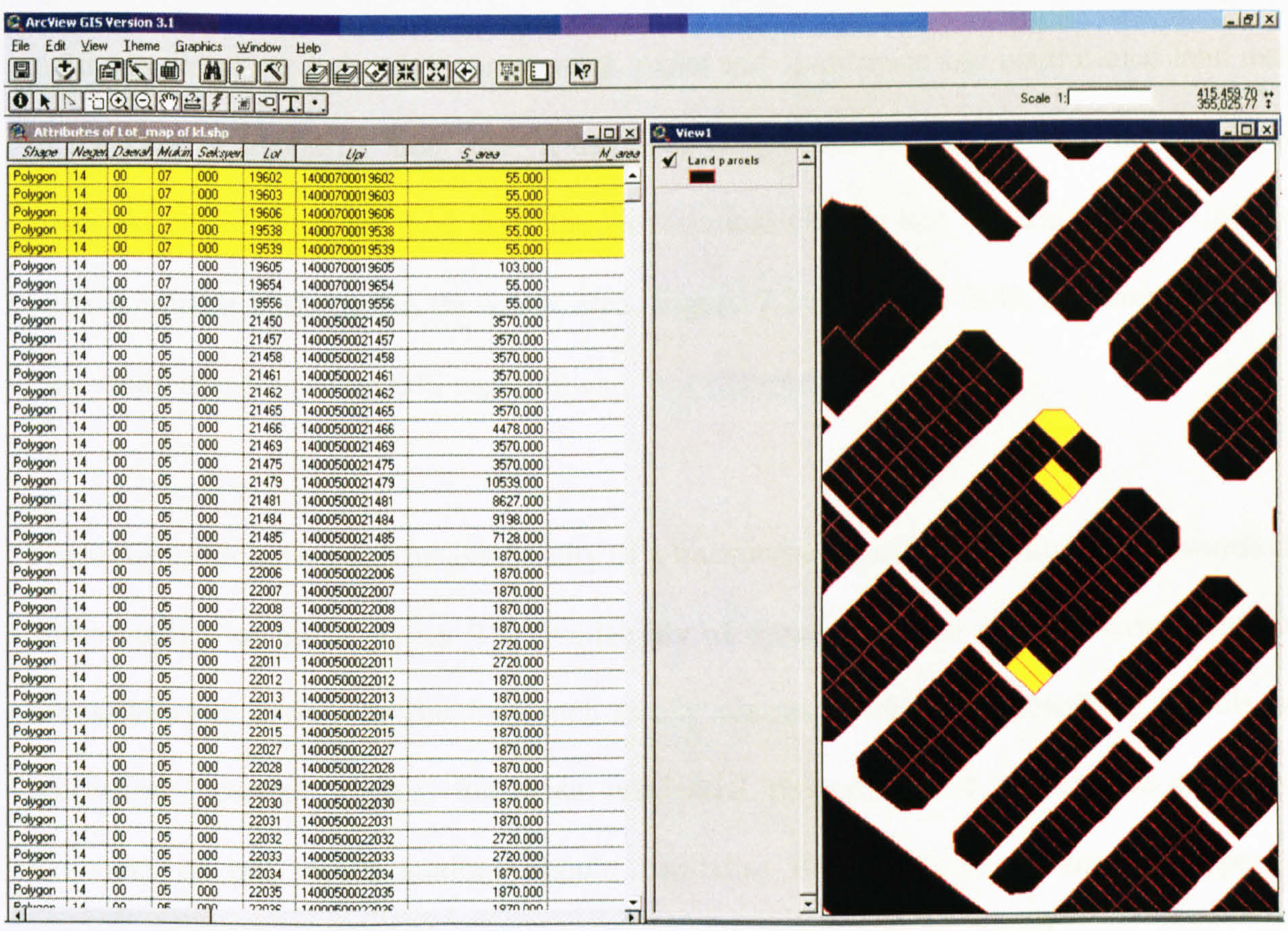



**Figure 7.1**: The land parcels and its attributes in ArcView GIS window

### 7.2.5 Constructing Land Uses Coverage

*Non-Residential Land Uses*: At the outset, it must be noted that the non-residential land uses data is very important in the process of measuring the effect of the LRT system on house prices. In the context of this study, the set of non-residential land uses data which represents the land use of 2004 were obtained from the Centre of Spatial Analysis, University Science of Malaysia. The existing non-residential land uses data were then updated with the present data that were obtained from Kuala Lumpur City Hall and Department of Agricultural. The process of updating the non-residential land uses were done through manual inputting using ArcView. The non-residential land uses were grouped into four main categories. These four main categories are industrial, commercial, parks and open space and institutional land uses. In the case of industrial land uses, it has been categorised into heavy and light industrial areas. As for institutional land uses, the Government Offices and the Universities/Colleges were dominant buildings in the study area. Figure 7.2 shows the built environment of the case study prepared using GIS capabilities.

*Transportation Network*: The availability of a transportation network contributes towards the determination of house prices. The availability of a transportation network would improve accessibility to desired destinations such as city centres, workplaces, hospitals, schools and recreational centres. Hence, for those residential properties that are located near road networks or rail transit stations should capitalise its prices. There are two types of transportation networks in the Klang Valley; rail and road networks. The former can be

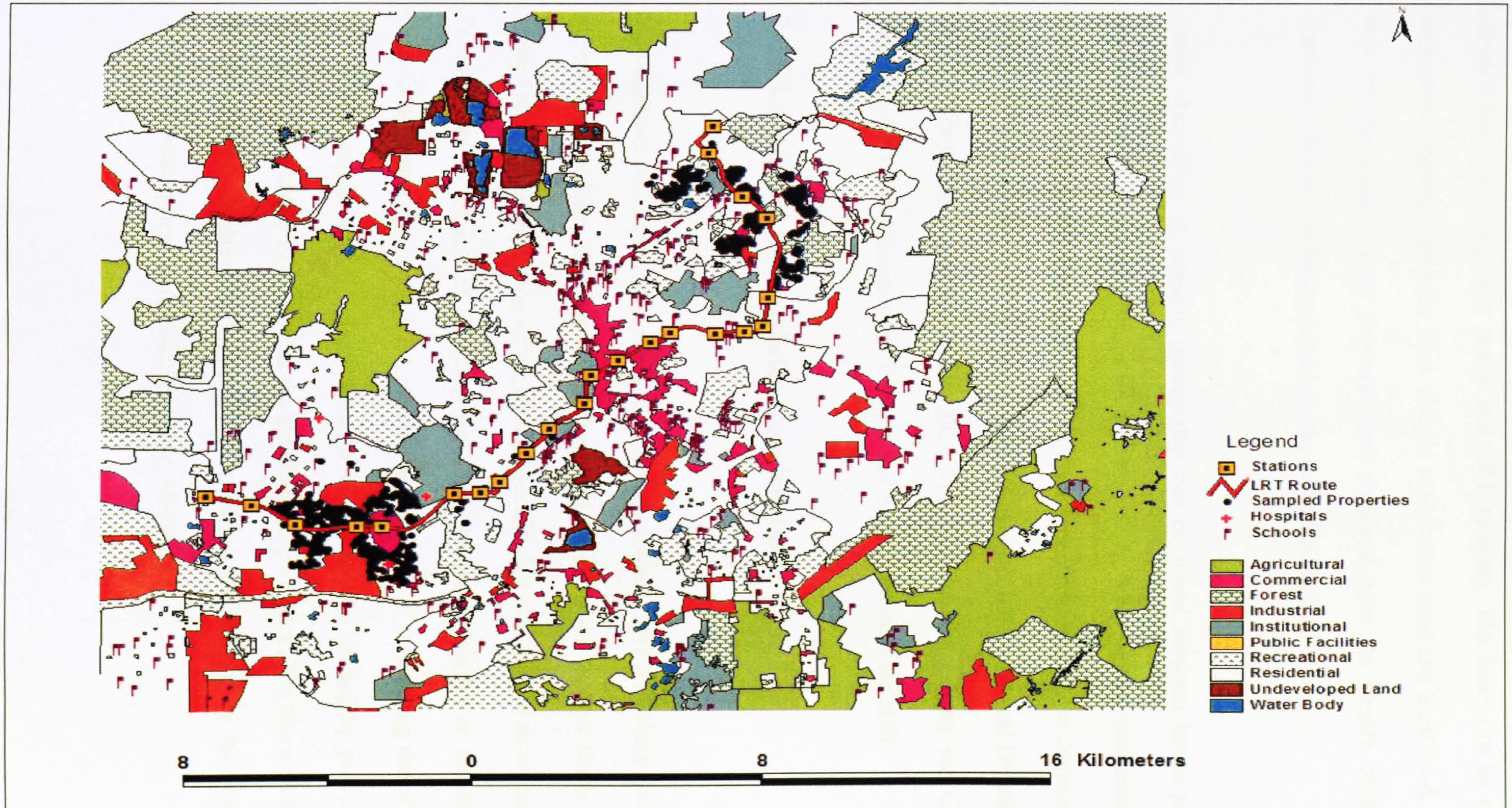



**Figure 7.2**: The built environment of the case study

divided into two categories; heavy and LRT systems. The latter can be divided into five categories; highway, primary road, district road, minor road and local road. Note that digital data on the transportation network were obtained from the Centre of Spatial Analysis, University Science of Malaysia and Kuala Lumpur City Hall.

*Public Amenities*: A positive relationship can be found between house prices and public amenities such as schools, hospitals and clinics. In other words, residential properties are much more expensive if located closer to these amenities. In order to capture the locations of public amenities, they will be represented by using point coverages. Digital data for public facilities between years 2004 and 2005 were also obtained from the Centre of Spatial Analysis, University Science of Malaysia and Kuala Lumpur City Hall.

### 7.2.6 Locational Externalities Construction

*Introduction:* Most externalities are local in their impact, with a distance decay effect in their extent and intensity. The impact of locational externalities for this study was constructed using GIS. The construction of locational specific data will permit us to measure a distance decay effect of locational attributes on house prices, in particular the effect of an LRT stations on house prices because it was the primary aim of conducting this study. The process of constructing locational externalities for this study was guided by previous research that has been extensively examined in the previous chapter. Next, the discussion will focused on the process of constructing locational externalities for measuring the effects of the LRT system on house prices in the Klang Valley, Malaysia.

*Introduction:* The locational attributes that are needed to be constructed for the purpose of this study are measures of accessibility and proximity to locational attributes, and measures of neighbourhood quality.

*Locational attributes:* As has been noted in the preceding discussion, two types of measures have been identified in order to measure externalities from locational attributes; straight-line-distance and network-distance. By using network-distance, accessibility between each observation and locational attributes is the shortest route on the road network connecting them. Straight-line-distance in metres was calculated within ArcView 3.2, and drawn using lines and connecting each observation to the nearest selected locational attributes. In the network-distance, the distance in metres is measured along the street network by using a user-developed GIS programmed named Multiple Origins to Multiple Destinations, obtained from the Environmental Systems Research Institute (ESRI) support centre. The programme was written based on Avenue programming language of ArcView by Dan Paterson from the US and it was made accessible to the public (see Appendix C). The network-distance measurement using this programme requires three layers of spatial data; points of origin (observations), points of destinations (LRT station and other interested amenities and facilities) and the road network data. The distances between the origins and destinations measured are automatically saved in a *shapefile*. Figure 7.3 and 7.4 illustrates straight-line-distance and network-distance methods in measuring the distance for each observation to locational attributes.

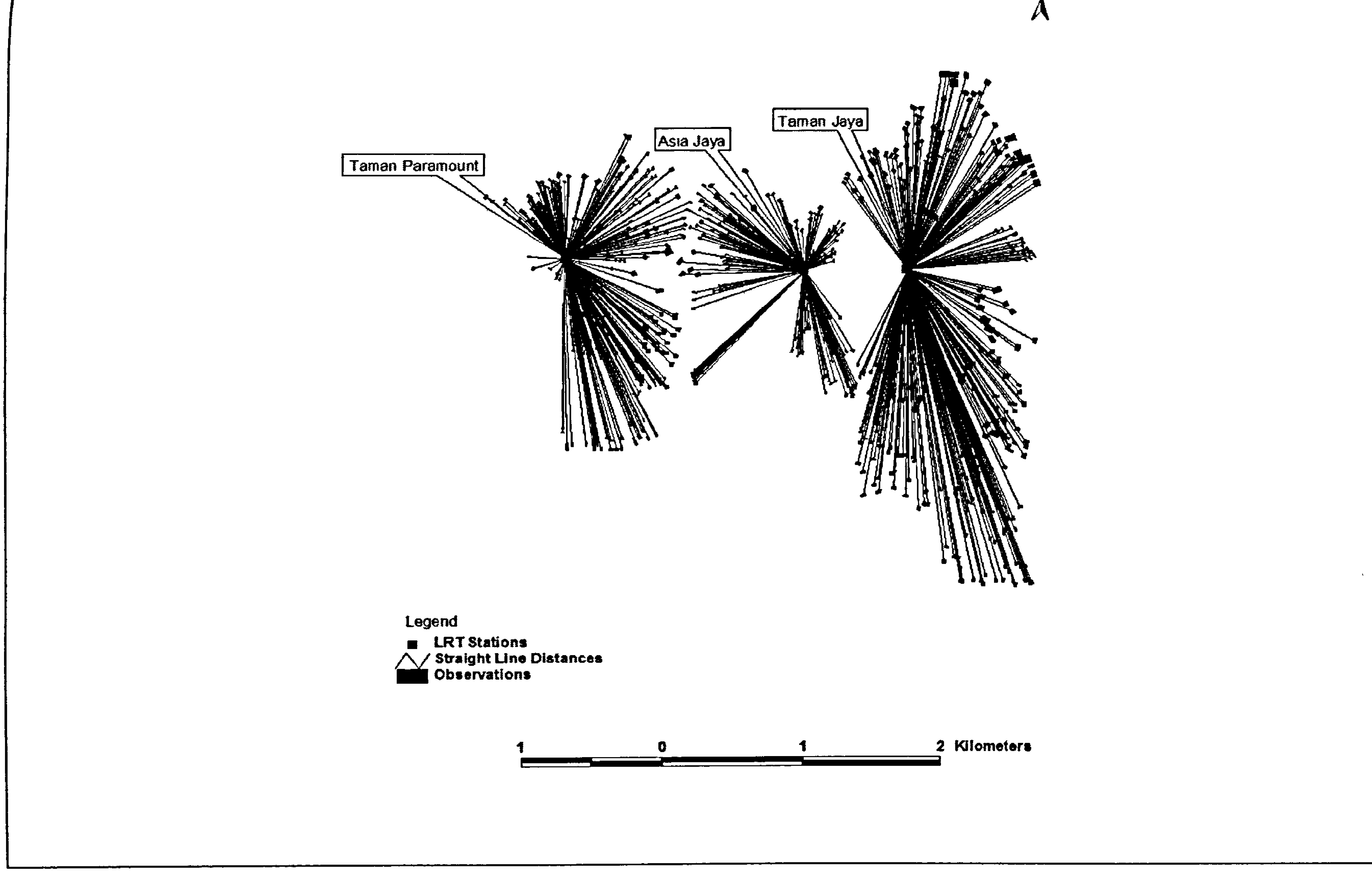



**Figure 7.3**: Straight-line-distance

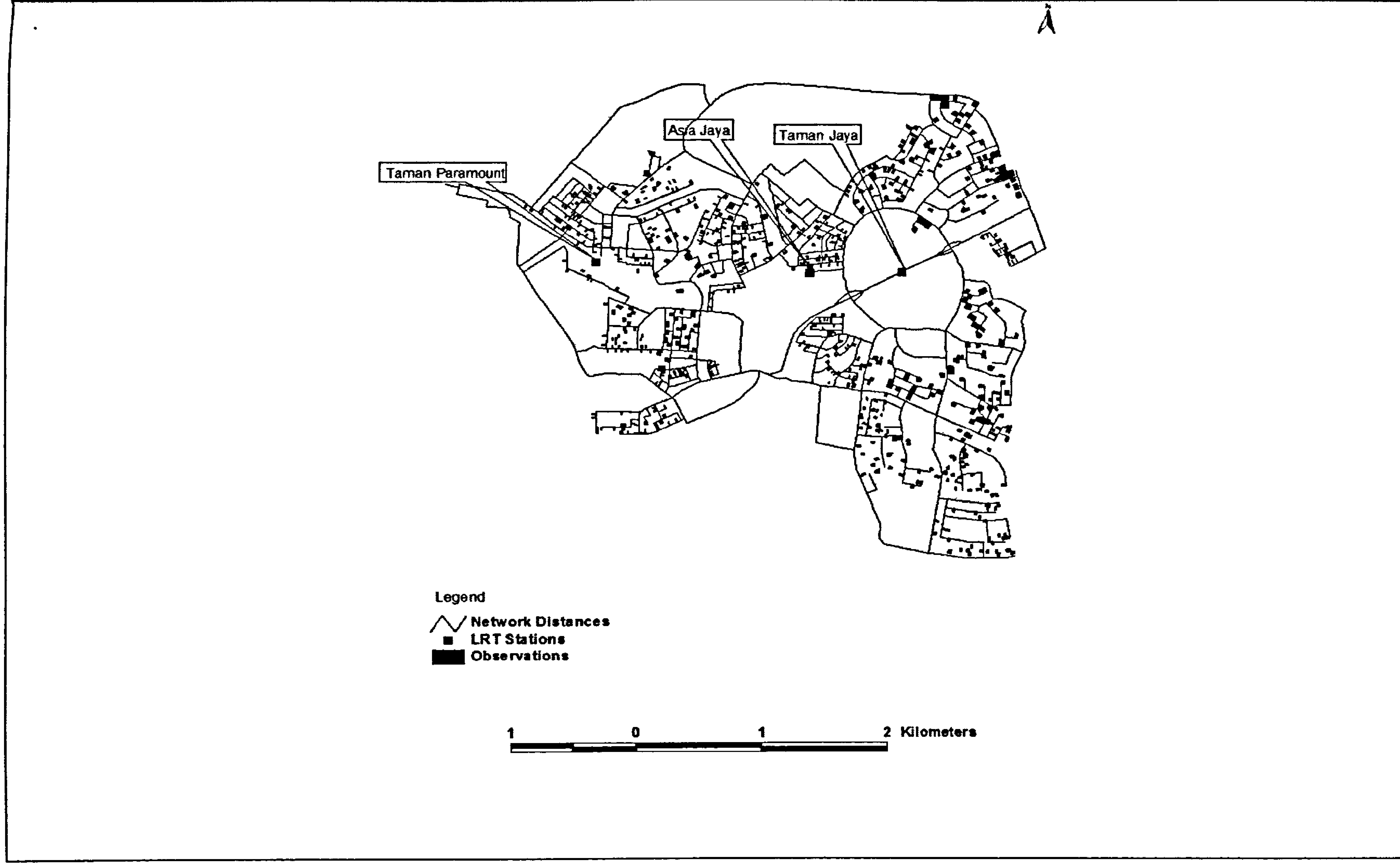



**Figure 7.4**: Network-distance

As mentioned above, straight-line-distance and network-distance were used to measure the distance between each observation and an LRT station (Hess and Almeida, 2007). The main reason for employing these two methods to measure the distance between each observation and an LRT station was to explore the difference between perceived distance to a station and actual distance to a station. In the case of perceived distance, the assumption that can be made is a house buyer may perceive a house to be within a certain distance of the transit station, although there are certain barriers that may restrict residents from travelling along the shortest straight-line route to reach the transit station. In addition, the existence of an LRT system can also affect people's perception of their neighbourhood. It has been argued by Davies (2005), that house prices have a tendency to be affected by perceptions of place and the perceived desirability of an area. For instance, the existence of the LRT system will improve the image of the areas it serves. In the context of the Klang Valley, it is clear that the LRT system had a better image and seemed more fashionable as a mode of public transport compared to bus services.

As for actual distance, it is appropriate to measure actual distance experienced by the resident by walking or easy driving along the shortest route from his or her house to the transit station. Using these two methods, house price variations in the study area can be explained. Furthermore, the importance of these two methods could be identified in explaining the house price variations in the study area. As has been mentioned in Chapter one, higher property values are expected in places with superior access to transit stations. Yet in the case of residential property, it has been assumed that house prices have potentially decreased for properties that are located too close to a transit station due to traffic congestion and noise pollution effects, whilst properties radiating out from the station and within walking and easy driving distance of the station should increase in price.

In relation to the aforementioned assumption, the distance between each observation to an LRT station was then divided further into distance intervals. Table 7.3 is a summary of the distance intervals that will be used in the principal analysis. As can be seen in Table 7.3, various distances from an LRT station have been considered. The distance intervals used in this study were then used as dummy variables. Note that the selection of distance intervals should address the aforementioned assumptions.

**Table 7.3**: Distance intervals from LRT stations

| Straight-line-distance | | Network-distance | |
|---|---|---|---|
| Distance intervals | Sample | Distance intervals | Sample |
| 0-500m | 301 | 0-500m | 146 |
| 501-1000m | 467 | 501-1000m | 365 |
| 1001-1500m | 521 | 1001-1500m | 218 |
| 1501-2000m | 291 | 1501-2000m | 397 |
| | | >2001m | 454 |
| Total | 1580 | | 1580 |

In the case of accessibility to the city centre, network-distance from each observation to Kuala Lumpur city centre was used as a measurement. The use of network-distance allows simultaneous calculation of minimum travel times from each observation to the CBD. The travel time to the CBD by car can be measured by taking into account impedance costs that may affect accessibility such as speed limits. Besides measuring travel times to the CBD by car, travel times from observations to the CBD by LRT were also measured. By comparing travel times from these two different modes of transportation, travel time savings can be deduced. The purpose of obtaining travel time savings between these two modes to the CBD responds to the debate surrounding increasing house prices resulting from the existence of rail transit systems, which has been extensively discussed in preceding chapters.

Previous discussion clearly states that the effects of the LRT system on house prices can be expected if the system has improved travel time from residential areas to the CBD. Therefore, efforts were made to measure travel times to the CBD by car and the LRT system. It must be noted that an assumption was made that each household has at least one car since field surveys were not carried out to identify car ownership. This is a fair assumption since it is based on the study conducted by several government agencies and independent consultants where conclusion was made that nearly 80 per cent of the households in the Klang Valley own at least one car. With this understanding established, the methodology of measuring these travel times will now be discussed.

The first step of analysis was to obtain the appropriate network for each observation to and from the CBD for example by road networks and appropriate network to an LRT station. In order to generate an accurate measurement of travel time to the CBD by car, it is important to take into account several factors namely, treatment of time, regular streets to the CBD for each observation and speed limits. The time that people take to travel to and from the CBD in the morning and evening were chosen since these are the two time periods which have been identified as peak periods during the day where people travel to and from work and other activities. As for regular streets to the CBD, the choice is based on the data obtained from the extensive study conducted by two geography departments at University of Malaya and University Science of Malaysia. Regarding speed limits it is important to consider barriers caused by serious traffic congestion to and from Kuala Lumpur city centre during peak periods.

As mentioned previously, traffic congestion to and from Kuala Lumpur city centre has seriously affected the accessibility level for residents of the Klang Valley. The speed limits for each street in this study were obtained from studies conducted by Mohamad and Kiggundu (2007) and the Ministry of Transports, Malaysia. The second step of analysis in measuring travel time to the CBD by car is to obtain the travel distance from each observation to the CBD. The analysis was carried out using the same methods that have been used in measuring network-distance to an LRT station as discussed above. The results of travel distance are then divided by speed limits that have already been identified. Finally, the results of travel time to the CBD by car are obtained.

In the case of travel time to the CBD by LRT system, several factors have been considered in measuring accurate travel time; access time from house to an LRT station, waiting time and in-vehicle travel time. The sources for waiting and in-vehicle travel time from each station are obtained from the resource centre of RapidKL. The process of measuring access time from a house to an LRT station is discussed above. By adding access time to an LRT station, waiting time and in-vehicle travel time, the total travel time to the CBD by LRT system can be calculated. Finally, the subtraction of travel time by car over LRT to the CBD yields travel time savings, and is then used as one of the key variables in principle analysis. It is vital to note that the analysis that has been carried out in this study has clearly indicated that the existence of the LRT system in the Klang Valley has improved accessibility to and from Kuala Lumpur city centre. Thus it is appropriate to expect house prices to be affected by the existence of the LRT system. The discussion can then take place around; to what extent house prices are affected by this improvement? This key question will be examined in the next chapter by conducting principal analysis.

Accessibility from each observation to main roads and highways were calculated using straight-line-distance and network-distance. Straight-line-distance was used since the effects of noise pollution created by crowded main roads and highways do not necessarily move by road networks, but spread randomly from its source. On the other hand, network-distance was used in order to obtain actual distance from each observation to the nearest main roads and highways junction, since being highly accessible to these facilities will improve accessibility to other desired destinations.

Proximity measures from each observation to institutional areas, shopping malls, hospitals, universities, parks, forests and places of worship were also calculated by using network-distance. In the case of proximity to industrial areas and cemeteries, straight-line-distance is measured from each observation to industrial areas and cemeteries location.

*Neighbourhood quality measures:* Three groups of neighbourhood qualities that have been identified by the literature and are highly relevant for this study are local public amenities such as the quality of local schools, the existence of public parks, golf courses and the availability of local shops), socio-economic attributes and racial composition. Neighbourhood quality for local public amenities was constructed from the land use types in Table 6.10, whereas neighbourhood quality for socio-economic attributes and racial composition was constructed from the census data in Table 6.11. The process of constructing neighbourhood quality is as follows.

Proximity to local schools, public parks, golf courses and local shops was calculated using the Multiple Origins to Multiple Destinations programme. This allowed the shortest route from each observation to these local amenities to be calculated. As has been mentioned above, the Multiple Origins to Multiple Destinations programme allows more than one destination to be selected at any one time. Thus, proximity to local amenities can be calculated simultaneously for each observation. In the case of neighbourhood quality for socio-economic attributes and racial composition such as proportion of young (age 26-34), proportion of elderly (age above 60), proportion of professionals, rate of male employment, rate of female employment, rate of male unemployment, rate of female unemployment, proportion of Malays, Chinese and Indians was calculated by deviding the number of population with the smallest administrative areas that is Mukim.

## 7.3 Final Dataset for Principal Analysis

The discussion in this subsection will be focused on the characteristics of the final dataset for principal analysis. It has to be noted that great efforts were taken in preparing the dataset for this study. In this research, the preparation of dataset is indeed a time-consuming process in order to ensure completeness and accuracy. However, once this is achieved the research process has finally come to the final stage that is measuring the effects of LRT on house prices by employing hedonic house price models and GWR. The characteristics of the final dataset of this study can be illustrated by using descriptive statistics and it could easily be done in SPSS. Note that the main objective of this subsection is to illustrate the nature of the final dataset that will be used for principal analysis. If abnormality issues occur in the dataset, those issues need to be addressed and it is essential to find the best approach in order to do this.

### 7.3.1 Descriptive Statistics and Variable Descriptions

As mentioned above, it is necessary to provide some descriptive statistics for the observation and a description of each variable used in the principal analysis. Figure 7.5 shows the distribution of selling prices in the final dataset. Evidently, the selling price of 1,580 observations has a positively skewed distribution. This can be interpreted as the majority of observations in the dataset being represented by low-price properties. In order to obtain a normal distribution, the selling price variable was transformed using natural log and the results of this transformation can be seen in Figure 7.6. It must be noted that transforming selling price into natural log was found to be used widely by many researchers in hedonic studies (see for example, Orford, 1999; Cheshire and Sheppard, 2004; Ismail, 2005). In addition, the continuous independent variables were also transformed using natural log (see Appendix D). Figure 7.7 illustrates the distribution of 1,580 observations by the housing types. It is clear that 36.23 per cent of the total sample is accounted for by Terraced houses. Condominiums and Flats account for about 20.72 per cent each. The least housing types used in the principal analysis are Cluster and Semi-detached houses. The highest percentage of the terraced house in the dataset can be considered as an indication of the areas served by the LRT system that have been dominated by a medium income group.

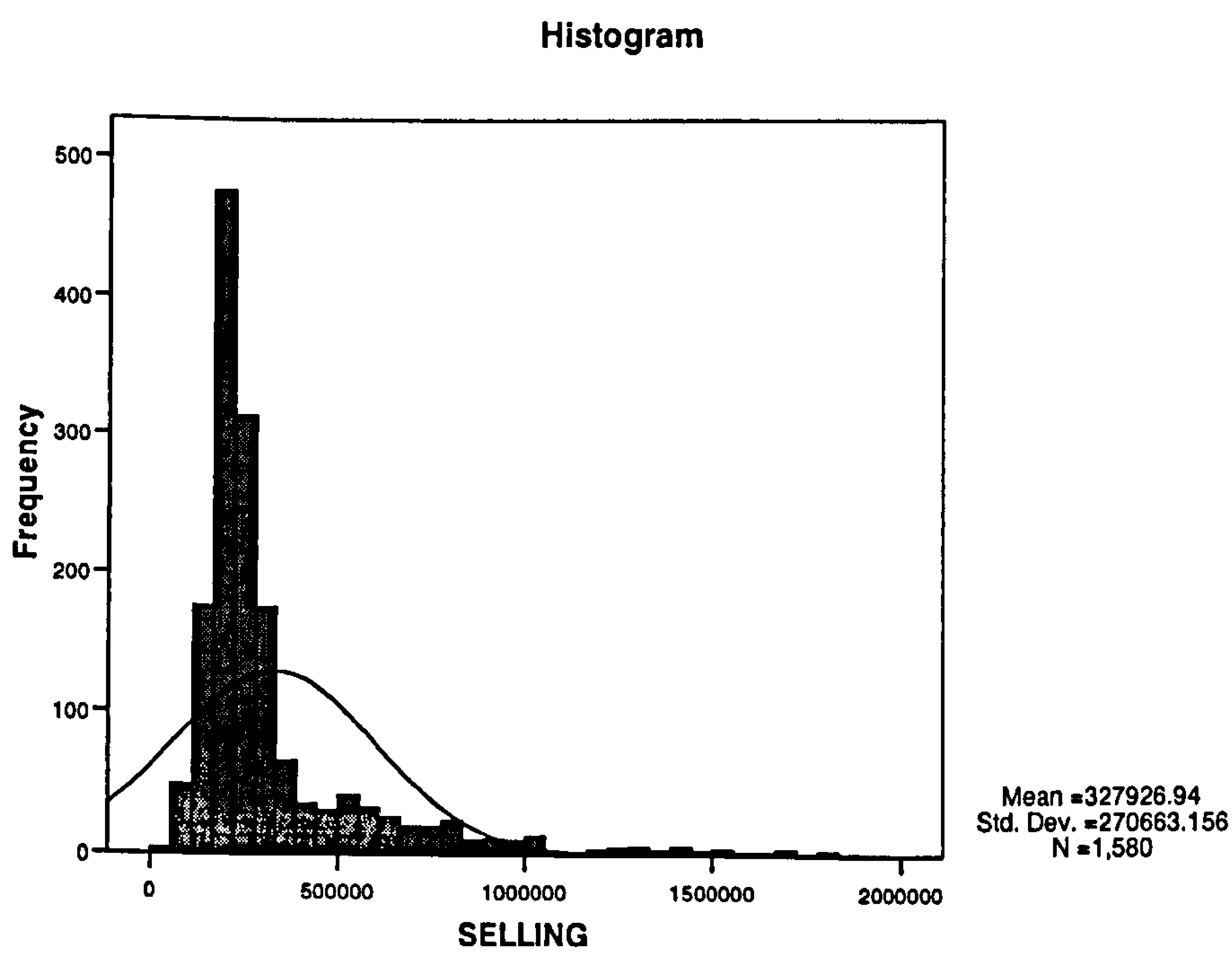



**Figure 7.5**: Distribution of 1,580 actual selling prices

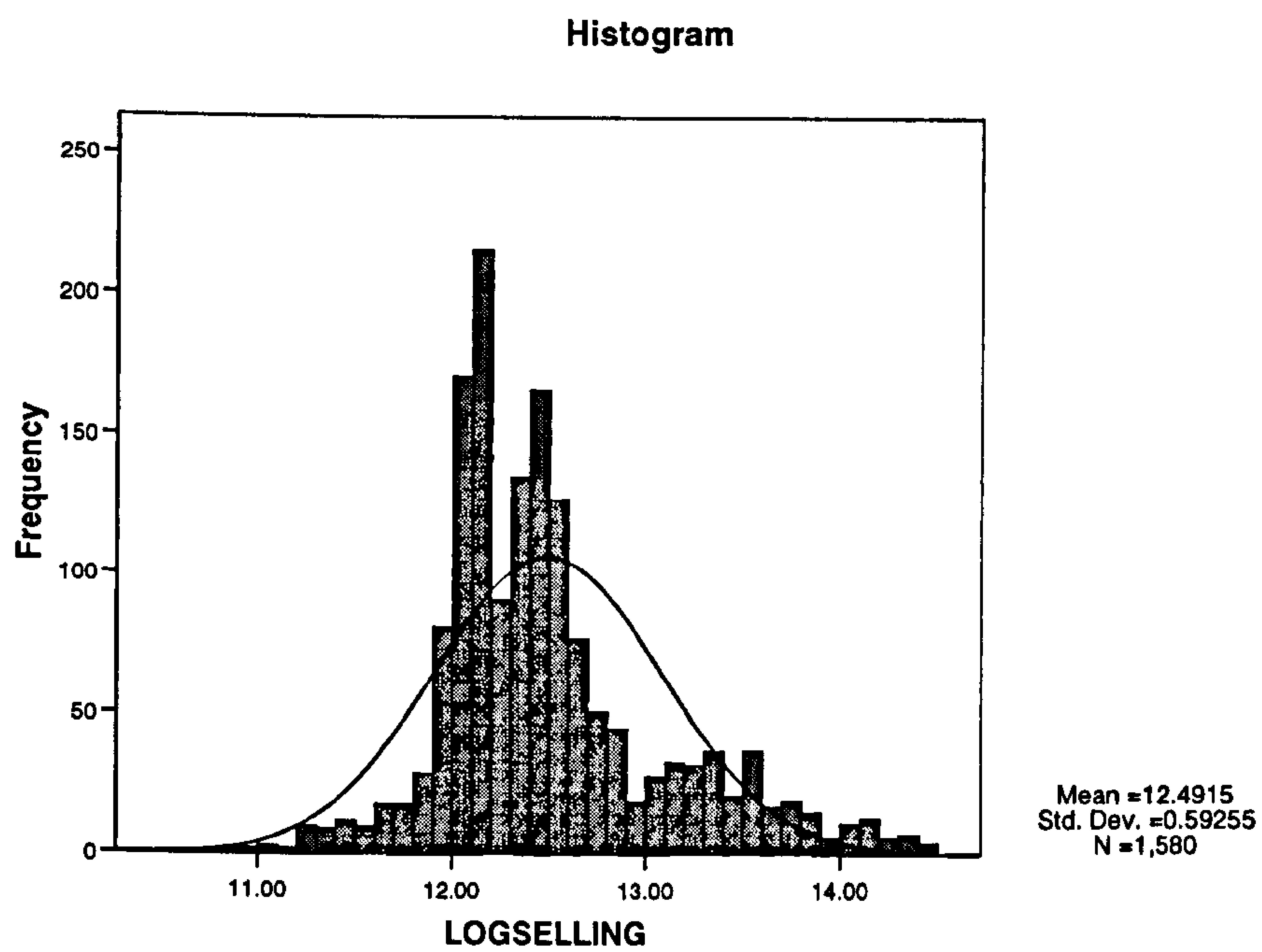



**Figure 7.6**: Distribution of 1,580 natural log of selling prices

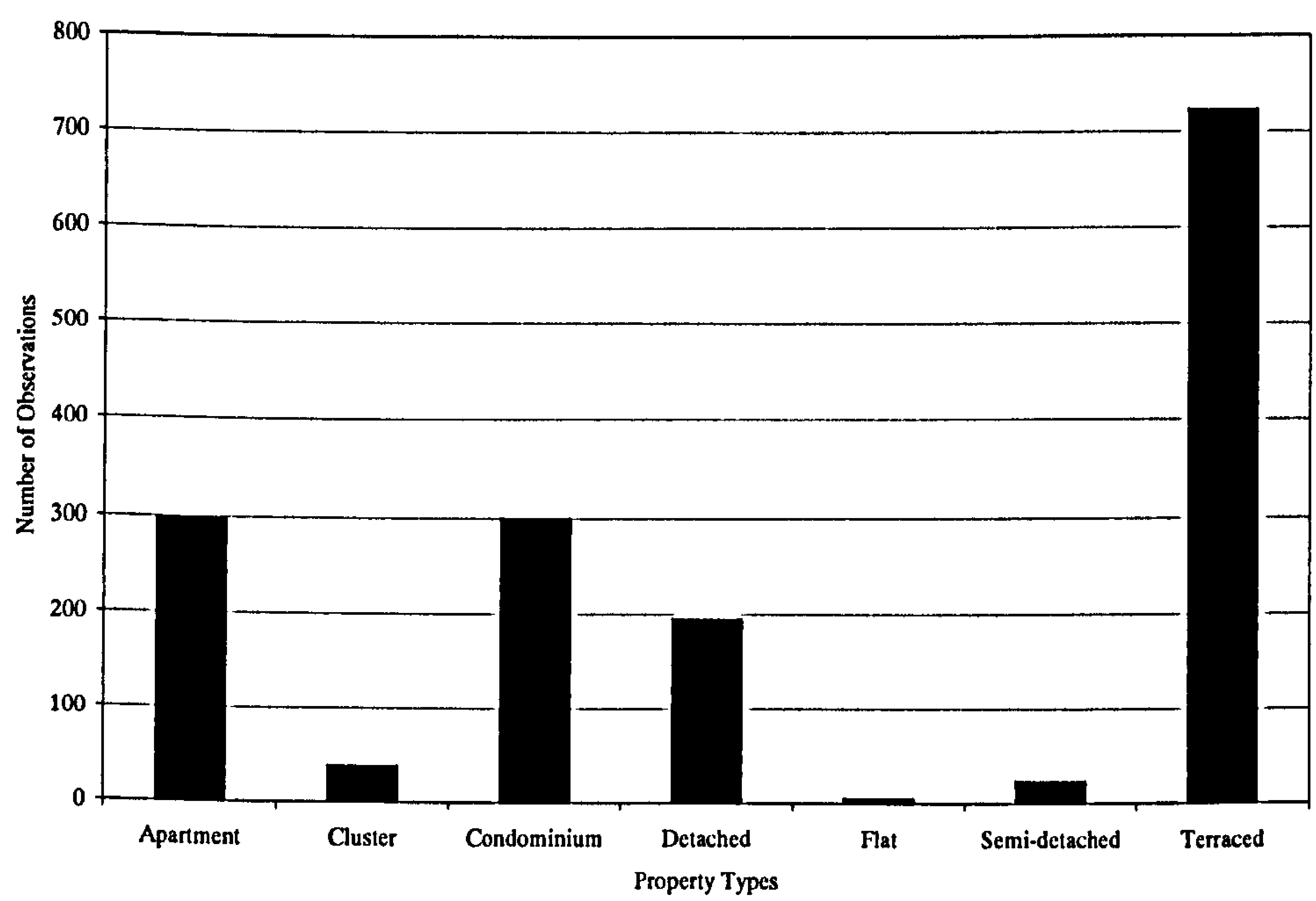



**Figure 7.7**: Distribution of 1,580 observations by property types

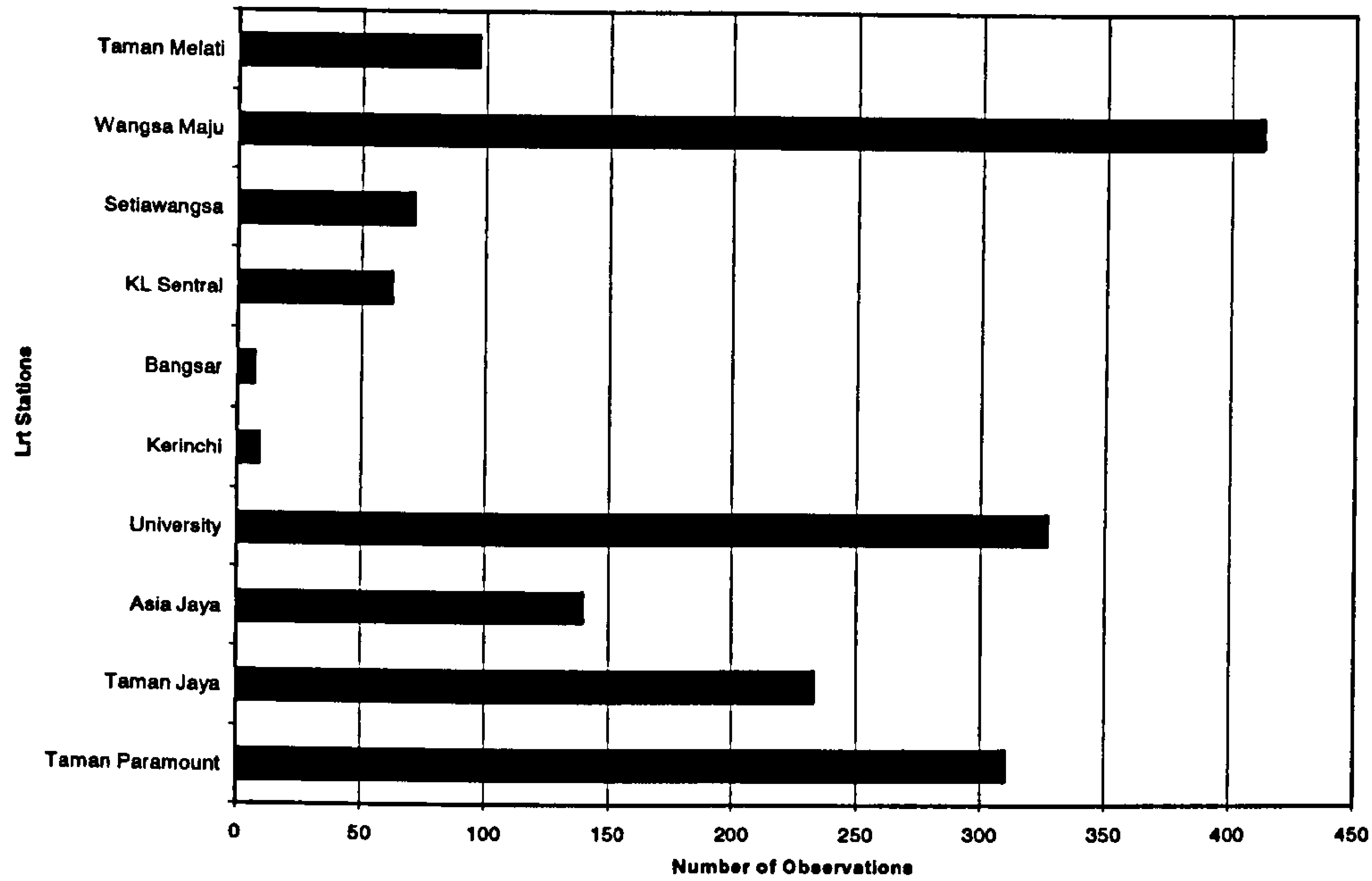



**Figure 7.8**: Distribution of 1,580 observations for ten LRT stations

In terms of the distribution of observations for each of the LRT stations, the data depicted in Figure 7.8 has clearly shown that some of the stations have larger observations than the other. Based on the data depicted above, observations within two kilometres of Wangsa Maju LRT station (which constitute 37.03 per cent), dominate the whole dataset. The lowest percentage of the observations in the dataset is for Kerinchi and Bangsar LRT station, which comprise 0.45 per cent and 0.35 per cent respectively. It should be noted that most of the observations are located outside of Kuala Lumpur city centre. As for Kerinchi and Bangsar, there were only two apartments located within two kilometres of an LRT station. These two stations primarily served several offices and commercial areas. However, there were several residential schemes accessible to these two stations, but their locations were quite distant from being affected by the LRT system. Therefore, there were not considered to be included as a sample of this study.

The discussion above has comprehensively described the distribution of observations used in this study. Next, let us discuss the descriptive statistics for the dependent and independent variables, accounting for the minimum, maximum, standard deviation and mean. Descriptive statistics of the dependent variables show that it has a wide-ranging distribution of price from MYR 50,000 minimum to MYR 1,850,000 maximum. The average price is approximately MYR 283,300. To illustrate the variation of selling price it can then be statistically expressed by ten LRT stations and housing types. These variations are shown in Table 7.4 and 7.5 respectively.

Based on the LRT stations (Table 7.4), KL Sentral LRT station has the highest mean among ten LRT stations of almost MYR 747,000. The highest mean for residential properties situated closer to KL Sentral can be associated with the location factor and its type. This location is highly accessible and within five minutes drive of the CBD. The other two LRT stations that are also among the highest mean are Taman Jaya and Asia Jaya, which constitute approximately MYR 460,500 and MYR 475,800 respectively. Taman Jaya and Asia Jaya LRT stations are located in one of the most prosperous districts of the Klang Valley, namely Petaling Jaya. In addition, residential properties of this area were dominated by semi-detached and detached houses. Therefore, the mean price is expected to be highest in this area.

There were two LRT stations that were identified as an area with the lowest mean among ten LRT stations. These two stations are University and Wangsa Maju LRT stations. These two areas have mixed residential development, comprising low-cost, medium cost and high-cost housing. Hence, it is understandable that the mean selling prices for these areas are lowest compared to the other areas. In the case of selling price by property types, the highest mean selling price comes from the detached house (MYR 865,200). Meanwhile, the flat has the lowest mean selling price (MYR 85,100). Most of the flat type properties are located in Wangsa Maju area.

**Table 7.4**: 1,580 selling prices (MYR) by LRT stations

| LRT stations | Sample (N) | Per cent of total sample | Minimum (MYR) | Maximum (MYR) | Std. deviation | Mean |
|---|---|---|---|---|---|---|
| Taman Paramount | 310 | 15.55 | 63,500 | 2,000,000 | 329,905.75 | 361,217.50 |
| Taman Jaya | 233 | 11.69 | 80,000 | 2,000,000 | 366,558.42 | 460,554.34 |
| Asia Jaya | 140 | 7.02 | 65,000 | 2,800,000 | 43,8905.28 | 475,869.04 |
| University | 327 | 16.41 | 50,000 | 530,000 | 55,318.96 | 211,348.01 |
| Kerinchi | 9 | 0.45 | 205,000 | 305,000 | 38,366.03 | 263,571.43 |
| Bangsar | 7 | 0.35 | 170,000 | 320,400 | 44,543.64 | 231,028.89 |
| KL Sentral | 62 | 3.11 | 475,000 | 1,850,000 | 355,476.25 | 747,670.16 |
| Setiawangsa | 71 | 3.56 | 175,000 | 790,000 | 114,138.78 | 421,282.03 |
| Wangsa Maju | 413 | 36.98 | | 700,000 | 85,368.46 | 211,723.44 |
| Taman Melati | 97 | 4.87 | 110,000 | 750,000 | 106,002.35 | 251,613.40 |
| *Total* | 1,580 | 100 | | | | |

**Table 7.5**: 1,580 selling prices (MYR) by property types

| Housing Types | Sample (N) | Per cent of total sample | Minimum (MYR) | Maximum (MYR) | Std. deviation | Mean |
|---|---|---|---|---|---|---|
| Apartment | 185 | 9.30 | 63,500 | 320,400 | 50,591.72 | 194,781.41 |
| Cluster | 37 | 1.90 | 74,000 | 150,000 | 21,328.56 | 104,310.81 |
| Condominium | 413 | 20.70 | 63,500 | 1,850,00 | 237,664.71 | 311,558.35 |
| Detached | 200 | 10.00 | 150,000 | 2,800,000 | 427,076.35 | 865,252.73 |
| Semi-detached | 23 | 1.20 | 135,000 | 950,000 | 219,190.38 | 494,173.91 |
| Terraced | 722 | 36.20 | 65,000 | 716,592 | 96,526.91 | 244,640.39 |
| *Total* | 1,580 | 100 | | | | |

Table 7.6 is a summary of the fifty-five variables that have been prepared in this chapter to measure the effects of the LRT system on house prices in the principal analysis including focus variables, structural, locational, and socio-economic and ethnic variables. These variables are represented by two categories; continuous and dummy variables. It is important

to note that the fifty-five variables that have been prepared for the principal analysis has enough variability since it take into account all relevant variables in measuring the LRT system-house price relationship. The selection of these variables is guided by the previous study as discussed extensively in Chapter five and of course is supported by the availability of the data. Table 7.7 provides some descriptive statistics for dependent and independent variables and a description of each variable used in the principal analysis. Note that the variability of independent variables that are available is sufficient for the purpose of measuring LRT-house prices relationships.

## 7.4 Conclusion

This chapter has described the preparation process for the case study. This process began with the construction of the database which includes structural and locational data. For this, GIS have been employed to organise and manage large spatial datasets, position each observation and locational attribute on a local map, measuring the distance from each house to an LRT station, the CBD, commercial areas, parks, schools, universities, lake recreations, hospitals, institutional centres, religious centres, green areas, industrial areas, forests, cemeteries, major roads and highways. It should to be noted that two approaches were used to measure the distance and proximity from these mentioned attributes; straight-line distance and network-distance. In total, 1,580 selling prices (dependent variable) and fifty independent variables were prepared for use within the estimation of the effects of the LRT system on house prices presented in the next chapter.

**Table 7.6:** List of 56 variables and their description

| Variable | Abbreviation | Focus | Structural | Locational | Socio-economic | Sales | Type |
|---|---|---|---|---|---|---|---|
| 1. Straight-line-distance | STRDIST | √ | | | | | continuous |
| 2. Location within 500m | STRSTN1 | √ | | | | | dummy |
| 3. Location within 501-1,000m | STRSTN2 | √ | | | | | dummy |
| 4. Location within 1,001-1,500m | STRSTN3 | √ | | | | | dummy |
| 5. Location within 1,501-2,000m | STRSTN4 | √ | | | | | dummy |
| 6. Network-distance | NETDIST | √ | | | | | continuous |
| 7. Location within 500m | NETSTN1 | √ | | | | | dummy |
| 8. Location within 501-1,000m | NETSTN2 | √ | | | | | dummy |
| 9. Location within 1,001-1,500m | NETSTN3 | √ | | | | | dummy |
| 10. Location within 1,501-2,000m | NETSTN4 | √ | | | | | dummy |
| 11. Location beyond 2,001m | NETSTN5 | √ | | | | | dummy |
| 12. Travel time savings to CBD | TIMESAVINGS | √ | | | | | continuous |
| 13. Floor area | FLRAREA | | √ | | | | continuous |
| 14. Number of bedrooms | BED | | √ | | | | continuous |
| 15. Number of bathrooms | BATH | | √ | | | | continuous |
| 16. Terraced house | TYPTRRD | | √ | | | | dummy |
| 17. Cluster House | TYPCLTR | | √ | | | | dummy |
| 18. Semi-detached house | TYPSEMID | | √ | | | | dummy |
| 19. Detached house | TYPDETCH | | √ | | | | dummy |
| 20. Flat | TYPFLAT | | √ | | | | dummy |
| 21. Apartment | TYPAPT | | √ | | | | dummy |
| 22. Condominium | TYPCONDO | | √ | | | | dummy |
| 23. Car parking | PARKING | | √ | | | | dummy |
| 24. Garden | GARDEN | | √ | | | | dummy |
| 25. Swimming pool | SWMPOOL | | √ | | | | dummy |
| 26. Sauna | SAUNA | | √ | | | | dummy |
| 27. Cafeteria | CAFÉ | | √ | | | | dummy |

| | | | | | |
|---|---|---|---|---|---|
| 28. Gymnasium | GYM | √ | | | dummy |
| 29. Sport facilities | SPORTF | √ | | | dummy |
| 30. Launderette | LAUNDRY | √ | | | dummy |
| 31. Security | SECURE | √ | | | dummy |
| 32. Mini shop | MSHOP | √ | | | dummy |
| 33. Landscaping | LANDSCAPE | √ | | | dummy |
| 34. Accessibility to CBD | CBD | | √ | | continuous |
| 35. Proximity to major roads | MJRROAD | | √ | | continuous |
| 36. Proximity to highways | HIGHWAY | | √ | | continuous |
| 37. Proximity to primary schools | PRIMARYSCH | | √ | | continuous |
| 38. Proximity to secondary schools | SECONDARYSCH | | √ | | continuous |
| 39. Proximity to college/university | UNIVERSITY | | √ | | continuous |
| 40. Proximity to hospitals | HOSPITALS | | √ | | continuous |
| 41. Proximity to institutional centres | INSTITUTE | | √ | | continuous |
| 42. Proximity to commercial areas | COMMERCIAL | | √ | | continuous |
| 43. Proximity to religious centres | WORSHIP | | √ | | continuous |
| 44. Proximity to green areas | GREEN | | √ | | continuous |
| 45. Proximity to parks | PARK | | √ | | continuous |
| 46. Proximity to industrial areas | INDUSTRY | | √ | | continuous |
| 47. Proximity to forest | FOREST | | √ | | continuous |
| 48. Proximity to cemeteries | CEMETERY | | √ | | continuous |
| 49. Proportion of elderly (age 55-64) | ELDERLY | | | √ | continuous |
| 50. Proportion of young adults (age 26-34) | YOUNG | | | √ | continuous |
| 51. Proportion of professionals | PROF | | | √ | continuous |
| 52. Rate of employment | EMPLOY | | | √ | continuous |
| 53. Proportion of Malays | MALAY | | | √ | continuous |
| 54. Proportion of Chinese | CHI | | | √ | continuous |
| 55. Proportion of Indians | IND | | | √ | continuous |
| 56. House price transactions 2004/05 (after opening LRT system) | SELLING | | | √ | continuous |

**Table 7.7**: Characteristics of the dependent and independent variables

| | Predictor | Minimum | Maximum | Std. deviation | Mean |
|---|---|---|---|---|---|
| 1 | SELLING | 50,000 | 1,850,000 | 270,663.16 | 327,926.94[2] |
| 2 | LOGSELLING | 10.82 | 14.43 | 0.59 | 12.49 |
| 3 | LOGSTRDIST | 4.33 | 7.64 | 0.64 | 6.73 |
| 4 | STRSTN1 | 0 | 1 | 0.39 | 0.19 |
| 5 | STRSTN2 | 0 | 1 | 0.45 | 0.30 |
| 6 | STRSTN3 | 0 | 1 | 0.47 | 0.33 |
| 7 | STRSTN4 | 0 | 1 | 0.38 | 0.18 |
| 8 | LOGNETDIST | 4.33 | 8.08 | 0.65 | 7.15 |
| 9 | NETDIST1 | 0 | 1 | 0.21 | 0.04 |
| 10 | NETDIST2 | 0 | 1 | 0.42 | 0.23 |
| 11 | NETDIST3 | 0 | 1 | 0.35 | 0.14 |
| 12 | NETDIST4 | 0 | 1 | 0.45 | 0.29 |
| 13 | NETDIST5 | 0 | 1 | 0.46 | 0.30 |
| 14 | LOGTIMESAVINGS | -4.07 | 3.38 | 1.14 | 2.15 |
| 15 | LOGFLRAREA | 4.79 | 8.54 | 0.68 | 6.17 |
| 16 | LOGBEDS | 0.00 | 1.79 | 0.26 | 1.07 |
| 17 | LOGBATH | 0.00 | 1.39 | 0.34 | 0.65 |
| 18 | TYPTRRD | 0 | 1 | 0.49 | 0.46 |
| 19 | TYPCLUSTER | 0 | 1 | 0.15 | 0.02 |
| 20 | TYPSEMID | 0 | 1 | 0.12 | 0.01 |
| 21 | TYPDETCH | 0 | 1 | 0.32 | 0.12 |
| 22 | TYPFLAT | 0 | 1 | 0.05 | 0.00 |
| 23 | TYPAPT | 0 | 1 | 0.39 | 0.19 |
| 24 | TYPCONDO | 0 | 1 | 0.39 | 0.19 |
| 25 | PARKING | 1 | 1 | 0.00 | 1.00 |
| 26 | SWMPOOL | 0 | 1 | 0.46 | 0.32 |
| 27 | SAUNA | 0 | 1 | 0.43 | 0.25 |
| 28 | CAFÉ | 0 | 1 | 0.42 | 0.23 |
| 29 | GYM | 0 | 1 | 0.45 | 0.29 |
| 30 | SPORTSF | 0 | 1 | 0.46 | 0.33 |
| 31 | LAUNDRY | 0 | 1 | 0.22 | 0.05 |
| 32 | SECURE | 0 | 1 | 0.48 | 0.38 |
| 33 | MSHOP | 0 | 1 | 0.46 | 0.30 |
| 34 | LANDSCAPE | 0 | 1 | 0.46 | 0.32 |
| 35 | LOGCBD | 7.91 | 9.43 | 0.29 | 9.08 |
| 36 | LOGMJRROAD | 0.01 | 7.73 | 1.37 | 5.84 |
| 37 | LOGHIGHWAY | 4.84 | 9.32 | 0.93 | 7.50 |
| 38 | LOGPRIMARYSCH | 1.45 | 7.85 | 0.82 | 6.65 |
| 39 | LOGSECONDARYSCH | 2.73 | 7.93 | 0.64 | 6.65 |
| 40 | LOGUNIVERSITY | 3.93 | 8.81 | 0.48 | 7.88 |
| 41 | LOGHOSPITALS | 4.25 | 9.04 | 0.89 | 7.87 |
| 42 | LOGINSTITUTE | 2.59 | 8.56 | 0.71 | 7.29 |
| 43 | LOGCOMMERCIAL | 2.27 | 7.94 | 0.99 | 6.62 |
| 44 | LOGWORSHIP | 1.41 | 8.63 | 2.08 | 6.38 |
| 45 | LOGGREEN | 1.04 | 8.03 | 0.99 | 6.60 |

**Table 7.7**: (continued)

| | | | | | |
|---|---|---|---|---|---|
| 46 | LOGPARK | 0.52 | 9.04 | 2.27 | 6.94 |
| 47 | LOGINDUSTRY | 4.29 | 7.94 | 0.55 | 7.19 |
| 48 | LOGRECREATION | 7.09 | 9.44 | 0.49 | 8.67 |
| 49 | LOGCEMETERY | 4.75 | 8.17 | 0.60 | 7.59 |
| 50 | LOGFOREST | 4.27 | 9.22 | 1.10 | 8.15 |
| 51 | LOGYOUNG | 2.89 | 3.01 | 0.04 | 2.94 |
| 52 | LOGELDERLY | 0.34 | 2.38 | 0.44 | 1.84 |
| 53 | LOGEMPLOY | 4.07 | 4.18 | 0.03 | 4.09 |
| 54 | LOGMALAY | 3.46 | 4.49 | 0.24 | 3.73 |
| 55 | LOGCHI | 1.79 | 3.82 | 0.27 | 3.59 |
| 56 | LOGIND | 0.93 | 2.87 | 0.34 | 2.47 |

[3] Converted at official exchange rate: 1.00 GB pounds = 6.33 Malaysia Ringgits (MYR)

# CHAPTER 8

## The Effects of the LRT System on House Prices in the Klang Valley: Global vs. Local Models

### 8.1 Introduction

This chapter continues the empirical investigation as initiated in Chapter six and seven. The aim of this chapter is to measure the effects of the LRT system on house prices using the Kelana Jaya Line LRT system as a case study. The preliminary analysis that has been carried out in the preceding chapter has established the potential of the LRT system to capitalise on house prices within a two kilometre radius of its station. Therefore, the principal analysis needs to be carried out in order to identify the range and magnitude of the effects.

As has also been identified in the previous chapters, the existence of the LRT system in the Klang Valley has improved accessibility to and from the CBD. The improvement of accessibility can be translated into travel time savings. Hence, the trade-off between housing and travel time savings is expected to result in a negative rent gradient from an LRT station outwards. The discussion in Chapters four and five has identified that the hedonic house price model and GWR technique are appropriate tools in order to measure the range and magnitude of LRT effects on house prices in this study. As has also been noted in Chapter five, the spatial variation of LRT effects on house prices can be identified by employing GWR technique. The results from the hedonic house price model will be compared to the results from GWR.

This chapter is structured as follows. Section 8.2 presents the variable selection and statistical tests for hedonic house price models. There are several issues considered and possible approaches have been identified for the selection of variables. This section will conclude with the establishment of the final variables for the global model and the choice of suitable functional form for this study. Section 8.3 presents the findings of the effect of the LRT system on house prices using global and local models produced by the GWR 3.0 software. In trying to identify variation in the LRT effects on house prices, two possible models involving straight-line-distance and network-distance measures have been proposed. The results will be presented in table form, and t-values and parameters estimates from local models related to the proximity to an LRT station and various distances from the station will be depicted in map form. The effect of the LRT system on house prices is examined further in Section 8.4 by classifying the proximity to an LRT station into various catchment areas. Section 8.5 investigates the presence of local multicollinearity in the previous four models. Section 8.6 concludes the chapter by highlighting several important points of this principal analysis. To aid an understanding of the discussion, the process of conducting principal analysis is shown in Figure 8.1.

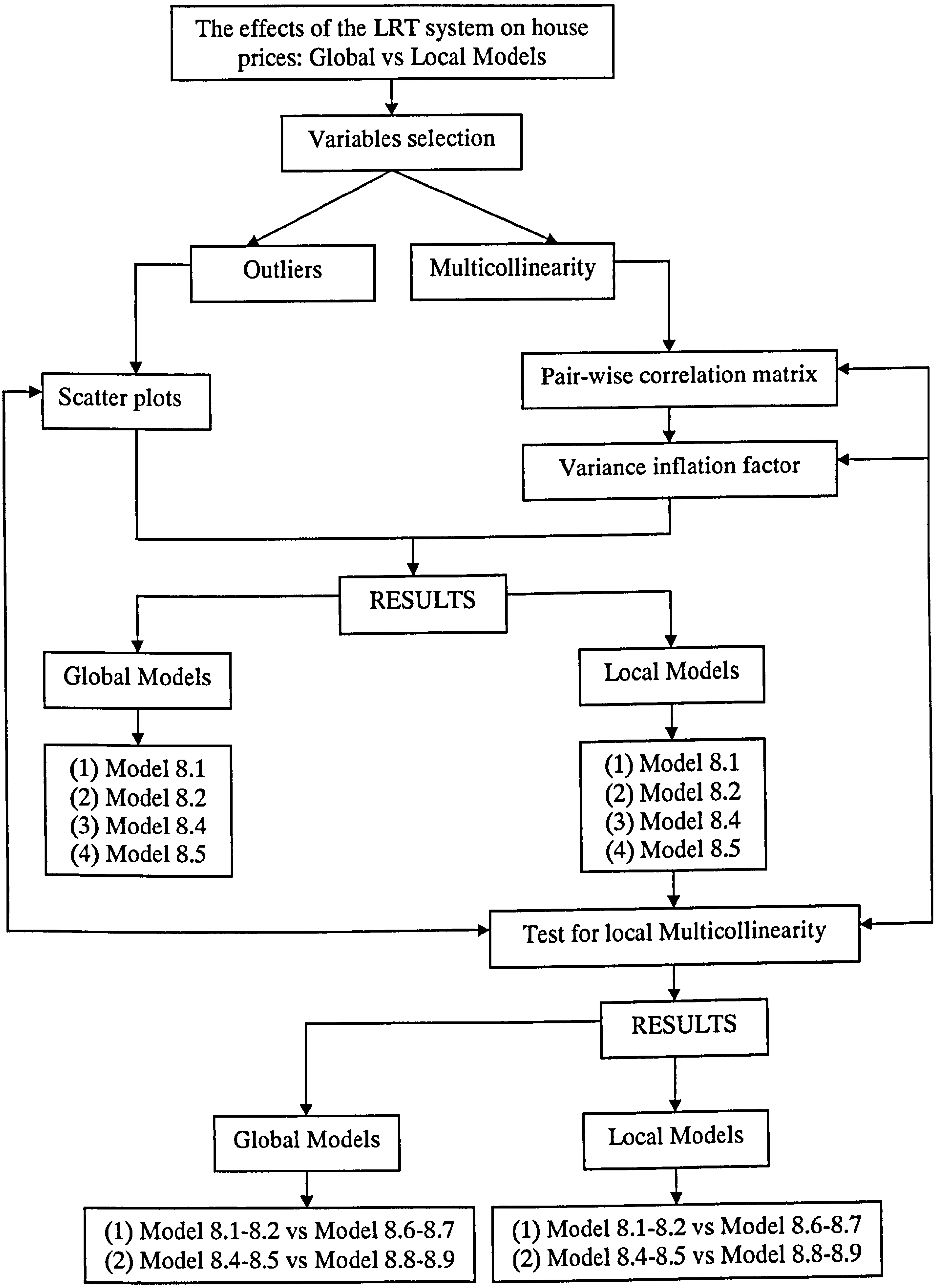



**Figure 8.1**: The process of conducting principal analysis

## 8.2. Variables Selection and Statistical Tests: Issues and Approach

The starting point for principal analysis using hedonic house price models is the recognition of several important issues that need to be addressed in selecting variables to be included in the final models. This is in relation to the five key assumptions of hedonic model as noted in Chapter four. Based on these assumptions, there are two major issues that need to be considered in selecting variables; outliers and multicollinearity.

In relation to this point, this section presents the main processes of variables selection including the statistical tests. These procedures are now discussed.

### 8.2.1 Outliers Issue

Outliers or an unusual observation is one of the problems of hedonic house price models. The presence of outliers may have an abnormal influence on the regression parameters. To detect potential outliers in the dataset, the common tests that have been suggested by the literature are scatter plots or box plots. In this study, the dependent variable (selling price) was plotted against each of the independent variables. The results from the scatter plots show that observations with the price MYR 2,500,000 and MYR 2,800,000 looked unusual in all the scatter plots. In total, four outliers were identified and were later removed from the dataset (see Appendix E). It should be noted that, these four outliers need to be romoved from the dataset since there are look unusual in all the scatter plots.

### 8.2.2. Multicollinearity issue

Another issue that always causes problems in hedonic house price models is multicollinearity. The literature has shown that the presence of multicollinearity between the independent variables can be detected by employing two statistical tests; pair-wise correlation matrix and Variance Inflation Factor (VIF). These tests can be performed by using the SPSS software for all the final variables.

The first test that was carried out in detecting multicollinearity in this study was to examine the correlation between a pair of independent variables. Studies have shown that the value of 0.8 indicated serious multicollinearity. The results of a high correlation between the pair of independent variables is summarised in Table 8.1, whereas the results of other final variables are shown in Table A8.1 of Appendix F.

**Table 8.1**: Results of highly correlated between pairs of independent variables

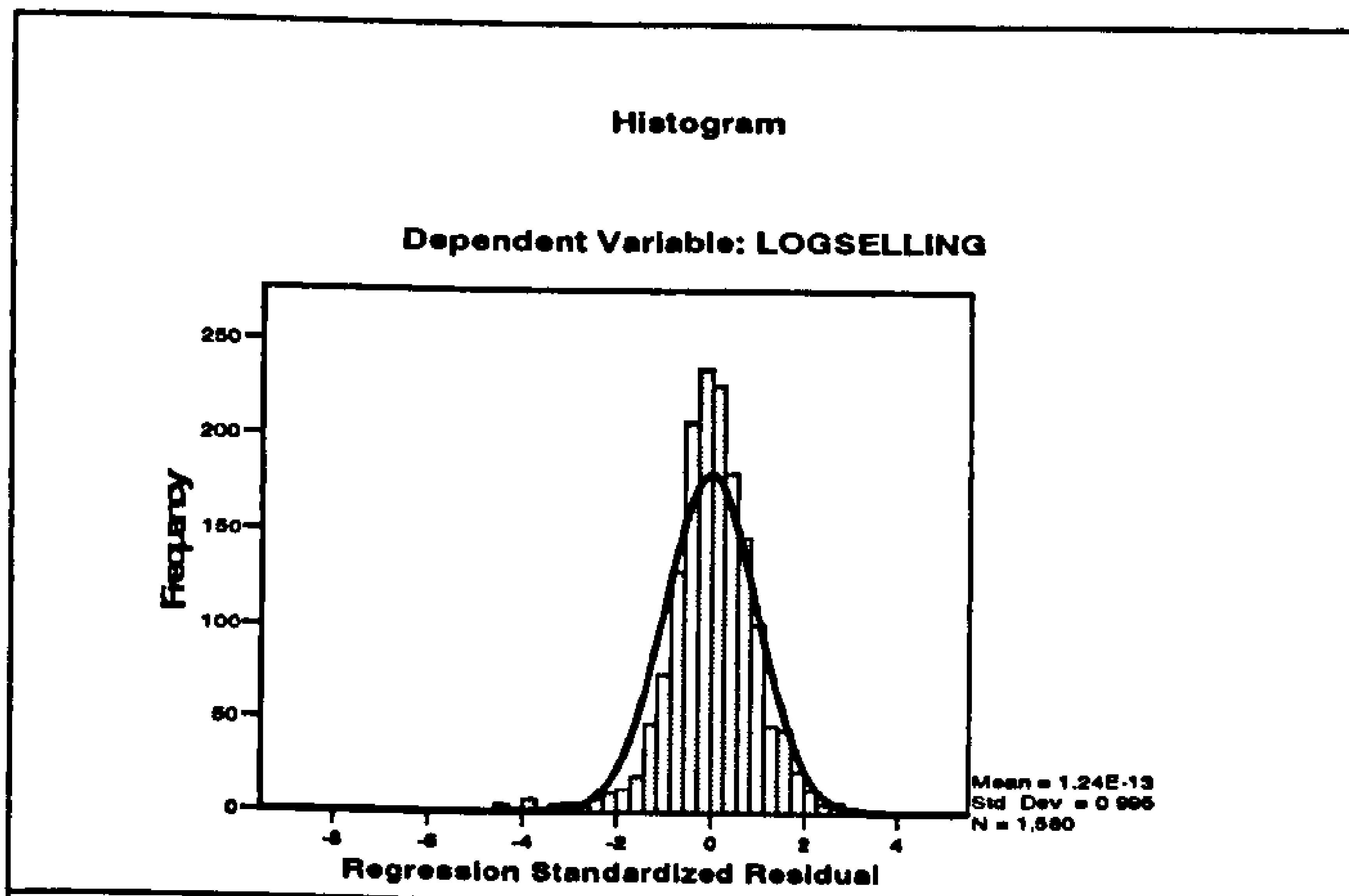
| Variable 1 | Variable 2 | Correlation coefficient |
|---|---|---|
| STRDIST | WALKDIST | 0.828 |
| BEDS | BATH | 0.946 |
| HIGHWAY | HOSPITALS | 0.845 |
| HIGHWAY | RECREATION | 0.862 |
| HIGHWAY | FOREST | 0.860 |
| RECREATION | FOREST | 0.806 |
| RECREATION | CHI | 0.863 |

Although the results from Table 8.1 above have shown that several independent variables are highly correlated, it is still difficult to determine which variable is causing the problem. Therefore, a step-wise regression approach was used by including all the independent variables. This approach suggested variables that are highly significant in explaining house price variation. If pairs of multicollinearity variables depicted above are included by this approach, then only variables with high significance would be chosen to remain in the final model. However, it has been argued by Whittingham et al. (2006) there are some limitations with stepwise regression; bias in parameter estimation, inconsistencies among model selection algorithms, an inherent (but often overlooked) problem of multiple hypothesis testing, and an inappropriate focus or reliance on a single best model. Although the stepwise regression has been frequently criticised by statisticians, it is still widely used in the literature. For instance, an examination of papers published in 2004 by three leeding ecological and behavioural journals suggested that the use of this method remains widespread; 57 per cent of 65 papers was used stepwise procedure in the studies (Whittingham et al. 2006). Yet, it has been argued by Thayer (2002) there are certain conditions when stepwise regression may have a valuable function. As Thayer argued further stepwise method can be appropriate for variable evaluation since the value of a variable as a predictor is highly specific to the other variables in the prediction model. Therefore, the use of stepwise methods can provide many reduced models in which the characteristics of the variable can be examined. Thayer also provided a guideline on how stepwise methods can be used effectively. Firstly, stepwise methods should be used in conjuction with a best subsets procedure and zero-order correlations. Secondly, default criterion values should be modified. Thirdly, models should not be selected by the computer and finally, models should be generated from multiple subsets of the data. In the context of this study, a guideline provided by Thayer is followed in order to carry out an anlysis.

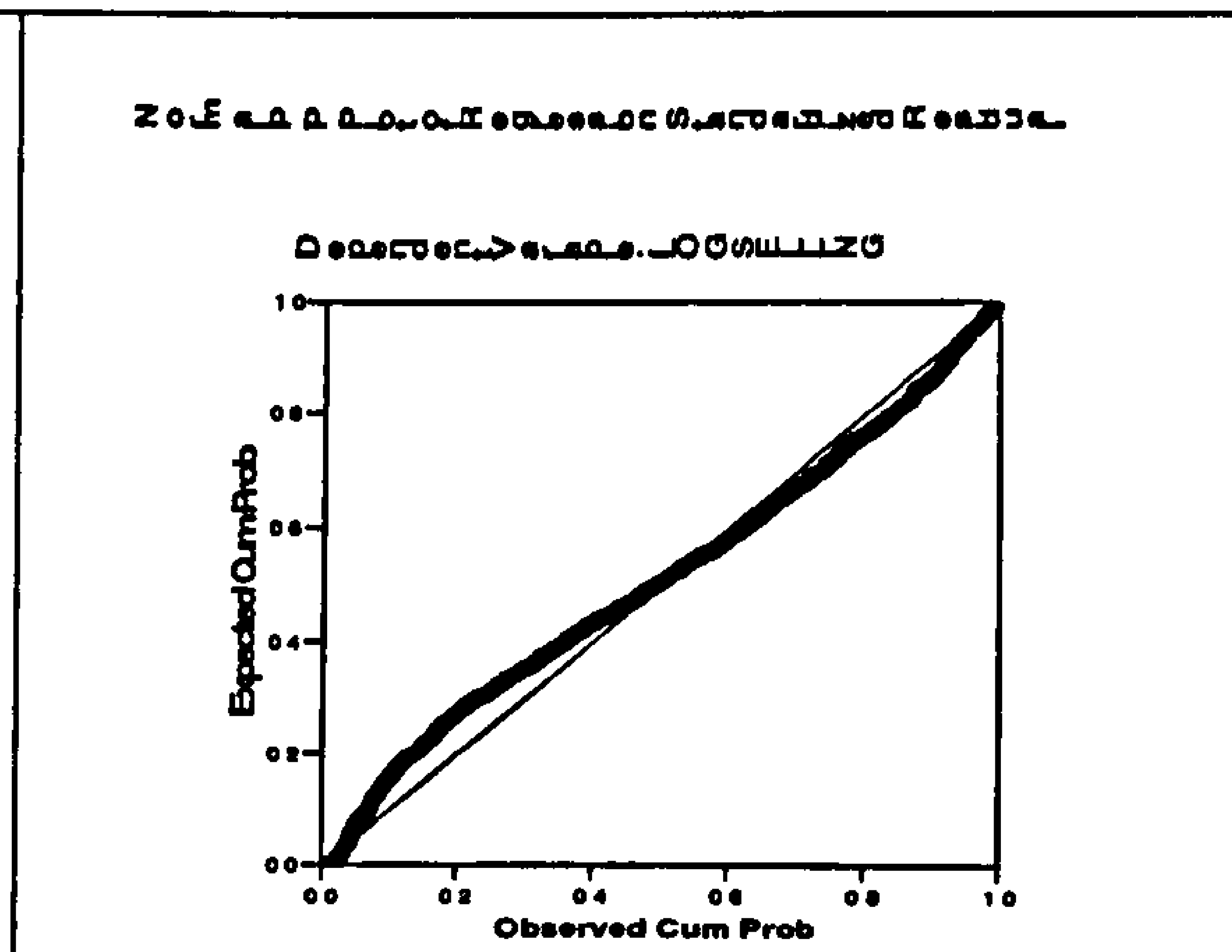
The second statistical test that can be used to detect the presence of multicollinearity is variance inflation factor (VIF). As mentioned in Chapter four, a VIF above ten indicates harmful collinearity. This implies that a VIF value of variables below ten, the least likely the model will suffer serious multicollinearity. The process of selecting variables to be included in the final model can also be assessed by identifying the significance of t-statistic for each variable. Studies have shown that a cut-off value of a t-statistic greater than 1.96 is considered significant and so those variables will remain in the final model. As has been noted earlier, four possible models have been proposed for the principal analysis in examining the variation of the LRT effect on house prices: general distance models (straight-line-distance vs. network-distance) and various specified distance (straight-line-distance vs. network-distance). Finally, note that the variables that were not significant at a 5 per cent level have been removed from the results of these two models.

### 8.2.3 Heteroscedasticity Issue

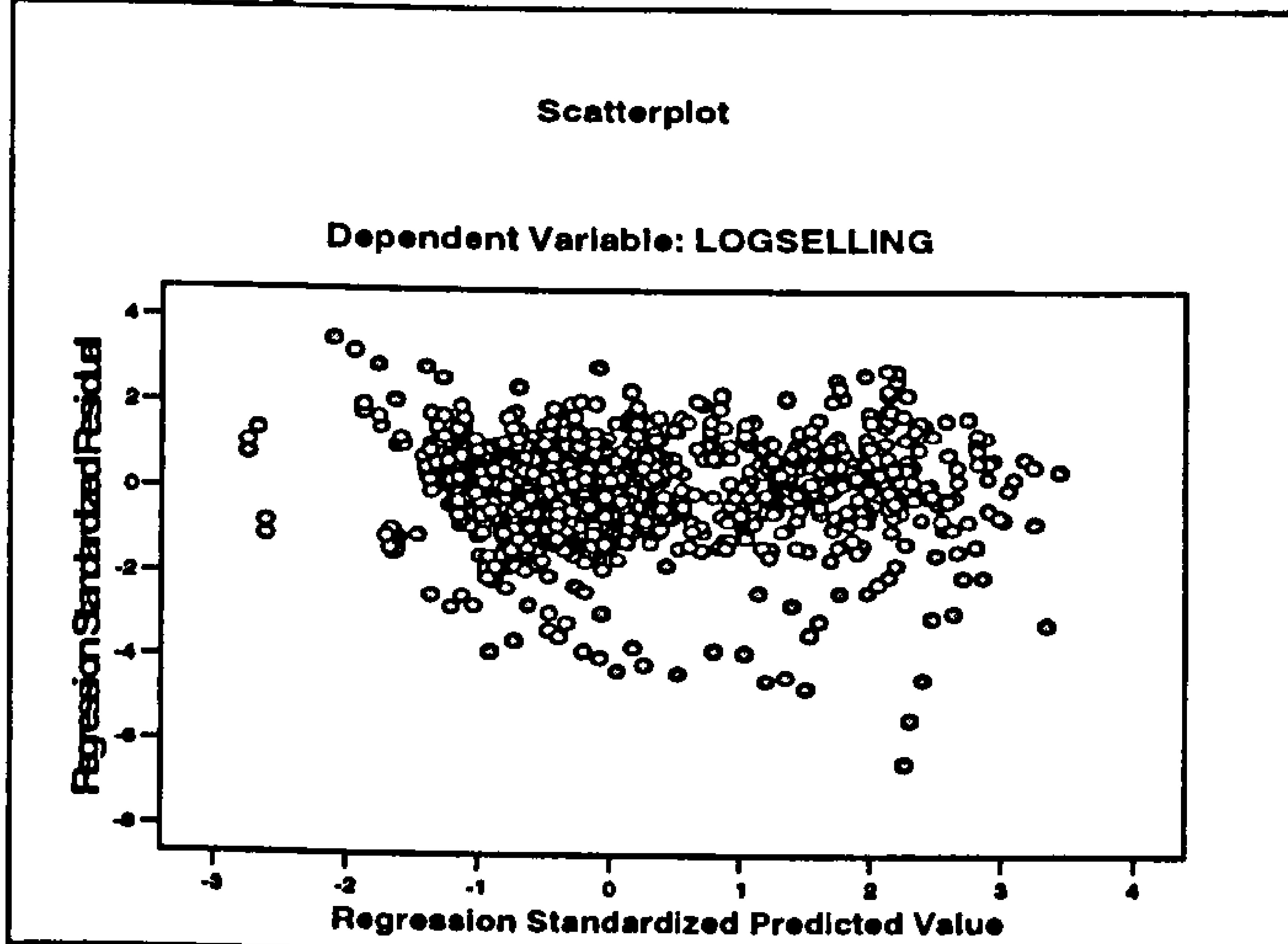
Heteroscedasticity is another problem of using OLS in estimating hedonic pricing model. The presence of heteroscedasticity was tested by performing visual examination of residuals in SPSS. In the context of this study, three examinations of residuals have been carried out in SPSS; histogram of residuals, normal probability plot of residuals and scatter plot of the standardised residuals. The result of this examination is presented in Figure 8.2. As mentioned earlier, if heteroscedasticity is present it is shown by the plot fans out in (or fan in) a funnel shape. The residuals are pretty much normally distributed (see Figure 8.2c). Although there is evidence of heteroscedasticity for the estimation since the residual plot slightly "fans out" but it is not harmful. Thus, the result of estimation using OLS is still robust and reliable.




(a) Histogram of residuals




(b) Normal probability plot of residuals




(c) Scatter plot of the standardised residuals

**Figure 8.2:** Three examinations of residuals for detecting heteroscedasticity; (a) Histogram of residuals (b) Normal probability plot of residuals (c) Scatter plot of the standardised residuals.

The results from the hedonic house price models are presented in standard format. This standard format is shown in Table 8.2. Note that the results from straight-line-distance and network-distance were separately displayed. As can be seen in Table 8.2, the results from the hedonic house price models include five attributes which represent the predictor, coefficient, standard error, t-value and VIF. The predictor is the variable that has been used to measure the house prices and it has included focused, structural, locational and socio-economic variables. The second column provides coefficients which represent the prices of each

**Table 8.2**: The traditional hedonic specification of Model 8.1 and Model 8.2

| Vector | Predictor | Straight-line distance (Model 8.1) | | | | Network distance (Model 8.2) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Coefficient | Standard error | t-value | VIF | Coefficient | Standard error | t-value | VIF |
| | Constant | 35667.67 | 1.74 | 18.85 | | 43739.2 | 1.76 | 18.89 | |
| Focus variables | *STRDIST* | -10.56 | 4.95 | -2.16 | 1.85 | | | | |
| | *NETDIST* | | | | | -6.61 | 3.03 | -2.31 | 1.70 |
| | *TIMESAVINGS* | 2019.25 | 296.16 | 6.82 | 3.27 | 2046.17 | 296.15 | 6.87 | 3.30 |
| Structural variables | *FLRAREA* | 310.63 | 13.09 | 24.07 | 6.23 | 312.65 | 13.09 | 23.99 | 6.35 |
| | *BEDS* | 31485.34 | 3922.05 | 8.01 | 1.87 | 31594.29 | 3922.04 | 8.06 | 1.87 |
| | *TYPTRRD* | 71160.14 | 9509.88 | 7.44 | 4.33 | 72143.93 | 9509.88 | 7.61 | 4.29 |
| | *TYPSEMID* | 139696.87 | 22626.95 | 6.19 | 1.40 | 138713.09 | 22626.95 | 6.15 | 1.40 |
| | *TYPDETCH* | 173145.42 | 17052.20 | 10.16 | 6.02 | 170849.93 | 17052.20 | 10.02 | 6.03 |
| | *TYPCONDO* | 184622.86 | 10165.74 | 18.23 | 3.02 | 184950.79 | 10165.73 | 18.25 | 3.03 |
| Locational variables | *CBD* | -17.96 | 1.52 | -11.75 | 3.18 | -18.61 | 1.55 | -11.92 | 3.33 |
| | *PRIMARYSCH* | 26.25 | 3.94 | 6.75 | 1.93 | 26.57 | 3.93 | 6.79 | 1.93 |
| | *SECONDARYSCH* | -11.11 | 4.66 | -2.40 | 1.41 | -11.11 | 4.66 | -2.36 | 1.41 |
| | *COMMERCIAL* | -10.13 | 3.28 | -3.17 | 2.41 | -9.54 | 3.28 | -2.94 | 2.50 |
| | *PARK* | -1.13 | 0.31 | -3.33 | 1.24 | -1.13 | 0.31 | -3.36 | 1.24 |
| | *HOSPITAL* | 3.40 | 1.29 | 2.64 | 3.27 | 3.58 | 1.28 | 2.73 | 3.32 |
| | *RECREATION* | -4.81 | 1.70 | -2.84 | 5.87 | -4.65 | 1.70 | -2.76 | 5.80 |
| | *INDUSTRY* | 28.22 | 3.72 | 7.74 | 1.70 | 26.91 | 3.71 | 7.23 | 1.80 |
| Socio-economic and ethnic variables | *MALAY* | 3673.45 | 613.52 | 5.99 | 7.61 | 3520.07 | 605.85 | 5.83 | 7.37 |
| | | $R^2$ (adj.) = 78.2 per cent | | | | $R^2$ (adj.) = 78.2 per cent | | | |

predictor used in the model. The standard errors of the coefficients are presented in the third column. The fourth column gives us the results of a t-value of the predictor. The greater t-value of the predictors implies that the greater its function in determining a house price. The multicollinearity level of the predictors used in the final model is shown in the final column, namely the variance inflation factor (VIF). Meanwhile, the adjusted $R^2$ for the number of variables in the model are shown below each model.

## 8.3 The Findings: Straight-line-distance vs. Network-distance

The discussion in Chapter four presents the traditional hedonic specification that has been identified as the basic model in the many studies surrounding house-price analysis. Based on the specification 4.12, a log-log specification is found to be the best functional form for hedonic specification in measuring the effect of the LRT system on house prices. A log-log specification is chosen for this study after comparing it with two other specifications (linear and semi-log specification). These are further discussed and reported here. It is worth noting that the best specification needs to be used since it needs to be calibrated with GWR 3.0 software. In order to identify the difference between perceived-distance to a station and actual-distance to a station, the following hedonic house price model is constructed. The model for straight-line-distance can be stated as:

$$\begin{aligned}\mathrm{LnP}_i = {} & \alpha_0 + \alpha_1\mathrm{LnSTRDISTi} + \alpha_2\mathrm{LnTIMESAVINGS}_i + \alpha_3\mathrm{LnFLRAREA}_i + \alpha_4\mathrm{LnBEDS}_i + \\ & \alpha_5\mathrm{TYPTRRDi} + \alpha_6\mathrm{TYPSEMID}_i + \alpha_7\mathrm{TYPDETCH}_i + \alpha_8\mathrm{TYPCONDO}_i + \alpha_9\mathrm{LnCBD}_i + \\ & \alpha_{10}\mathrm{LnCOMMERCIAL}_i + \alpha_{11}\mathrm{LnSECONDARYSCH}_i + \alpha_{12}\mathrm{LnPRIMARYSCH}_i + \\ & \alpha_{13}\mathrm{LnPARK}_i + \alpha_{14}\mathrm{LnRECREATION}_i + \alpha_{15}\mathrm{LnHOSPITAL}_i + \alpha_{16}\mathrm{LnINDUSTRY}_i + \\ & \alpha_{17}\mathrm{LnMALAY}_i + \varepsilon_i \qquad (8.1)\end{aligned}$$

where $i$ is the subscript denoting each property; $P_i$ is the price of property $i$ in Malaysia Ringgit (MYR); Ln is natural logarithm; STRDIST is the straight-line-distance from the property to an LRT station measured in metres; TIMESAVINGS denotes travel time savings to the CBD when people travel with the LRT system; FLRAREA is the floor area of the property in square foot; BEDS is the number of bedrooms of the property; TYPxxx is a set of dummy variables that illustrate the type of house which are further described as follows:

TYPTRRD is 1 if the property is terraced, 0 otherwise;
TYPSEMID is 1 if the property is semi-detached, 0 otherwise;
TYPDETACH is 1 if the property is detached, 0 otherwise;
TYPCONDO is 1 if the property is condominium, 0 otherwise.

CBD, COMMERCIAL, SECONDARYSCH, PRIMARYSCH, PARK, RECREATION, HOSPITAL, and INDUSTRY are the network-distance from the property to Kuala Lumpur city centre, commercial areas, secondary schools, primary schools, parks, recreational areas, hospitals and industrial areas respectively. These variables are all measured in metres. Finally, MALAY is the percentage of Malay ethnics at Mukim level; $\alpha$ denotes a parameter to be estimated; and $\varepsilon$ denotes standard error of the estimation.

Similarly, the model for network-distance can be stated as:

$$\begin{aligned} \mathrm{LnP}_i = {} & \alpha_0 + \alpha_1 \mathrm{LnNETDIST}_i + \alpha_2 \mathrm{LnTIMESAVINGS}_i + \alpha_3 \mathrm{LnFLRAREA}_i + \alpha_4 \mathrm{LnBEDS}_i + \\ & \alpha_5 \mathrm{TYPTRRDi} + \alpha_6 \mathrm{TYPSEMID}_i + \alpha_7 \mathrm{TYPDETCH}_i + \alpha_8 \mathrm{TYPCONDO}_i + \alpha_9 \mathrm{LnCBD}_i + \\ & \alpha_{10} \mathrm{LnCOMMERCIAL}_i + \alpha_{11} \mathrm{LnSECONDARYSCH}_i + \alpha_{12} \mathrm{LnPRIMARYSCH}_i + \\ & \alpha_{13} \mathrm{LnPARK}_i + \alpha_{14} \mathrm{LnRECREATION}_i + \alpha_{15} \mathrm{LnHOSPITAL}_i + \alpha_{16} \mathrm{LnINDUSTRY}_i + \\ & \alpha_{17} \mathrm{LnMALAY}_i + \varepsilon_i \end{aligned} \tag{8.2}$$

where the difference between perceived-distance to a station and actual-distance to a station is given by NETDIST: the network-distance from the property to an LRT station measured in metres.

As illustrated in the equation above, only variables with significance level of 0.01 and 0.05 and free from multicollinearity are included in the final models. In addition to this, we need to bear in mind that the above global specification has excluded considerations of the spatial heterogeneity of house prices by assuming the relationship between house prices and its determinants to be constant over space.

### 8.3.1. The Results of the Global Model

Table 8.2 presents the summary of the parameter estimates of Models 8.1 and 8.2 – the basic model for straight-line-distance and network-distance in measuring the effect of the LRT system on house prices. To reduce the complication of the interpretation process, continuous independent variables are deviated around their means. In other words, the models are estimated with respect to the average property size of 651.35 square feet. The results of both models show that most of predictor variables that have been used to estimate the LRT-house prices relationship produce correct signs (positive or negative) as theoretically expected, except for primary school and significance level of 0.01 and 0.05 level. Figures 8.3 and 8.4 show the magnitude of effect of focus, structural, locational and socio-economic as well as ethnic attributes on house price for the straight-line-distance model and network-distance model respectively.

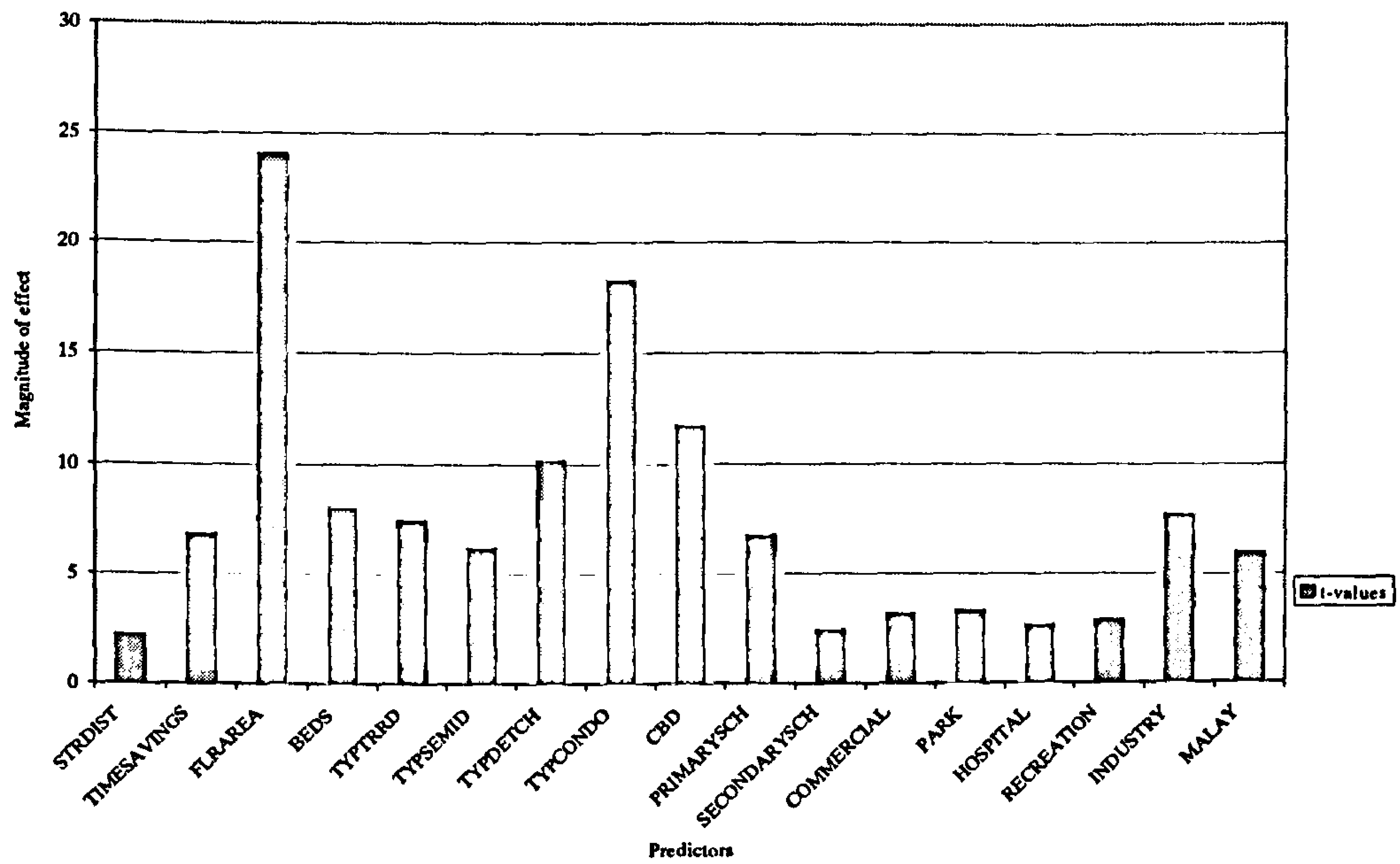



**Figure 8.3**: The magnitude of the effect of predictors on house price for straight-line-distance model

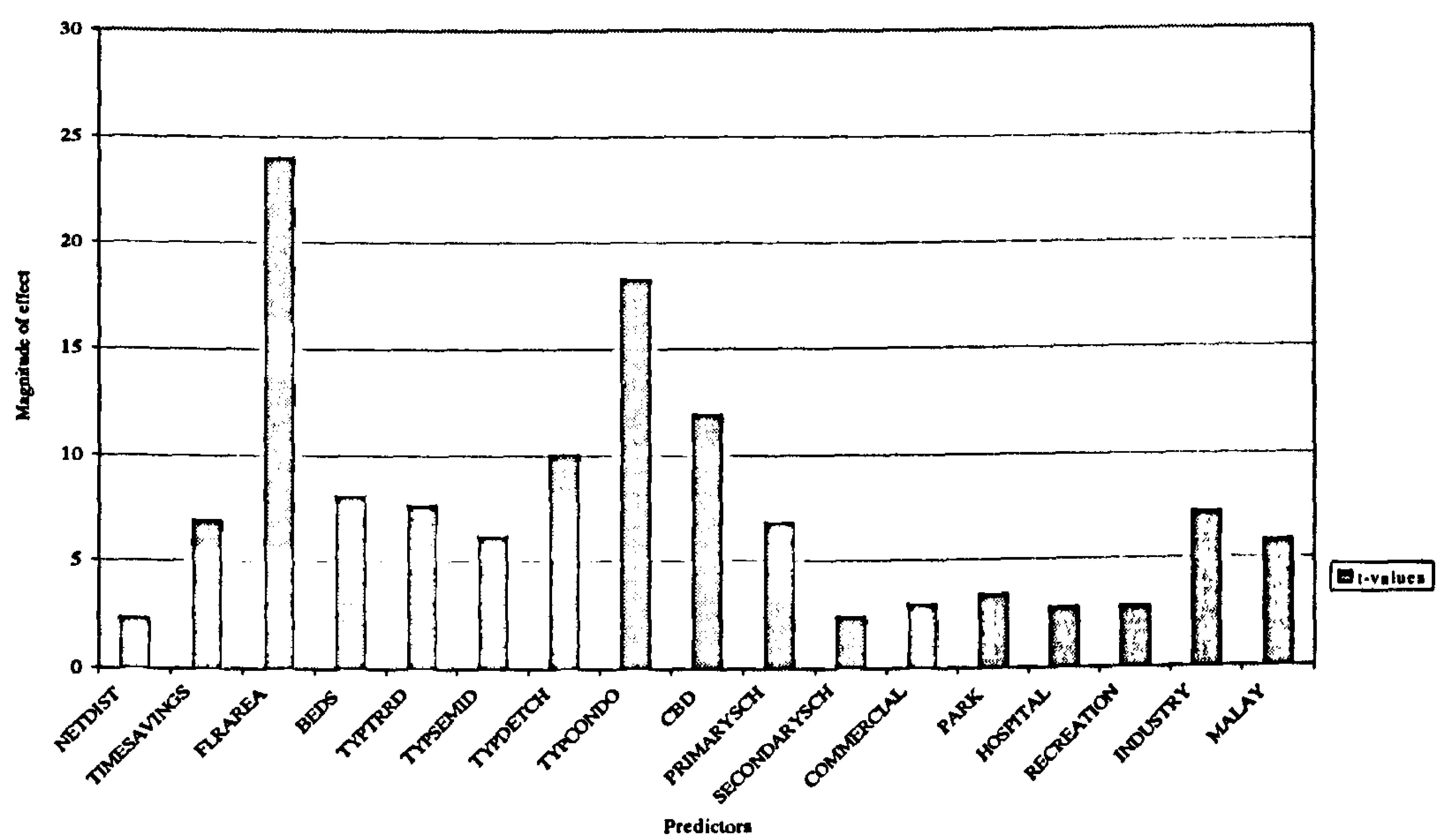



**Figure 8.4**: The magnitude of the effect of predictors on house price for network-distance model

In terms of the $R^2$ statistic, the model explains the variation of the house price within a two-kilometre radius from an LRT station in the Klang Valley reasonably well for both straight-line and network-distance model with 78.2 per cent, yet it still leaves 22 per cent of the variance in house prices unexplained. Having observed this, Fotheringham et al. (2002: pp. 36) argues that the unexplained variance in house prices is the result of 'assuming the relationship in the model to be constant over space'. The result of the global model also shows that the parameter estimates of several independent variables are found to be slightly different between these two models.

### 8.3.1.1 Value of the LRT system

An examination of Table 8.2 shows that the parameter estimates of focus variables are found to be statistically significant with the correct sign. Evidently, it can be seen that the house price decreases as we move further away from the LRT station – for every metre away from an LRT station, the value of a residential property decreases by MYR10.56 (straight-line-distance model) and by MYR6.61 (network-distance model) and this distance decay effect can be seen in Figure 8.5. This implies that a residential property located anywhere within 1,000 metres of an LRT station would generally be valued at an average rate between MYR10,560 (straight-line-distance model) and MYR6,610 (network-distance model) more than a residential property located outside of this distance. As for the magnitude of effect, the LRT system has significantly contributed at -2.16 (t-value of straight-line-distance) and -2.31 (t-value of network-distance) in determining house price in the study area. It is notable that the t-value of the parameter estimate from straight-line-distance measures is slightly higher than network-distance measures. In the case of travel time savings to the CBD by commuting with the LRT system, the results show on average, for every one minute saving to the CBD it brings about MYR2,019.25 (straight-line-distance model) and MYR2,046.17 (network-distance model) in terms of increment to house price.

Based on the above findings, several conclusions can be made in relation to the premium added to house prices due to the existence of the LRT system in the Klang Valley, Malaysia. Firstly, the straight-line-distance measures produce more positive effects on house prices than network-distance. Secondly, the results of this analysis have established the existence of distance decay relationship between house price and distance away from an LRT station. Finally, the improvement of accessibility to the CBD by commuting with the LRT system has really capitalised on house prices. Note that the basic estimation that has been implemented in this section will be expanded in subsequent sections by creating dummy variables for various specified distances of an LRT station. Next, the parameter estimates of other factors are discussed below according to vectors of independent variables; structural attributes, locational attributes and socio-economic and ethnic attributes.

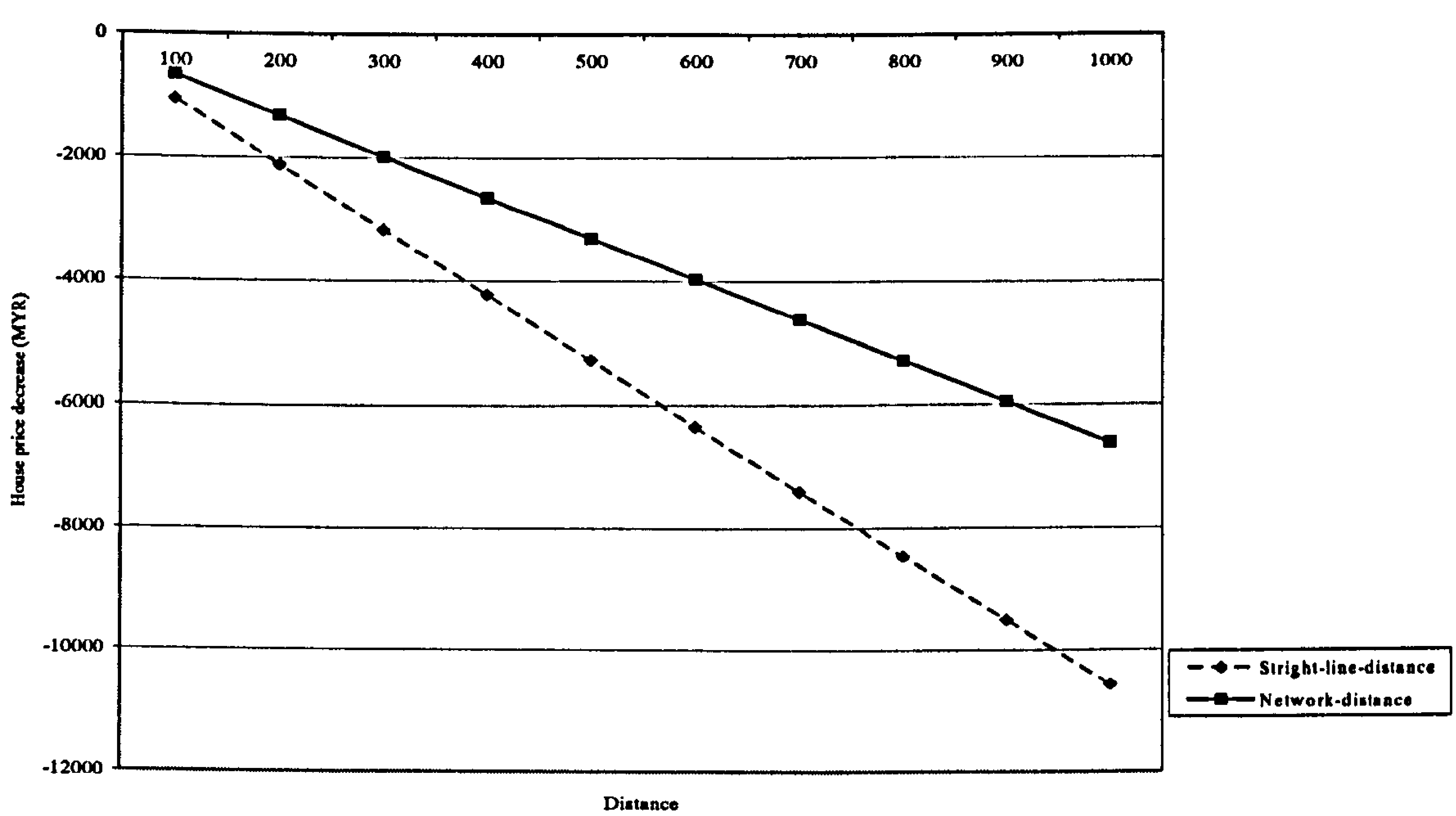



**Figure 8.5**: Average house price decrease for every 100 metres away from an LRT station

### 8.3.1.2 Value of structural attributes

The result of the estimation indicates that the most influential factor in determining the house price is floor area. For every square-foot increase in the floor area, the house price increases by an average of around MYR310.63 for straight-line-distance model. Similarly, around MYR312.65 an increase is deduced for network-distance model. The greater magnitude of the effect of floor area was expected since floor areas are always associated with the size of the property – this is consistent with most of the hedonic house price literature. In the case of number of bedrooms, a potential buyer has to pay on average MYR31,000 for one additional bedroom of a property for both models. As for property-type attribute, its role is only to indicate the price for different types of housing in the study area. As to be expected, the price for a detached or semi-detached house would be higher than a terraced house. After examining the results for both models, the conclusion that can be made is; there are significant differences in price between different types of housing. In other words, implicit prices of detached (MYR170,000), semi-detached (MYR139,000), condominium (MYR184,000) and terraced houses (MYR71,00) for both models should all have reflected some value-added by the attributes that they possess. In the case a condominium property, the explanation that could be given is; since a condominium property has various facilities such as swimming pool, sauna, club house, sport facilities, landscape and security, it can be expected that a condominium property has a positive effect on house price. The same thing can be expected from a detached property, since it stands exclusively on its own and normally it comes with a bigger plot of land with lower density – these attributes will definitely contribute to the positive effect on house price.

### 8.3.1.3 Value of locational attributes

The results of the estimation have also confirmed the importance of locational attributes in determining house prices. Distance from the CBD is significant with the correct sign of the estimated parameter for both models. The model suggests that a rent gradient for the Klang Valley of around MYR17.96 per metre for the straight-line-distance model and MYR18.61 per metre for the network-distance model. This can be interpreted as a distance decay relationship between land rent and the distance from the CBD. For every metre away from the CBD (Kuala Lumpur city centre), the property value decreases around MYR17.96 and MYR18.61 for straight-line and network-distance respectively.

The other locational attributes that also show significant contribution to the house price is proximity to commercial areas. The interpretation that can be made that for every metre away from the commercial areas, house price decreases at the rate of MYR10.15 (straight-line-distance model) and MYR9.54 (network-distance model). The parameter estimates for proximity to a secondary school also shows statistical significance with the anticipated sign. The implicit price for proximity to secondary schools suggests that for every metre away from secondary schools, house price would generally decrease by about MYR11 for both models. With regard to the proximity to primary schools, the result is statistically significant, but however, with unexpected signs. The model suggests that for every metre away from primary schools, there is a degree of increment in housing value. It clearly shows that on average, for every metre away from primary schools, the house price experiences an increase by about MYR26 for both straight-line and network-distance models. This supports the study on the impact of school on house prices carried out by Cheshire and Sheppard (2004).

The logical reason for the decreasing house value by being located too close to the primary schools is due to negative externalities such as noise and traffic congestion that can be associated with the existence of primary schools. The other possible reason is that house price would normally respond positively (increase) for being located in the neighbourhood where the school is regarded to perform well in major examinations (in practice most of the major examinations take place in secondary schools). In other words, the quality of schools assessed by its performance in major examinations is found to be more important than just being located near to an ordinary school. Thus, it is reasonable to expect house prices to increase for every metre away from primary schools after considering the explanation that has been given above.

Proximity to parks is also found to be statistically significant in determining house prices with the expected signs. The parameter estimates for proximity to parks is MYR1.13 per metre (rent gradient) for both models. Similarly, proximity to recreational areas is also found to be significant in determining house prices. For the proximity to recreational areas, the parameter estimates indicate that for every metre away from recreational areas, the house price reduces at the rate of MYR4 for both models. In terms of proximity to health centres for example hospitals, the parameter estimates suggest that house price increases by about MYR3 for straight-line and network-distance models of every metre away from this amenity.

Continuing the observation of the study, the price-distance function for proximity to industrial areas shows positive signs. The estimated parameter indicates that there is an increase in house price at the rate MYR28.22 (straight-line-distance model) and MYR26.91 (network-distance model) for every metre away from industrial areas. The rationale behind this observation is that being located adjacent to industrial areas suggests that residential property is prone to suffer from traffic congestion and air and noise pollution. Additionally, the norm of industry workers to populate surrounding areas close to factories for example, result in social problems and hence, brings the perceived value of properties in the area down. Therefore, it is very understandable at least in the context of this study (where house price increases for every metre away from industrial areas) since people tend to avoid negative externalities caused by the industry, the associated community and its activities.

#### 8.3.1.4 Value of socio-economic and ethnic attributes

The only significant factor of socio-economic and ethnic attributes in determining house prices in this study is the percentage of Malay ethnics. The model suggests that if a property is located in areas with a higher percentage of Malay ethnics, it would result in an increase in housing price of an average of MYR3,600 (straight-line-distance model) and MYR3,500 (network-distance model).

The independent variables that have been used to measure the price of the house (dependent variable) possess various units of measurements. Thus, it is difficult for us to compare the relative impact of each independent variable upon dependent variable. To overcome this problem, the standardised partial regression coefficient, $\beta_{standardised}$, is calculated for each independent variable by employing the following formula (Hess and Almeida, 2007):

$$B_{standardised} = [\beta_i * (std\ x_i)]/(std\ y) \qquad (8.3)$$

where, $\beta_i$ is the slop coefficient of an independent variable; std $x_i$ is the standard deviation of an independent variable; and std y is the standard deviation of the dependent variable.

Therefore, the partial regression coefficients are transformed to β-values in the above model by employing the following empirical relationship:

$$\text{PRICE} = \beta_0 - 0.02\ (\text{STR\_DIST}) + 0.04\ (\text{TIMESAVINGS}) + 0.73\ (\text{FLRAREA}) + 0.16\ (\text{BEDS}) + 0.03\ (\text{TYPTRRD}) + 0.04\ (\text{TYPSEMID}) + 0.18\ (\text{TYPDETCH}) + 0.37\ (\text{TYPCONDO}) - 0.03\ (\text{CBD}) - 0.13\ (\text{COMMERCIAL}) - 0.03\ (\text{SECONDARYSCH}) + 0.12\ (\text{PRIMARYSCH}) - 0.04\ (\text{PARK}) - 0.04\ (\text{RECREATION}) + 0.06\ (\text{HOSPITAL}) + 0.11\ (\text{INDUSTRY}) + 0.17\ (\text{MALAY})$$

$$\text{PRICE} = \beta_0 - 0.11\ (\text{NET\_DIST}) + 0.09\ (\text{TIMESAVINGS}) + 0.76\ (\text{FLRAREA}) + 0.16\ (\text{BEDS}) + 0.03\ (\text{TYPTRRD}) + 0.04\ (\text{TYPSEMID}) + 0.18\ (\text{TYPDETCH}) + 0.37\ (\text{TYPCONDO}) - 0.03\ (\text{CBD}) - 0.11\ (\text{COMMERCIAL}) - 0.02\ (\text{SECONDARYSCH}) + 0.11\ (\text{PRIMARYSCH}) - 0.05\ (\text{PARK}) - 0.08\ (\text{RECREATION}) + 0.01\ (\text{HOSPITAL}) + 0.09\ (\text{INDUSTRY}) + 0.14\ (\text{MALAY})$$

After standardising the unit of measurement for the independent variables to make them comparable, there are two variables that is size of the floor area (FLRAREA) and type of condominium (TYPCONDO) are more influencial than proximity of a house to an LRT station in predicting house prices.

It is important to note that the results of the global estimation discussed above have ignored the spatial heterogeneity of house prices by assuming the relationship between house prices and its determinants to be constant over space. In relation to this, the estimation may hide some very interesting and important local differences in the determinants of house prices. To account for this, Models 8.1 and 8.2 above were examined further by employing the local estimation (GWR model) to allow the spatial heterogeneity to be explicitly considered. The results of the local estimation will be discussed in the subsequent subsection.

## 8.3.2 The Results of GWR Model

The discussion in this subsection will focus on the interpretation of the results of GWR model. This dissection closely follows the strategy of interpreting the GWR results that have been set out in previous research incorporating GWR. The analysis using GWR software presents two diagnostic information; the information for global and local model – including general information on the model and an ANOVA (it can be used to tests the null hypothesis that the GWR model has no improvement over a global model). Tables 8.3 and 8.4 illustrate the diagnostic information of the GWR estimation for Models 8.1 and 8.2.

As illustrated in Tables 8.3 and 8.4 below, the adjusted $R^2$ has increased from 80.4 per cent and 80.7 per cent for both models in a global model to 88.0 per cent and 88.1 per cent for both models in the GWR model. After considering degrees of freedom, the conclusion that can be made is; the GWR model provides a better explanation of house price variation in this study. Therefore, the assumption that the GWR model has no improvement over a global model can be rejected. In addition, the reduction in the AIC from 281.739 and 251.309 for both models in a global model to -411.305 and -418.338 for both models in the GWR model suggests that the local model is better than a global model, after taking into account degrees of freedom.

**Table 8.3**: The results of GWR estimation for Model 8.1

| Global Model Estimation | |
|---|---|
| *Diagnostic information* | |
| Residual sum of squares | 119.66 |
| Effective number of parameters | 18.00 |
| Sigma | 27.80 |
| Akaike Information Criterion | 445.15 |
| Coefficient of determination | 78.40 |
| Adjusted $R^2$ | 78.20 |

| GWR estimation | |
|---|---|
| *Fitting geographically weighted regression model* | |
| Number of observations | 1580.00 |
| Number of independent variables (intercept is variable 1) | 18.00 |
| Number of locations to fit model | 1580.00 |
| | |
| *Diagnostic information* | |
| Residual sum of squares | 60.35 |
| Effective number of parameters | 118.93 |
| Sigma | 20.32 |
| Akaike Information Criterion | -415.17 |
| Coefficient of determination | 89.10 |
| Adjusted $R^2$ | 88.20 |

| Source | ANOVA | | | |
|---|---|---|---|---|
| | Sum of squares | Degrees of freedom | MS | F-value |
| OLS residuals | 119.70 | 18.00 | | |
| GWR improvement | 59.30 | 100.93 | 0.58 | |
| GWR residuals | 60.30 | 1461.07 | 0.04 | 14.22 |

**Table 8.4**: The results of GWR estimation for Model 8.2

| Global Estimation | |
|---|---|
| *Diagnostic information* | |
| Residual sum of squares | 119.61 |
| Effective number of parameters | 18.00 |
| Sigma | 27.67 |
| Akaike Information Criterion | 444.38 |
| Coefficient of determination | 78.40 |
| Adjusted $R^2$ | 78.20 |

| GWR Estimation | |
|---|---|
| *Fitting geographically weighted regression model* | |
| Number of observations | 1580.00 |
| Number of independent variables (intercept is variable 1) | 18.00 |
| Number of locations to fit model | 1580.00 |
| | |
| *Diagnostic information* | |
| Residual sum of squares | 61.18 |
| Effective number of parameters | 118.85 |
| Sigma | 20.29 |
| Akaike Information Criterion | -419.89 |
| Coefficient of determination | 89.10 |
| Adjusted $R^2$ | 88.20 |

| Source | *ANOVA* | | | |
|---|---|---|---|---|
| | Sum of squares | Degrees of freedom | MS | F-value |
| OLS residuals | 119.60 | 18.00 | | |
| GWR improvement | 59.40 | 100.85 | 0.5893 | |
| GWR residuals | 60.20 | 1461.15 | 0.0412 | 14.31 |

As has been shown in previous studies, the best possible way to interpret the results of GWR model is by visualising these local calibrations on a map. In relation to this point, Mennis (2006) and Du (2006) provide several guidelines on how to map GWR results in order to obtain meaningful interpretations of the results. The guidelines given by Mennis and Du can be simplified as follows: the spatial distribution of the parameter estimates must be presented by taking into account the distribution of local significance as indicated by t-values. The data range, including parameter estimates and t-values, is classified into classes of equal extent, an appropriate colour scheme that in turn gives a clear picture of local variation needs to be selected, and parameter estimates and t-values can be mapped in a single choropleth map in order to reduce the number of maps in the text.

The t-values and parameter estimates of predictors can be mapped by using Inverse Distance Weighted (IDW) interpolation that is available in ArcGIS software. Although the main focus of this study is to measure the effect of the LRT system on house prices, other variables that have also been used to determine house prices together with the LRT variables are mapped using ArcMap GIS software. To aid interpretation of the subsequent maps, the t-value of STRDIST, NETDIST, TIMESAVINGS, FLRAREA, BEDS, TYPTRRD, TYPSEMID, TYPDETCH, TYPCONDO, NETCBD, PRIMARYSCH, SECONDARYSCH, COMMERCIAL, PARK, HOSPITAL, RECREATION, INDUSTRY and MALAY are classified into four bands. The darkest areas indicate significant negative t-values while the lightest areas indicate significant positive t-values. To assist the readers with the place names mentioned in text, various housing estates regions that are included in the sample of this study is labelled on an overview map (See Figure 8.6 and Figure 8.7).

However, the areas between these two do indicate non-significant negative and positive t-values. It must be mentioned that a t-value of 2.0 is considered significant for the purpose of mapping after employing two-tailed alternative hypotheses (Du, 2006). Similarly in the subsequent maps, the parameter estimates are classified by five bands using coloured dots indicating negative and positive premium added to the house price in Malaysia Ringgit (MYR).

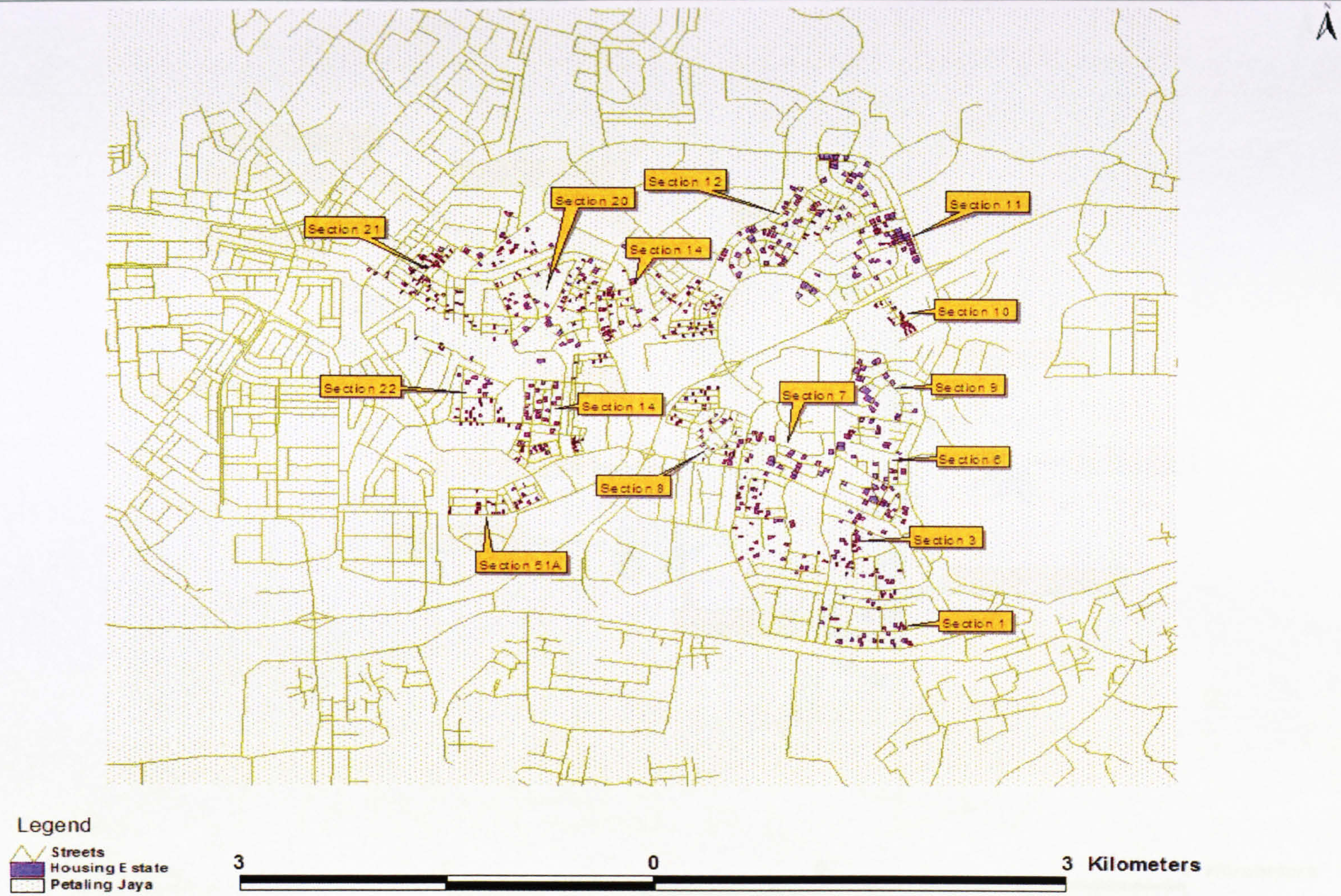



Figure 8.6: Housing estates of Petaling Jaya

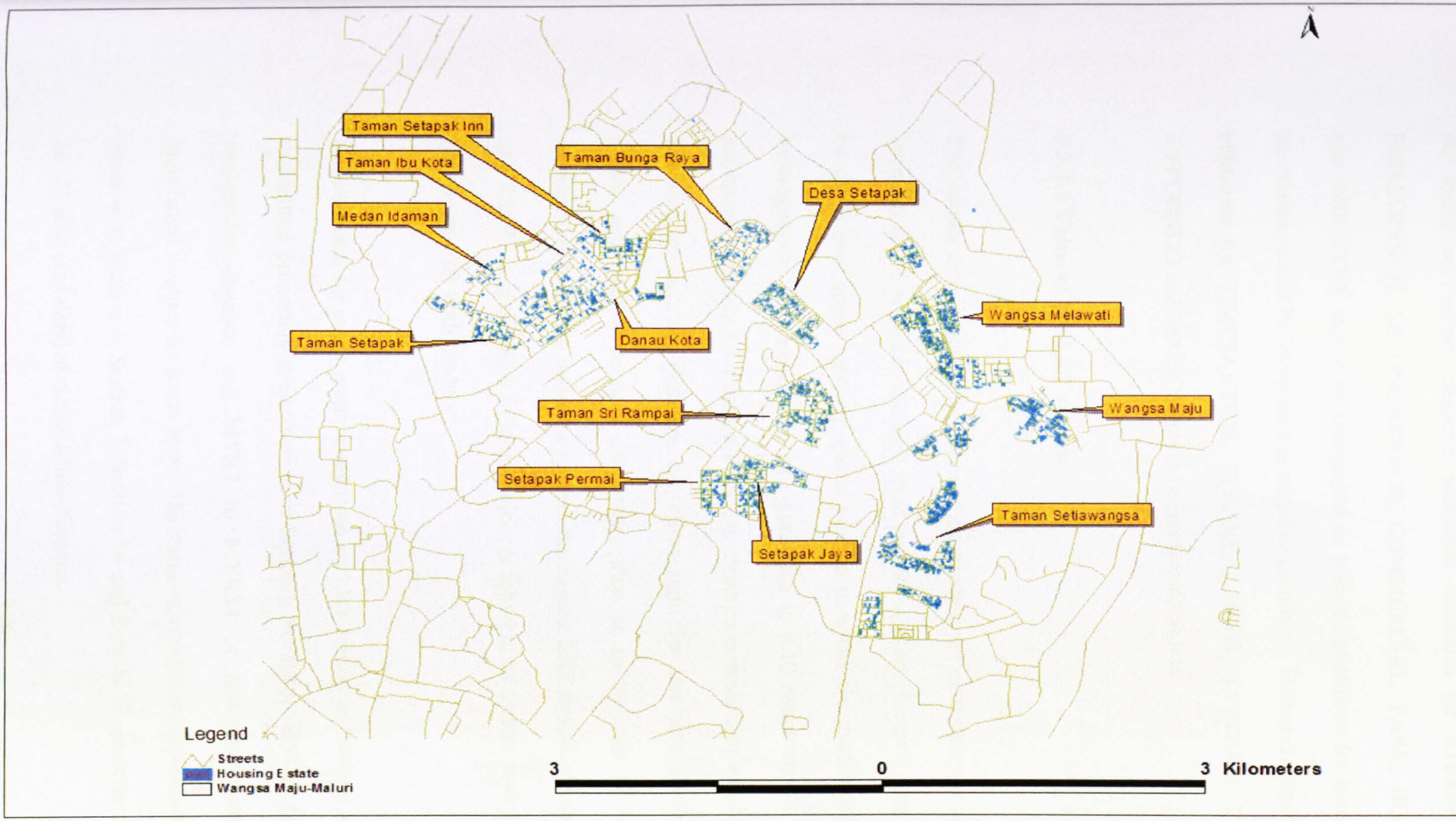



**Figure 8.7**: Housing estates of Wangsa Maju-Maluri

As mentioned earlier, negative parameter estimates for STRDIST, NETDIST NETCBD, PRIMARYSCH, SECONDARYSCH, COMMERCIAL, PARK, HOSPITAL, RECREATION and INDUSTRY should be interpreted as positive premiums for house prices, while a positive parameter should be interpreted as negative premiums. However, negative and positive parameter estimates for TIMESAVINGS, FLRAREA, BEDS, TYPTRRD, TYPSEMID, TYPDETCH, TYPCONDO and MALAY should be interpreted as it is.

#### 8.3.2.1 Value of the LRT system

The results from a global model have established the existence of a distance decay relationship between house price and distance from an LRT station. However, this relationship is assumed to be equal over space ignoring spatial process in which the relationship is said to exhibit spatial heterogeneity. An examination of Figures 8.8 to 8.10 below shows that both the t-values and estimated parameters for the LRT system variables considerably exhibit spatial heterogeneity that has been ignored by a global model. For straight-line and network-distance measures, the global model estimates a decrease of house price at an average of MYR10.56 and MYR6.61 respectively for every metre away from the nearest LRT station. As can be seen from Figures 8.8 and 8.9, the capitalisation in house prices is found to be greater than global models in some parts of the areas for both models.

For instance, for every metre away from an LRT station in Petaling Jaya, it reduces the value of residential properties at an average of between MYR3 to MYR23 (yellow and orange dots) of straight-line-distance and MYR7 to MYR23 of network-distance models with negative significant t-values for some areas. The value of some units of residential properties in Section 3, Section 4, Section 6, Section 7, Section 14 and Section 22 decrease even further that is MYR23 to MYR54 (red dots) of straight-line-distance.

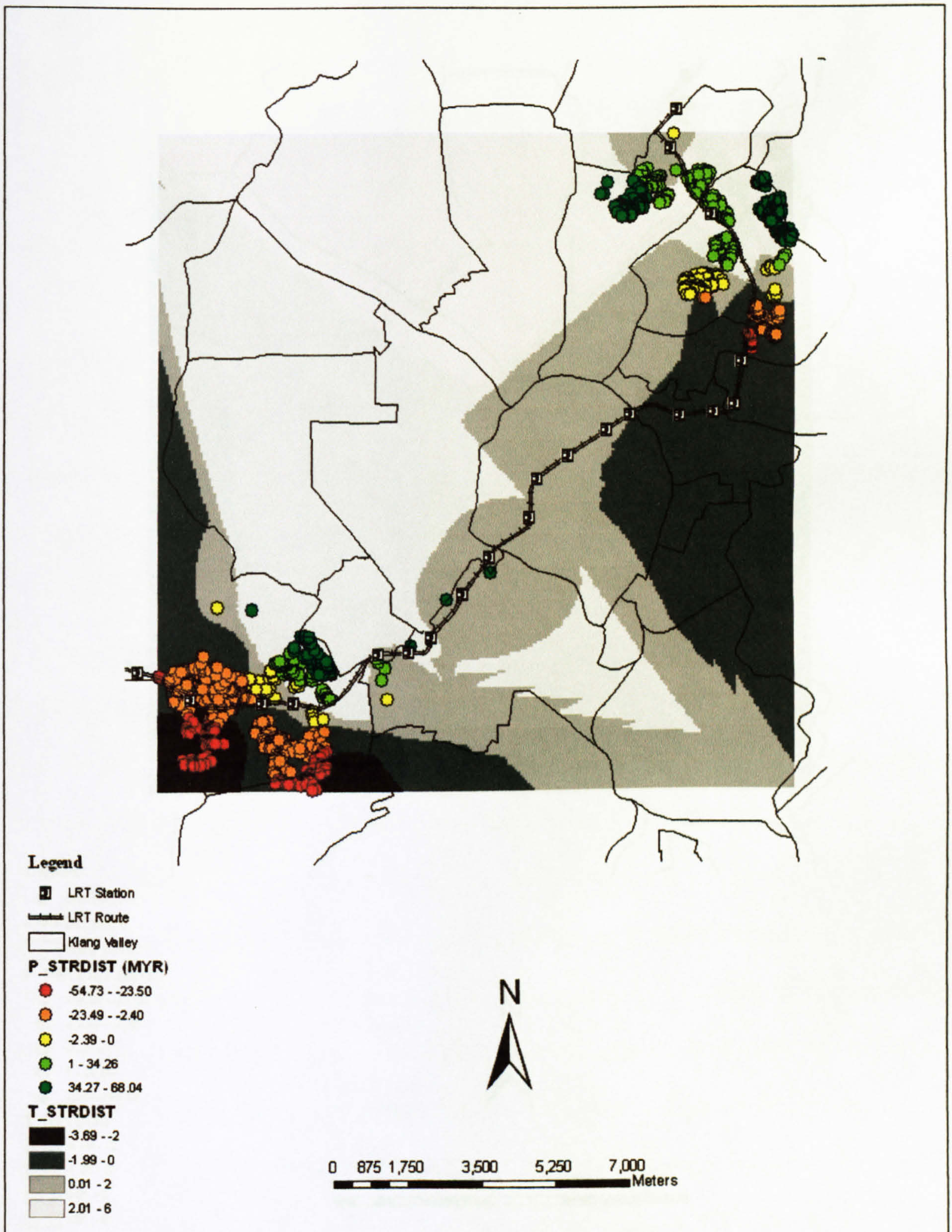



**Figure 8.8**: Map of t-values and parameter estimates associated with variable STRDIST

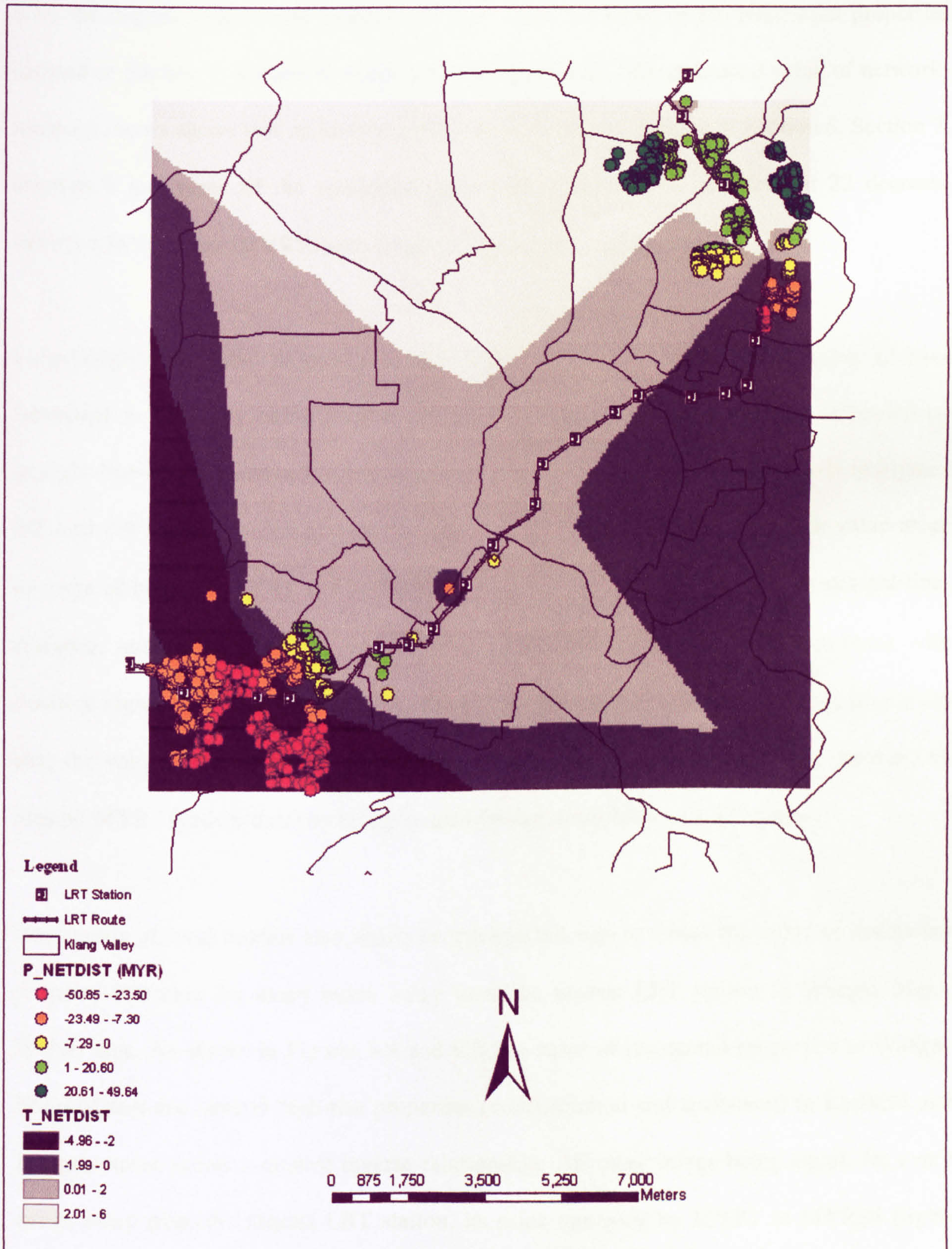



**Figure 8.9**: Map of t-values and parameter estimates associated with variable NETDIST

Yet, the negative significant t-values are only found for some of the residential properties located in Section 7, Section 8, Section 14 and Section 22. The estimated value of network-distance model shows that residential properties in Section 3, Section 4, Section 6, Section 7, Section 8 and some of the residential properties in Section 14 and section 22 decrease between MYR23 and MYR50 with negative significant t-values (red dots).

Surprisingly, residential properties located in Section 10, Section 11 and Section 12 have increased in value by being located further away from an LRT station as estimated by straight-line-distance and network-distance models. For instance, as can be seen from Figures 8.8 and 8.9 above, residential properties located in these sections increases in value at an average of between MYR1 and MYR68 (light-green and dark-green dots) for straight-line-distance, and between MYR1 and MYR20 (light-green dots) for network-distance with positive significant t-values. However, the estimation results of network-distance also show that the values of some of the residential properties located in these sections decrease by around MYR7 (yellow dots) by being located further away from an LRT station.

The results of local models also shows an unexpected sign in which the value of residential property increases for every metre away from the nearest LRT station in Wangsa Maju-Maluri area. As shown in Figures 8.8 and 8.9, the value of residential properties in Wangsa Maju-Maluri and several high-rise properties (condominium and apartment) in Kerinchi and Bangsar areas shows a modest inverse relationship. All other things being equal, for every metre away from the nearest LRT station, its price increases by MYR1 to MYR34 (light-green dots) for straight-line-distance and MYR1 to MYR20 for network-distance. House price increase is even greater in Taman Desa Setapak and Wangsa Melawati housing estates

– MYR34 to MYR68 of straight-line-distance and MYR20 to MYR49 of network-distance for every metre away from the nearest LRT station (dark-green dots).

The positive house price premium is only observed in Taman Setiawangsa with decreases of between MYR2 and MYR54 for straight-line-distance and MYR7 and MYR50 for network-distance (orange and red dots). The positive house price premium can also be found for those properties located in Taman Setapak Permai, Taman Sri Rampai, Pantai Hill Park apartment, Bangsar Permai apartment and Suasana Sentral condominium, with decreases up to MYR3 (yellow dots) of straight-line-distance and MYR7 of network-distance for every metre away from the nearest LRT station. Although the positive house price premium is found in these housing estates, the t-value appears to be insignificant (see Figures 8.8 and 8.9 above). It is clear that the positive relationship between the LRT system and house prices exists in some parts of the areas, whilst other areas are yet to be affected by the LRT system – this spatial variation has been completely ignored by a global model.

In the case of travel time savings to the CBD by commuting with the LRT system, the results of the global model have shown that on average, for every one minute saved travelling to the CBD, it brings about MYR2,019.25 (straight-line-distance model) and MYR2,046.17 (network-distance model) to the house price. However, this positive house price premium has been applied for the entire area. The spatial variation associated with the TIMESAVINGS variable can be seen by plotting the results of t-values and parameter estimates of GWR models on a map (see Figure 8.10 below). The map of t-values and parameter estimates show that some houses in Section 3, Section 4, Section 7, Section 8, Section 12, Section 14, Section 20, Section 51A and Section 52 of Petaling Jaya and Wangsa Melawati, Taman Setapak Jaya and Taman Sri Rampai of Wangsa Maju-Maluri, yield a positive house price

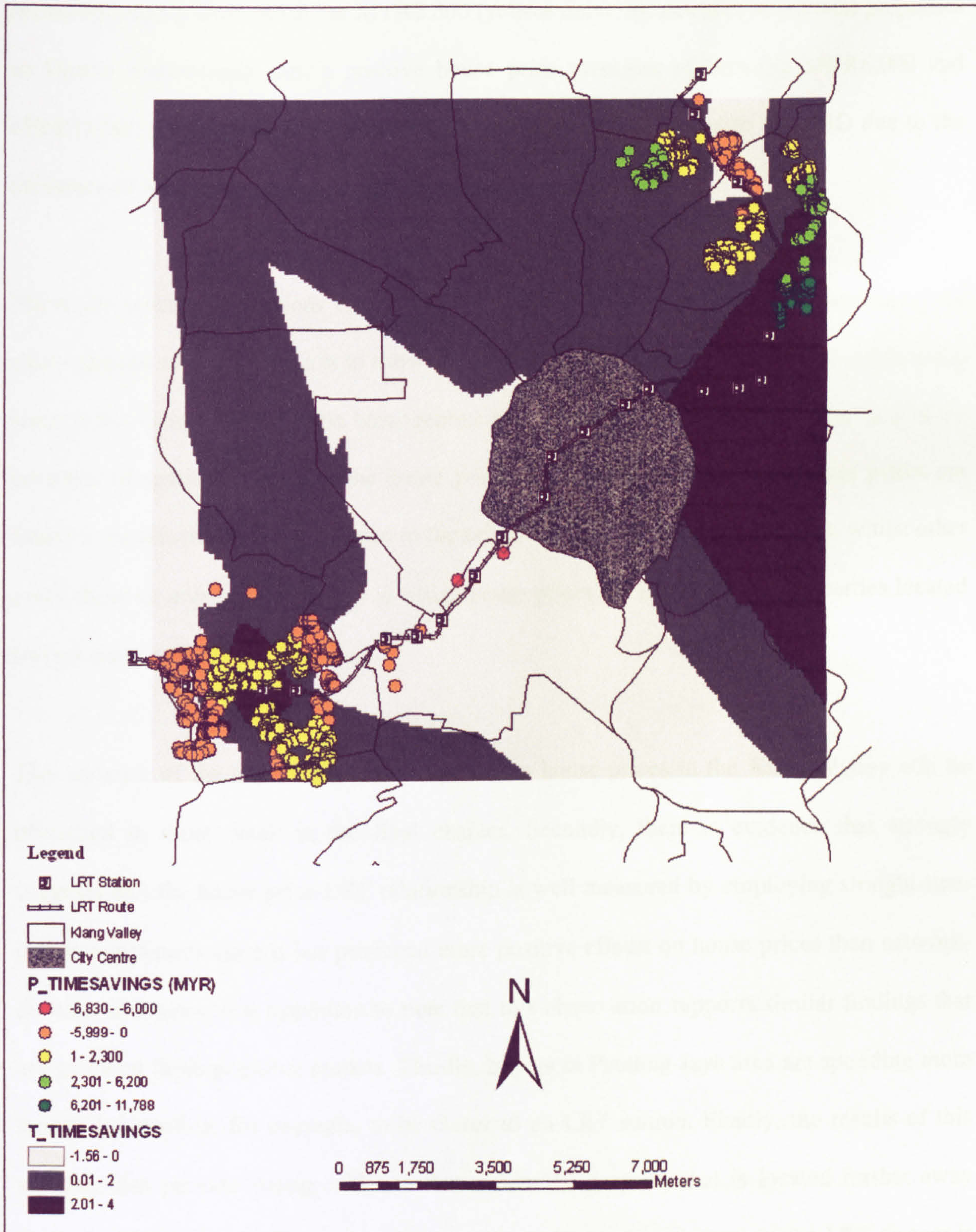



**Figure 8.10**: Map of t-values and parameter estimates associated with variable TIMESAVINGS

premium ranging from MYR1 to MYR2,300 (yellow dots). Meanwhile, residential properties in Taman Setiawangsa gain a positive house price premium of between MYR6,000 and MYR11,000 (dark-green dots) for every one minute saved travelling to the CBD due to the existence of the LRT system with significant t-values (black area).

There are several conclusions emerging from these findings. As mentioned previously, the main purpose of this analysis is to show spatial variation in the house price-LRT relationship since it has been assumed to be homogenous over space by a global model. The first is the presence of spatial variation in the house price-LRT relationship to which house prices are found to be affected by being located to the nearest to LRT station in some areas, whilst other areas show an inverse relationship in which house prices are higher for the properties located further away from an LRT station.

The variance of the effect of the LRT system on house prices in the Klang Valley will be discussed in more detail in the final chapter. Secondly, there is evidence that strongly suggests that the house price-LRT relationship is well measured by employing straight-line-distance measures since it has produced more positive effects on house prices than network-distance measures. It is important to note that this observation supports similar findings that are gathered through global models. Thirdly, buyers in Petaling Jaya area are spending more money on location, for example, to be closer to an LRT station. Finally, the results of this analysis also provide strong evidence that residential property that is located further away from the CBD and experiences travel time savings due to the existence of the LRT system is capitalised in a positive premium house price in some areas. This suggests that the introduction of the LRT system in the Klang Valley has brought about benefits to households by reducing travel-time to the CBD. Therefore, this leads to capitalisation of these values to the housing units located nearest to the LRT stations.

#### 8.3.2.2 Value of Structural Attributes

In a global model, the value of floor area is estimated at an average of MYR300 per square foot for both straight-line and network-distance models. However, the local model illustrates how the implicit price of floor area varies from one place to another (see Figure 8.11). For instance, the implicit price of floor areas in Wangsa Maju-Maluri is estimated to be between MYR300 and MYR540 per square foot (yellow and light-green dots), with positive significant t-values.

For some housing estates in Wangsa Maju-Maluri such as Taman Setiawangsa, Wangsa Maju Section 5, Taman Setapak Jaya and Taman Sri Rampai, the implicit price of floor area is even greater that is estimated to be between MYR540 to MYR670 per square foot (dark green dots). A higher implicit price of floor area is also estimated for several high-rise properties located in Bangsar and Kerinchi areas. For instance, the price of floor area for high-rise properties in these two areas is estimated to be between MYR450 and MYR670 per square foot (light-green and dark green dots). Meanwhile, in the Petaling Jaya area, the implicit price of floor area is estimated at a much cheaper rate compared to the previously mentioned areas. For instance, the implicit price of floor area is estimated to be between MYR16 and MYR300 per square foot (red and orange dots). A slightly higher implicit price of floor area is estimated for houses located in Section 3, Section 4, Section 6 and Section 7; in these areas floor area is estimated between MYR300 and MYR450 per square foot (yellow dots).

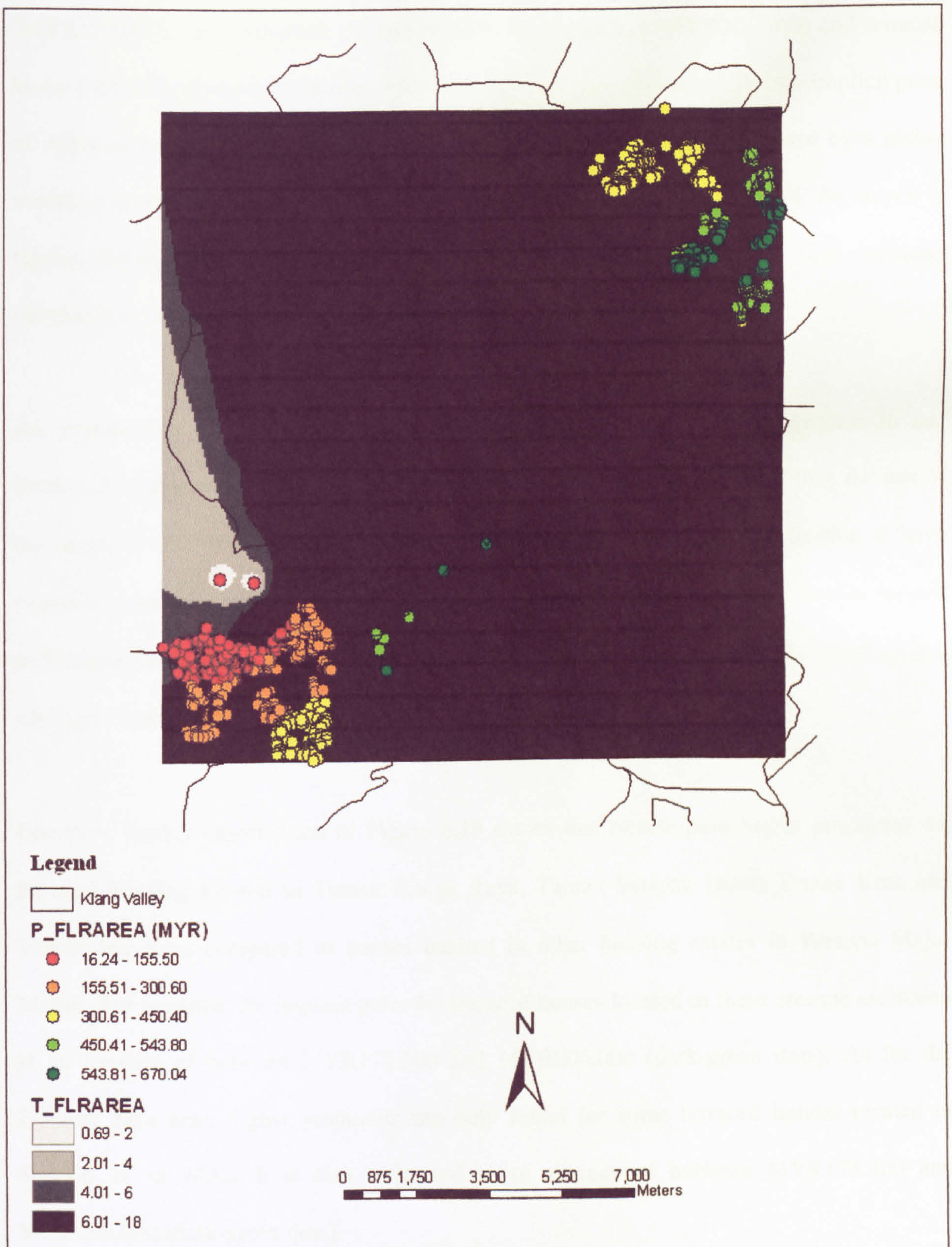



**Figure 8.11**: Map of t-values and parameter estimates associated with variable FLRAREA

Globally, the implicit price of different housing types is estimated as follows; detached (MYR170,000), semi-detached (MYR139,000), condominium (MYR184,000) and terraced house (MYR71,00) for both models. However, the local model reveals how the implicit price of different housing types that have been estimated to be constant over space by a global model in fact vary between locations – this can be seen in Figures 8.12-8.14. As shown in figures below, detached and semi-detached housing still commands a high premium compared to terraced housing and high-rise property.

An examination of Figure 8.12 shows that detached housing located in Section 20 and Section 21 (dark-green dots) have higher premiums with significant t-values than the rest of the areas, whilst detached housing located in Section 3, Section 4 and Section 6 have negative premiums which is very surprising. In the case of terraced housing, houses located in Wangsa Maju-Maluri are more expensive compared to houses located in the Petaling Jaya area (see Figure 8.13).

However, further examination of Figure 8.13 shows that buyers paid higher premiums for terraced housing located in Taman Bunga Raya, Taman Setapak Indah, Danau Kota and Taman Ibu Kota compared to houses located in other housing estates in Wangsa Maju-Maluri. For instance, the implicit price for terraced houses located in these areas is estimated at an average of between MYR173,500 and MYR206,000 (dark-green dots). As for the Petaling Jaya area, higher premiums are only found for some terraced houses located in Section 21 in which it is also estimated at an average of between MYR173,500 and MYR206,000 (dark-green dots).

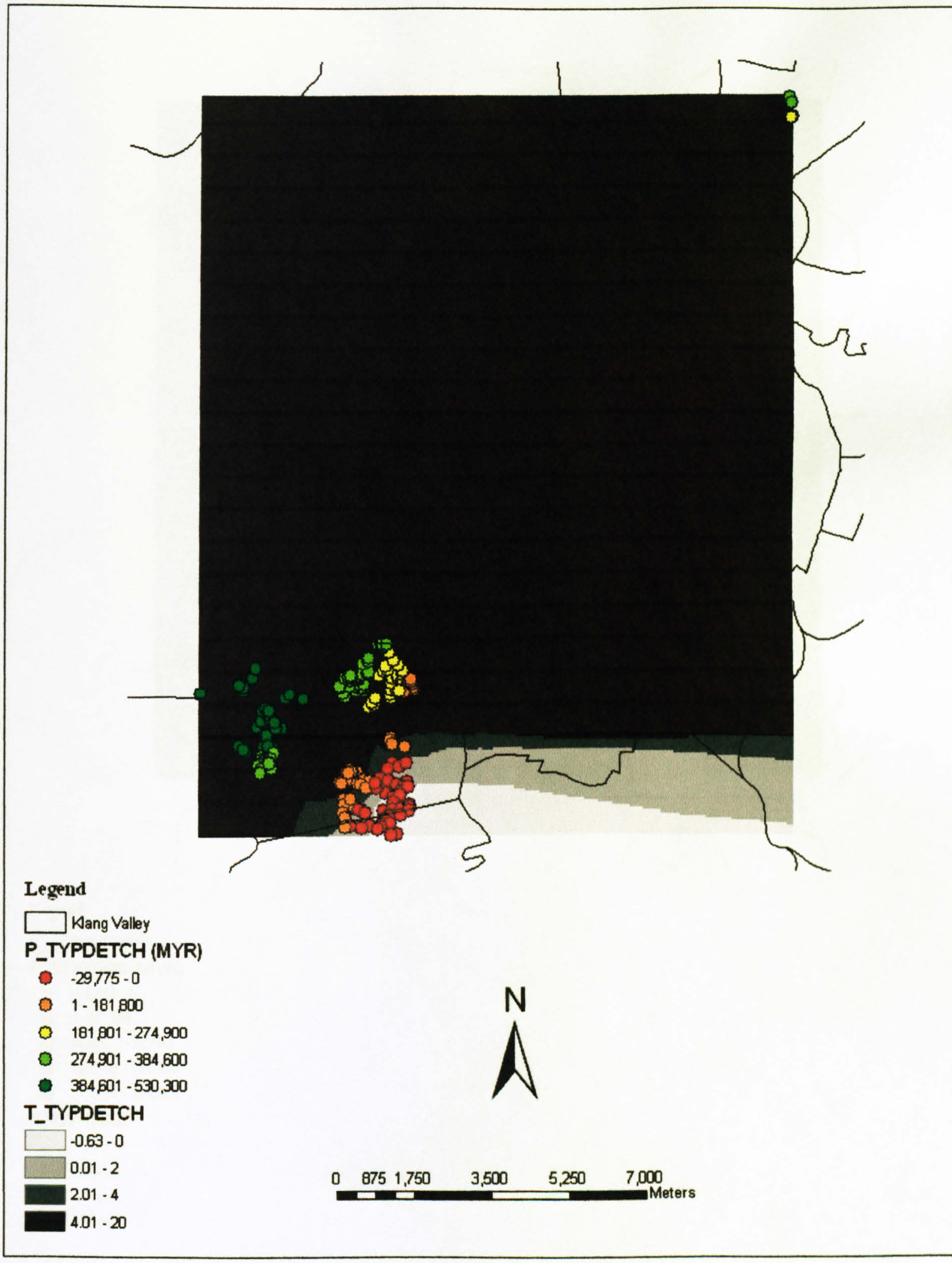



**Figure 8.12**: Map of t-values and parameter estimates associated with variable TYPDETCH

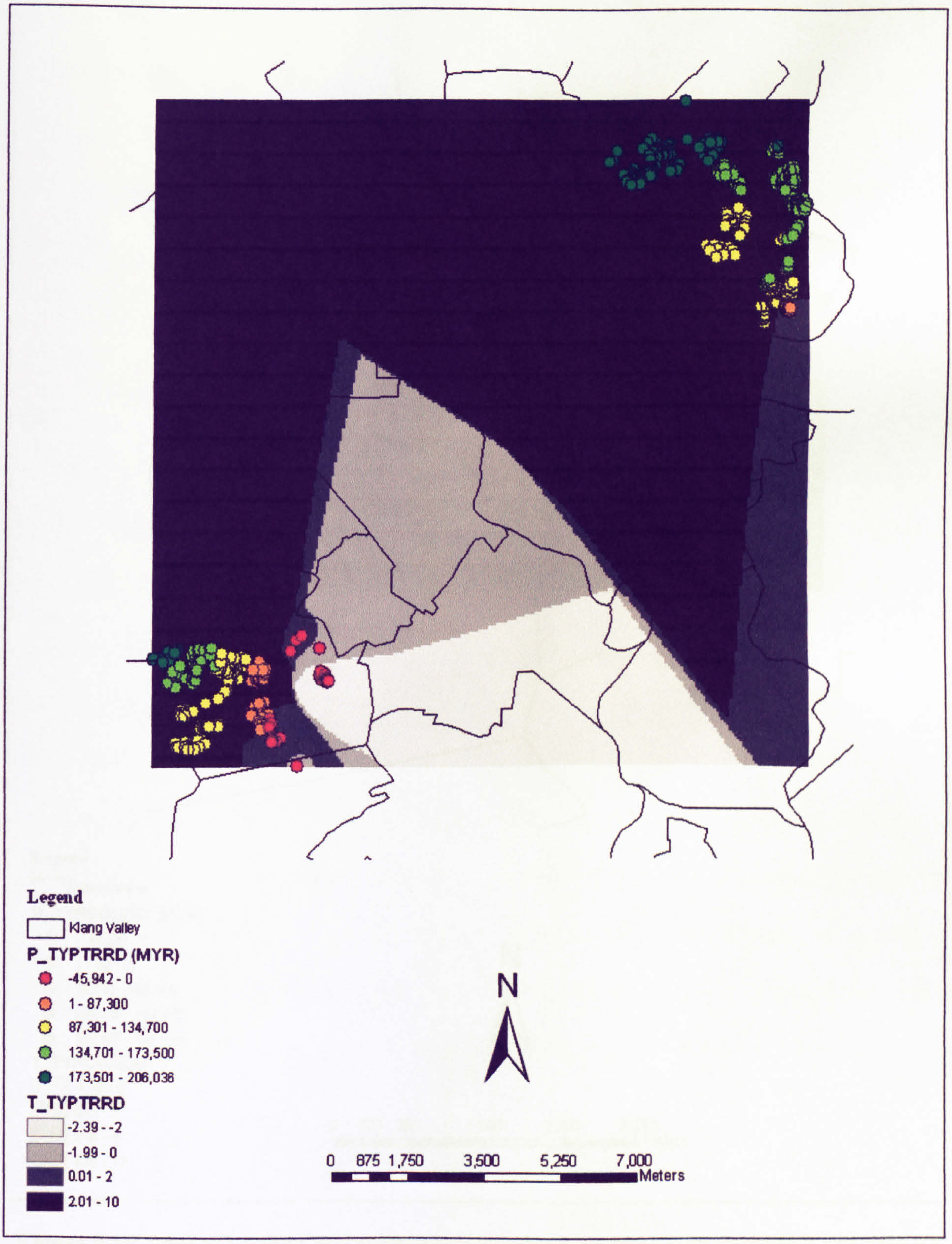



**Figure 8.13**: Map of t-values and parameter estimates associated with variable TYPTRRD

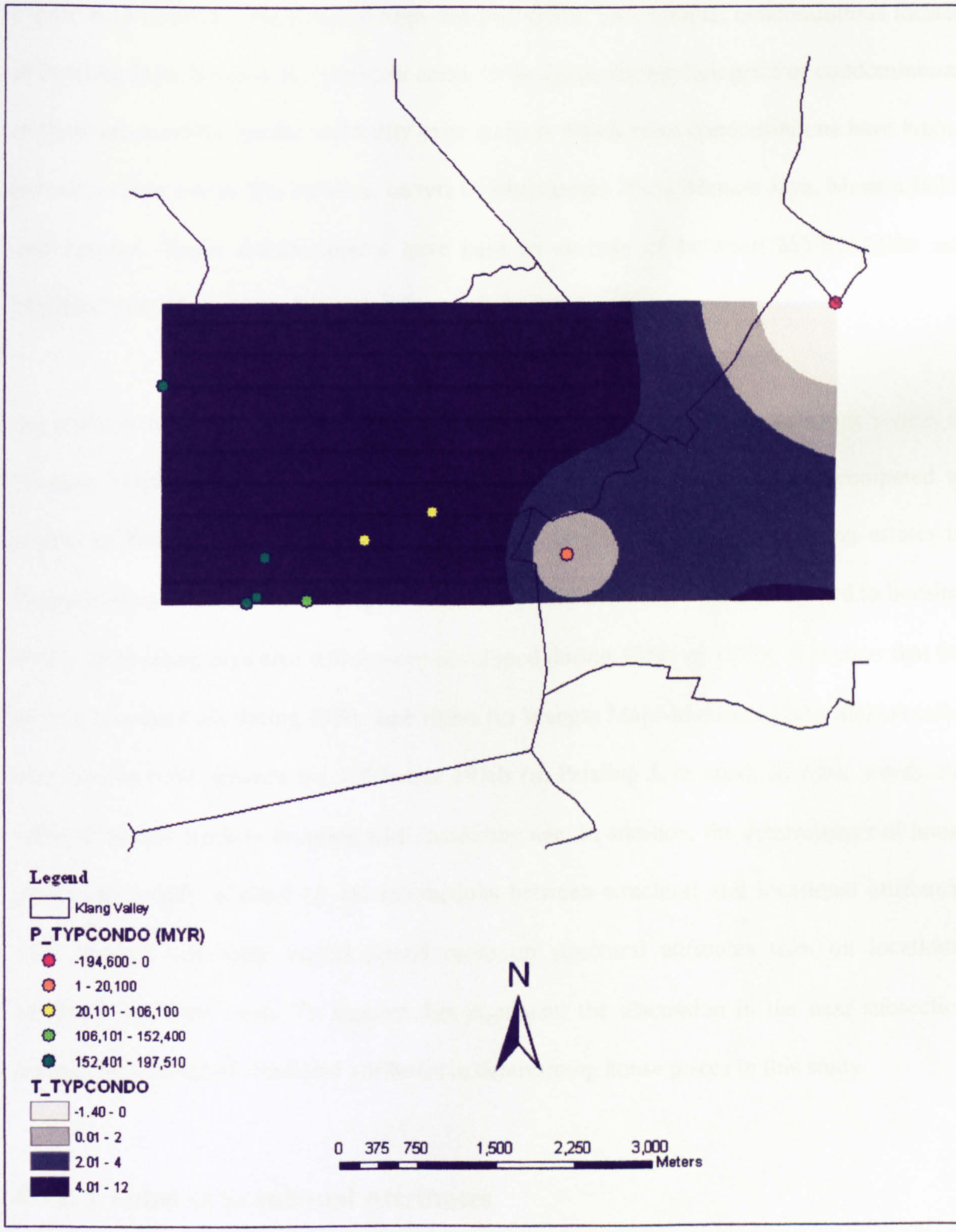



**Figure 8.14**: Map of t-values and parameter estimates associated with variable TYPCONDO

Figure 8.14 illustrates the value of high-rise properties, for example, condominiums located in Petaling Jaya, Bangsar and Kerinchi areas. Once again, the implicit price of condominiums in these areas exhibit spatial variability over space in which some condominiums have higher premiums than others. For instance, buyers of Millennium Place, Menara Jaya, Menara Bakti and Jasmine Tower condominiums have paid an average of between MYR152,000 and MYR197,000 (dark-green dots).

An analysis of the structural attributes in determining house prices suggests that buyers in Wangsa Maju-Maluri are spending marginally more on structural attributes compared to buyers in Petaling Jaya area. This is to be expected since most of the housing estates in Wangsa Maju-Maluri were developed in the late 1980s and early 1990s, compared to housing estates in Petaling Jaya area which were developed during 1950s to 1970s. It is clear that the newest housing built during 1980s and 1990s (in Wangsa Maju-Maluri) has the highest value over houses built between the 1950s and 1970s (in Petaling Jaya area). In other words, the value of houses tends to decrease with increasing age. In addition, the determinants of house prices are greatly affected by the interactions between structural and locational attributes. This implies that some buyers spend more on structural attributes than on locational attributes and *vice versa*. To support this argument, the discussion in the next subsection focuses on the role of locational attributes in determining house prices in this study.

### 8.3.2.3 Value of Locational Attributes

The preceding subsections have discussed the effects of rail transit system (focus variable) and structural attributes in determining house prices. It is now time to examine the effects of locational attributes on house prices, starting with the value of the CBD and then followed by proximity to primary and secondary schools, commercial areas, hospitals, parks, recreational and industrial areas. As highlighted previously, the effect of locational attributes has led to the concept of locational externalities – most externalities are local in their impact with a distance decay effect in their extent and intensity. In other words, the effects of locational attributes would only be expected over short distances.

In the global model, the house price is estimated to reduce at an average of MYR18 for every metre away from the CBD. However, the local model suggests that the distance decay relationship between house prices and distance from the CBD is only to be identified for some areas, whilst other areas exhibit a positive house price gradient. As can be seen from Figure 8.15, houses located further away from the CBD are more expensive than properties located closer to the CBD, particularly for properties located in Wangsa Maju-Maluri. For instance, there is no significant negative house price gradient to be found in a majority of properties located in Wangsa Maju-Maluri. This is completely opposite to the theoretical expectations in which house prices are expected to decrease as distance from the CBD increases. The existence of a positive house price gradient can be explained by the fact that most of the houses in Wangsa Maju-Maluri are within close enough proximity to make accessibility to the CBD less important. Note that Wangsa Maju-Maluri is located within a six kilometre radius of the CBD. Therefore, it is understandable why the majority of houses located in this area are not affected by the accessibility to the CBD. The significant negative house price gradient is estimated for some houses located in Petaling Jaya area. For instance, properties located in Section 3, Section 4, Section 6, Section 7, Section 10, Section 11, Section 12 and Section 52 decrease in value by between MYR3 and MYR47 (orange and red dots) for every metre away from the CBD. However, there are some houses located in

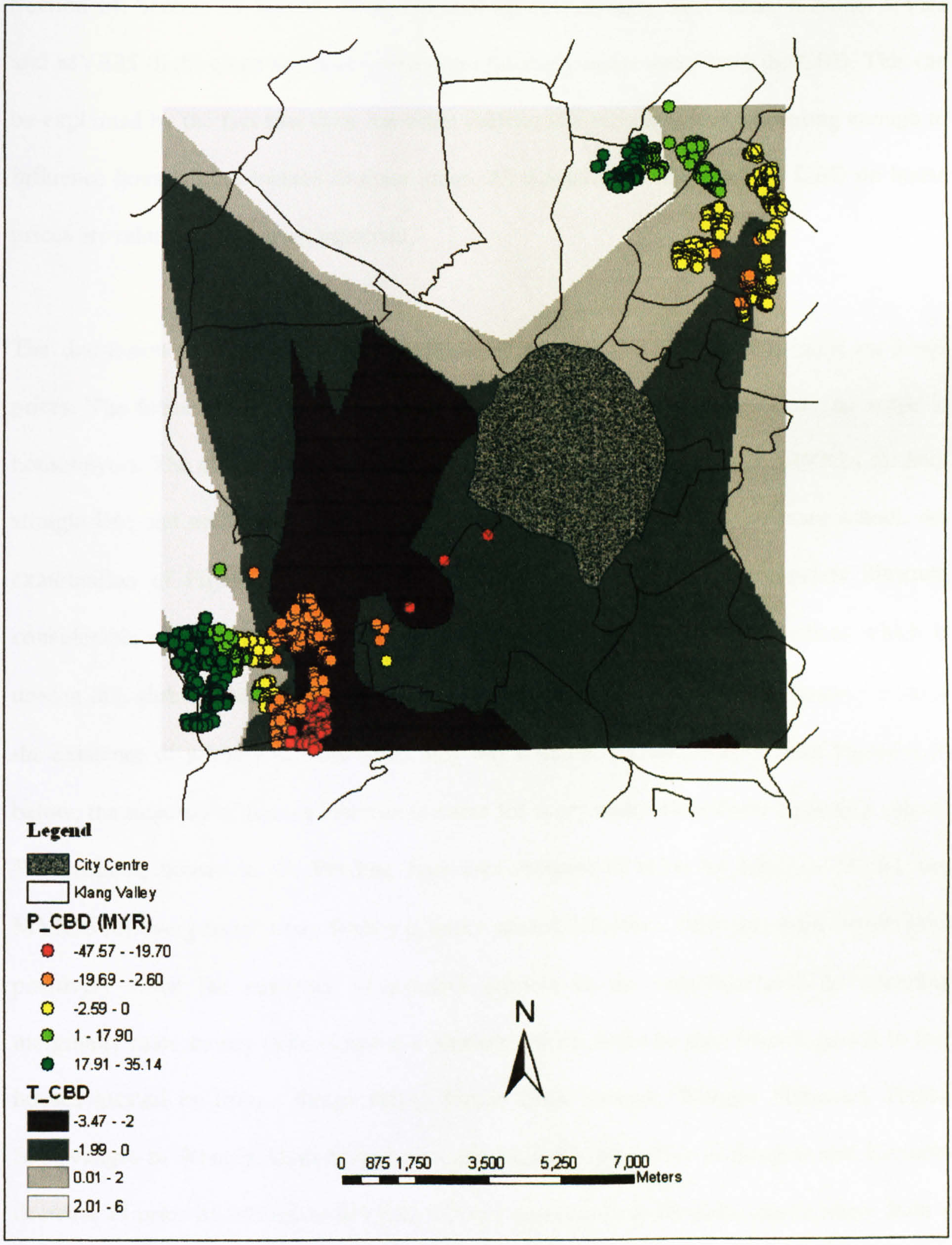



**Figure 8.15**: Map of t-values and parameter estimates associated with variable CBD

Section 14, Section 20, Section 21 and Section 22 that increase their values between MYR1 and MYR35 (light-green and dark-green dots) for every metre away from the CBD. This can be explained by the fact that there are other locational attributes which are strong enough to influence house prices located in these areas. As a result, the effects of the CBD on house prices are relatively few or unimportant.

The discussion now moves on to the effects of primary and secondary schools on house prices. The focus will be on the question of which types of schools are of greater value to housebuyers. The global model estimates that house prices will increase by MYR26 for both straight-line and network-distance models of every metre away from a primary school. An examination of Figure 8.16 shows that the t-values and estimated parameters illustrate considerable spatial variation on the impact of primary schools on house prices which is unseen in a global model. Generally, a majority of buyers in this area do not positively value the existence of primary schools when they buy a house. As can be seen from Figure 8.16 below, the majority of houses increase in value for every metre away from a primary school. For instance, houses in the Petaling Jaya area increase in value by between MYR1 and MYR36 for every metre away from a primary school. However, there are some buyers who positively value the existence of primary schools in the neighbourhood by spending marginally more money to be closer to a primary school. It can be seen from Figure 8.16 that houses located in Taman Bunga Raya, Taman Desa Setapak, Wangsa Melawati, Taman Setiawangsa in Wangsa Maju-Maluri area and high-rise properties in Bangsar and Kerinchi decrease in price by MYR5 to MYR26 (orange and red dots) for every metre away from a primary school, yet with insignificant t-values. Observation that can be made here is that there is degree of importance to be very close to a primary school for the affected house owners in the areas being dissected.


**Figure 8.16**: Map of t-values and parameter estimates associated with variable PRIMARYSCH

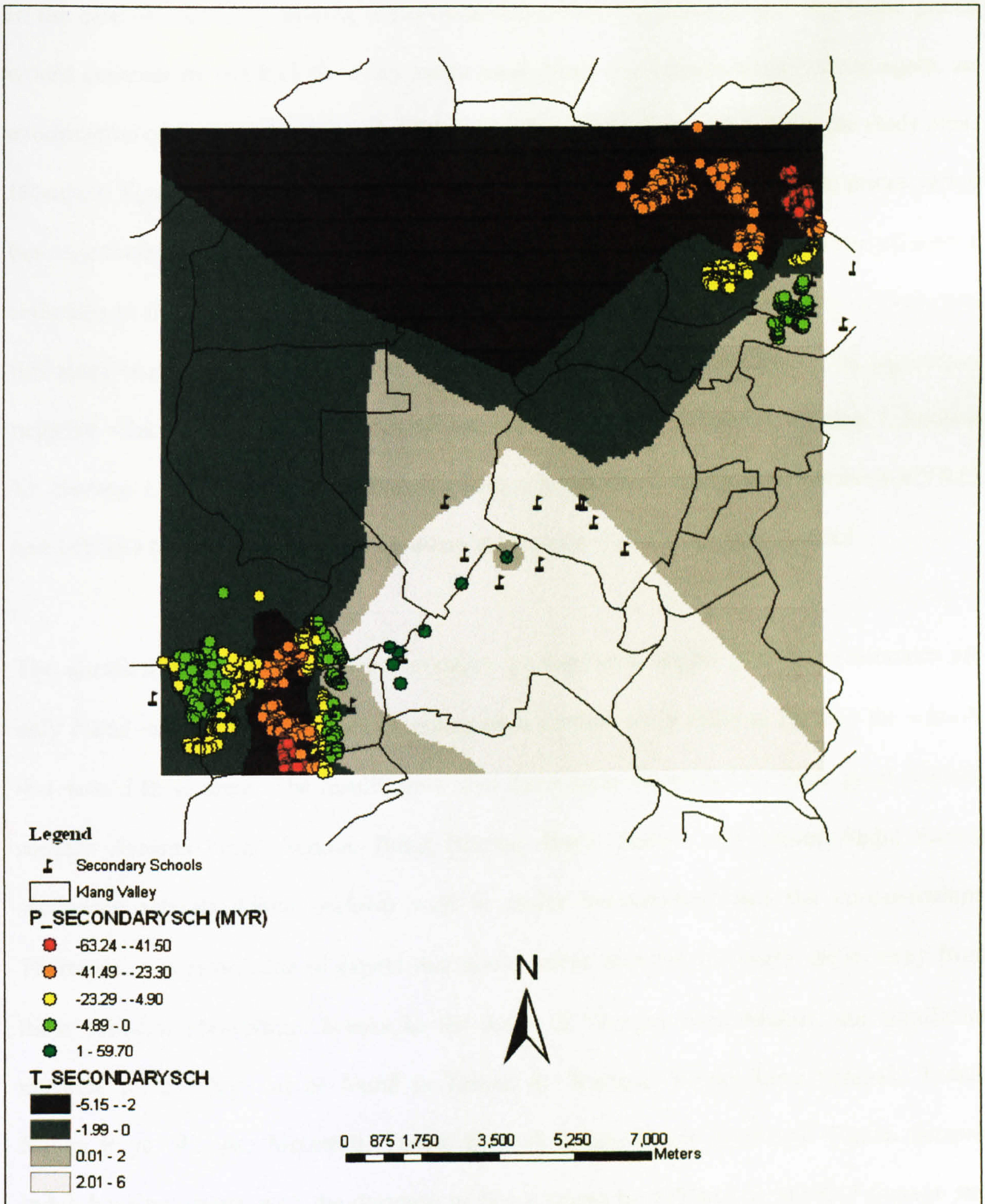



**Figure 8.17**: Map of t-values and parameter estimates associated with variable SECONDARYSCH

In the case of secondary schools, it has been estimated by a global model that house prices would decrease by MYR11 for every metre away from a secondary school. Once again, an examination of Figure 8.17 shows that this is true for the majority of houses in the study area. However, Figure 8.17 also shows that the effect of secondary schools on house prices varies between locations as indicated by t-values and parameter estimates. Looking at the parameter estimates in the figure below, the conclusion that can be made is that majority of houses in this study increased in value by being located closer to a secondary school. The significant negative relationship is found for houses located in Section 3, Section 4, Section 7, Section 11, Section 12 and Section 52 of Petaling Jaya – house price decreases of between MYR23 and MYR63 (orange and red dots) for every metre away from a secondary school.

The question is why the significant negative t-values with higher parameter estimates are only found in these areas. Further examination is carried out in order to identify the schools that served these areas. The results show that these areas are served by three good schools, namely Assunta Girls' School, Bukit Bintang Boys' School and Sultan Abdul Samad secondary schools which perform well in major examinations and the co-curriculum. Therefore, it is reasonable to expect that house prices decrease for every metre away from these schools. Meanwhile, houses in the areas of Wangsa Maju-Maluri, the significant negative relationship can be found in Taman Sri Rampai, Taman Desa Setapak, Taman Bunga Raya, Wangsa Melawati, Taman Setapak Indah, Danau Kota and Taman Setapak Indah housing estates with the decrease of house prices by MYR23 to MYR63 (orange and red dots). In summary, there are several conclusions that can be made from the discussion above. Firstly, the effect of secondary schools on house prices is higher than that of primary schools. Secondly, the effect of schools on house prices depends primarily on the quality of the schools. Finally, the effect of schools on house prices in this study varies between locations.

Another locational attribute that also contributes to the house prices is commercial areas. The house price premium decays for every metre away from commercial areas is estimated at an average of MYR10 by a global model. Figure 8.18 reveals the effect of commercial areas on house prices. This clearly shows that the proximity to commercial areas has a significant negative effect on house prices for some areas, whilst other areas seem not to be affected by being located closer to it. The negative significant effect of commercial areas on house prices is estimated for houses located in Section 12, Section 14, Section 20, Section 21 and Section 22 of the Petaling Jaya area, and Wangsa Melawati housing estate in Wangsa Maju-Maluri area, showing decays of between MYR15 and MYR48 (orange and red dots) for every metre away from commercial areas. Figure 8.18 also reveals that the proximity to commercial areas has a significant positive effect on house prices for those houses located in Section 3, Section 4, Section 6 and Section 7 in the Petaling Jaya area, ranging between MYR1 and MYR39 (light and dark-green dots) for every metre away. This is probably due to the fact that negative externalities such as traffic congestion and noise pollution exist since this area has high density of commercial activities, hence causing the value of a house to increase for every metre away from commercial areas.

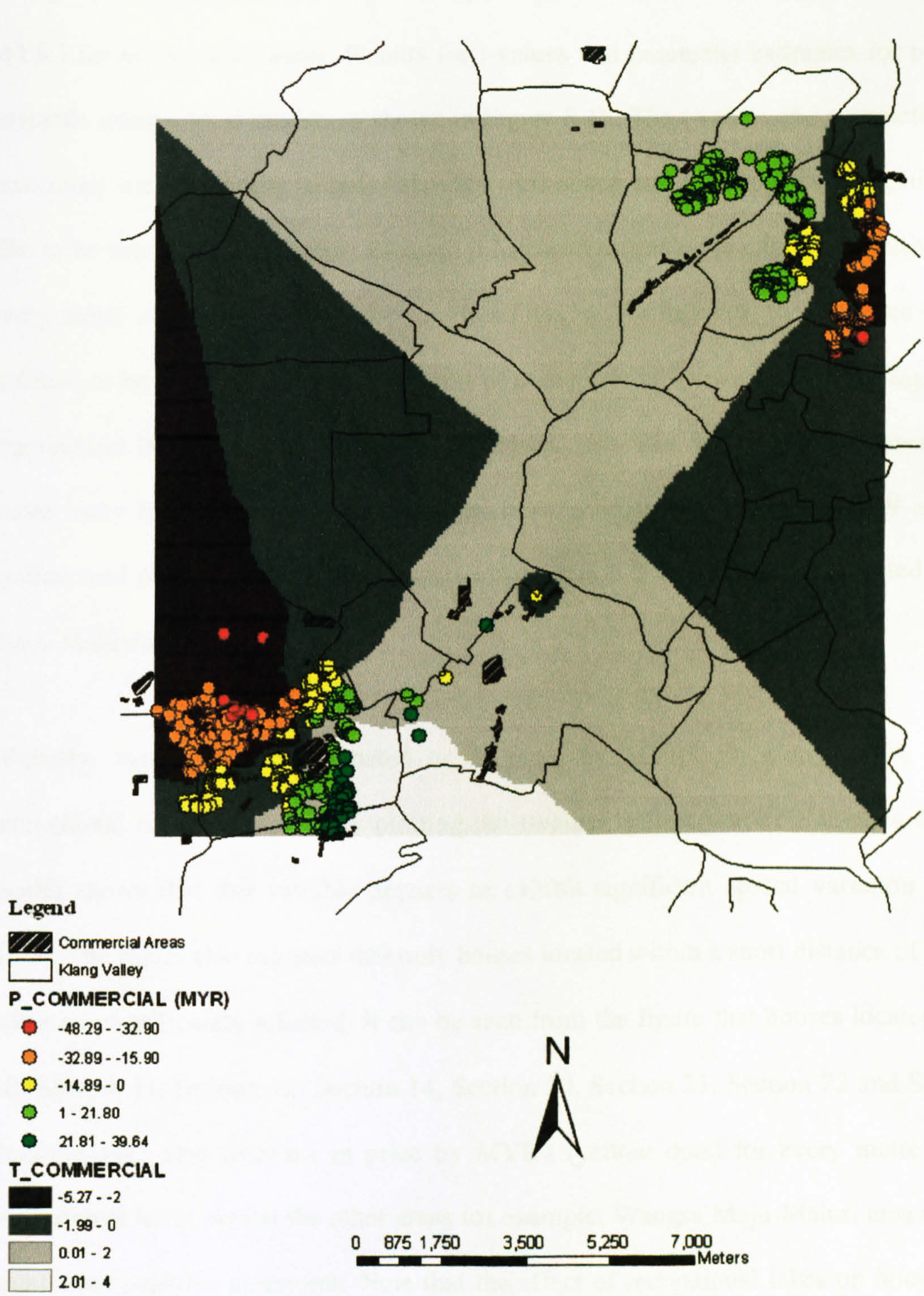



**Figure 8.18**: Map of t-values and parameter estimates associated with variable COMMERCIAL

In a global model, the proximity to hospitals is estimated to increase the house price by MYR3 for every metre away. Results for t-values and parameter estimates for proximity to hospitals using a local model are shown in Figure 8.19. The t-values and parameter estimates associated with proximity to hospitals vary over space and the significant negative effect is also to be found for some areas, although it has been estimated to exhibit a positive effect for every metre away from a hospital by a global model. For instance, the presence of hospitals is found to be valued positively by buyers of a majority of houses in Petaling Jaya and high-rise units in Bangsar and Kerinchi. This can be clearly seen in Figure 8.19, where for every metre away from a hospital, the house price would decrease between MYR9 and MYR29 (yellow and orange dots). Yet no significant t-value is found for houses located in Wangsa Maju-Maluri area.

Globally, house price is estimated to decrease by MYR1 for every metre away from recreational lakes. However, by plotting the t-values and parameter estimates from a local model shows that this variable appears to exhibit significant spatial variation (see Figure 8.20). The figure also suggests that only houses located within a short distance of recreational lakes are significantly affected. It can be seen from the figure that houses located in Section 10, Section 11, Section 12, Section 14, Section 20, Section 21, Section 22 and Section 52 in Petaling Jaya area decrease in price by MYR4 (yellow dots) for every metre away from recreational lakes, whilst the other areas for example, Wangsa Maju-Maluri area exhibit non-significant negative premiums. Note that the effect of recreational lakes on house prices are much more localised and the magnitude of the effect is also smaller since the recreational lakes that exist in this area were made for recreational purposes in the neighbourhood.


**Figure 8.19**: Map of t-values and parameter estimates associated with variable HOSPITAL

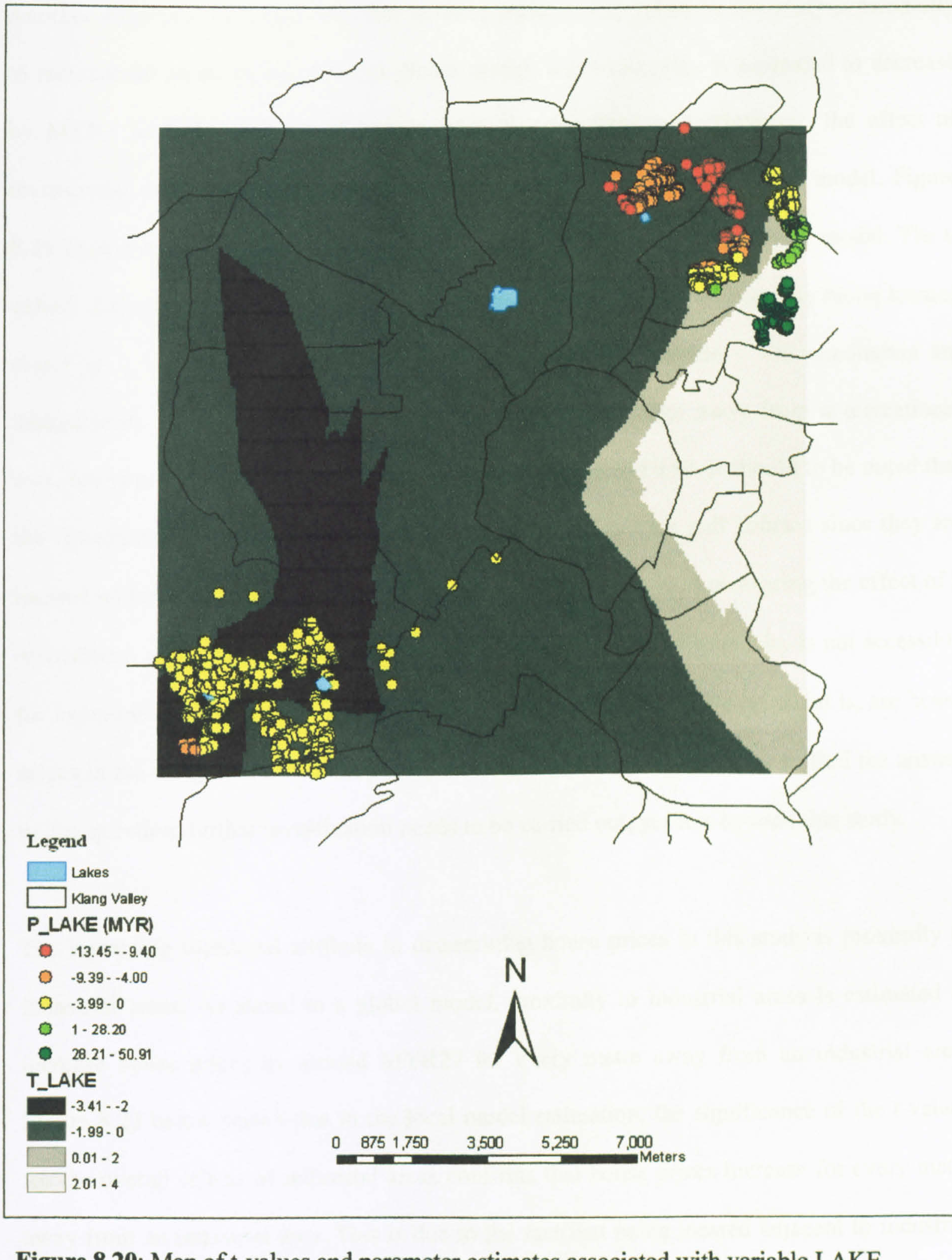



**Figure 8.20**: Map of t-values and parameter estimates associated with variable LAKE

Another influential locational attribute in determining house prices in this study is proximity to recreational areas. In the previous global model, the house price is estimated to decrease by MYR4 with the increase of houses from a recreational area. However, the effect of recreational areas on house prices is examined further by employing GWR model. Figure 8.21 illustrates the results of house price-recreational relationship from a local model. The t-values indicate that there are only three areas that are significantly affected by being located closer to a recreational area; Petaling Jaya, Bangsar and Kerinchi – the remainders are insignificant. As indicated by the figure below, for every metre away from a recreational area, house prices would decrease from around MYR20 to MYR50. It should to be noted that the recreational areas that have been included in the analysis are golf courses since they are located within study area. Therefore, one may argue the grounds of measuring the effect of a recreational area such as a golf course on house prices because this amenity is not accessible for everyone except for members of the club. The question that could be asked is, are house prices in the study area affected by the presence of golf courses? In order to find the answer to this question, further investigation needs to be carried out, yet it is beyond this study.

The remaining locational attribute in determining house prices in this study is proximity to industrial areas. As stated in a global model, proximity to industrial areas is estimated to increase house prices by around MYR27 for every metre away from an industrial area. Figure 8.22 below shows that in the local model estimation, the significance of the t-values for the overall effects of industrial areas confirms that house prices increase for every metre away from an industrial area. This is due to the fact that being located adjacent to industrial areas suggests that residential property is likely to suffer from traffic congestion and air and

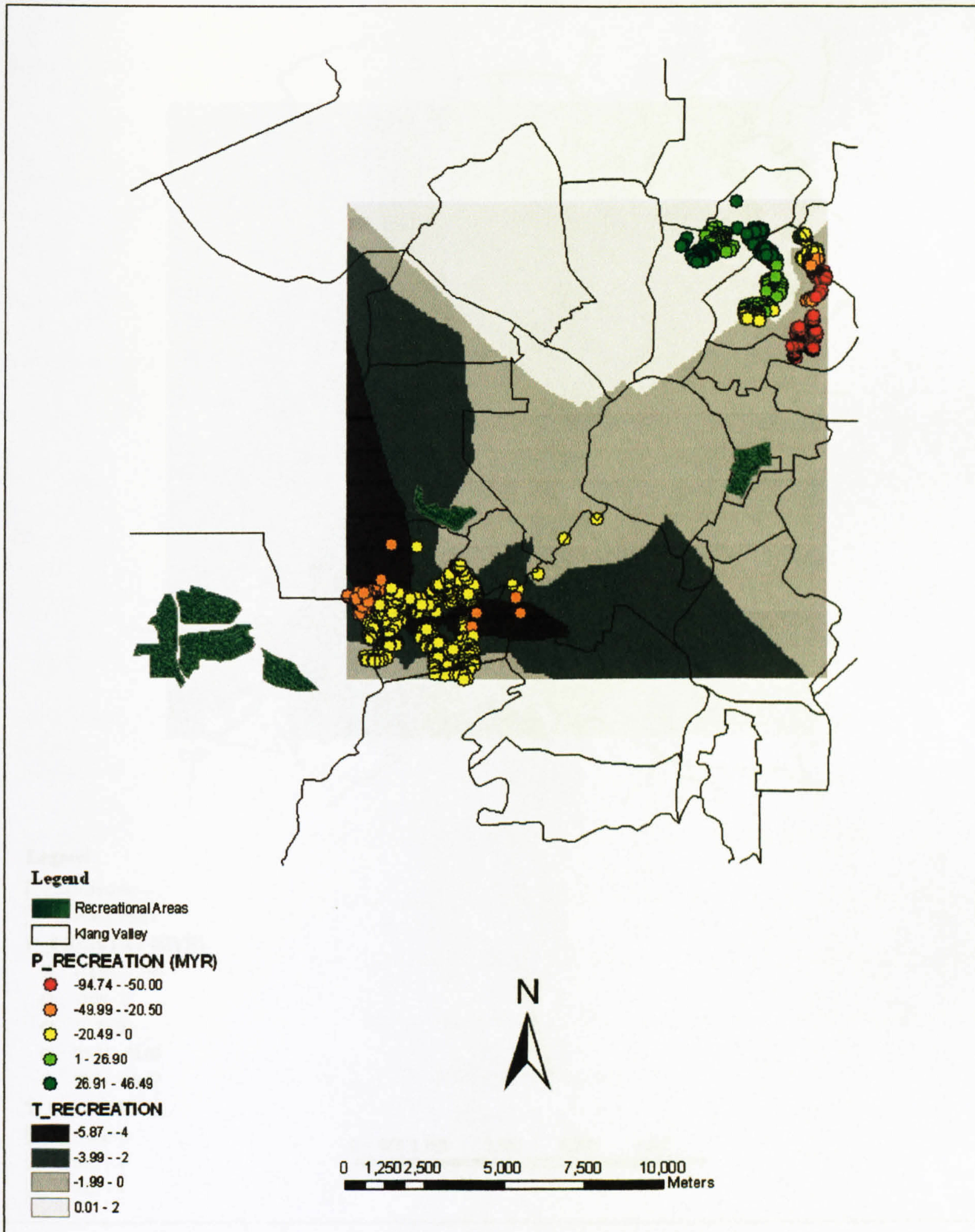



**Figure 8.21**: Map of t-values and parameter estimates associated with variable RECREATION

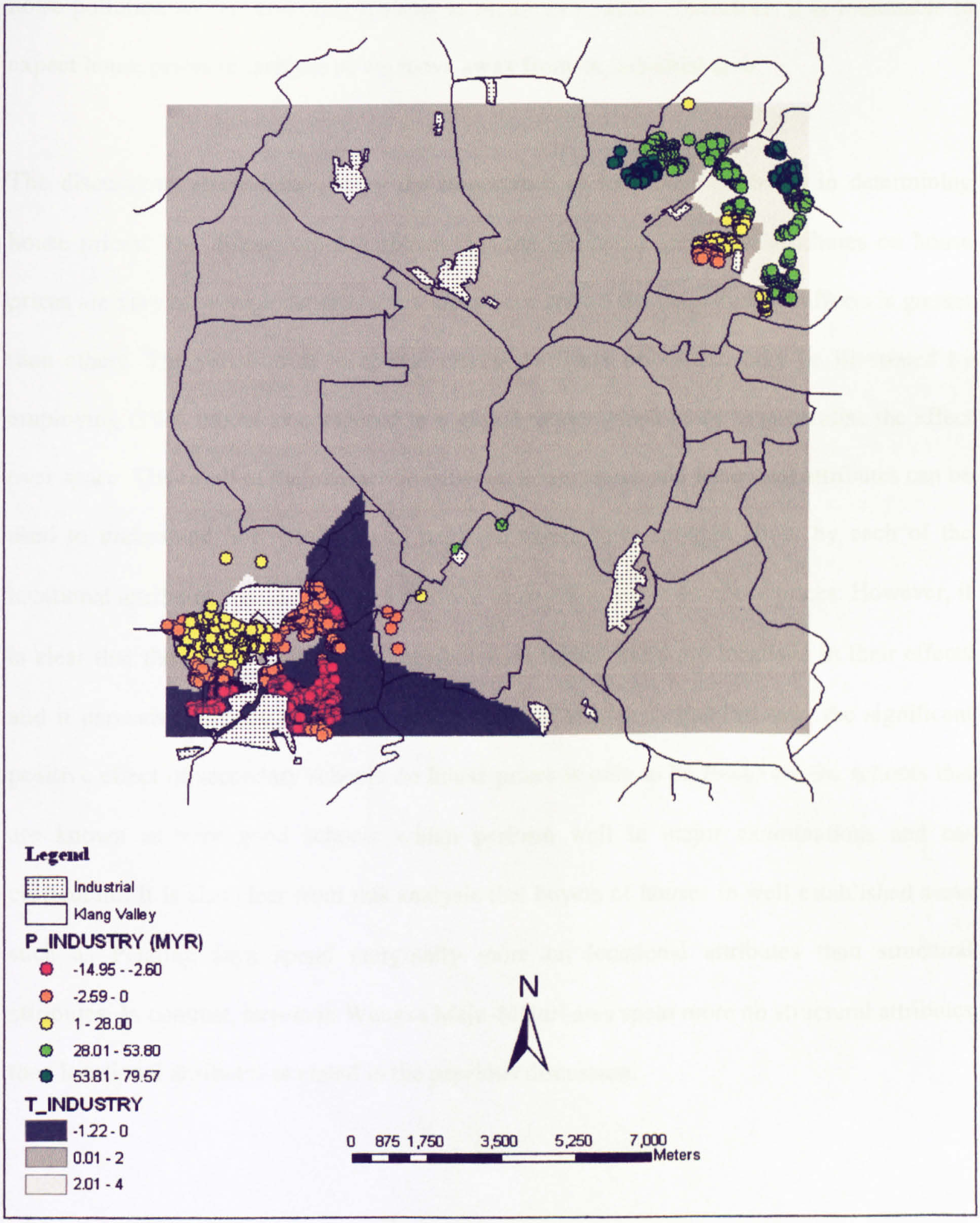



**Figure 8.22**: Map of t-values and parameter estimates associated with variable INDUSTRY

noise pollution and several other reasons as mentioned earlier. Therefore, it is reasonable to expect house prices to increase as we move away from an industrial area.

The discussions above have shown the importance of locational attributes in determining house prices. The discussion also shown that the effects of locational attributes on house prices are vary between locations; some areas have shown the magnitude of effects is greater than others. The variation of locational effects on house prices can only be illustrated by employing GWR model as compared to a global model which tends to generalise the effect over space. The result of the interaction between house prices and locational attributes can be used to understand how positive and negative externalities brought about by each of the locational attributes would result in a positive or negative effect on house prices. However, it is clear that the effects of locational attributes on house prices are localised in their effects and it depends primarily on the types of locational attributes. For instance, the significant positive effect of secondary schools on house prices is only to be found for the schools that are known as very good schools which perform well in major examinations and co-curriculum. It is also clear from this analysis that buyers of houses in well established areas such as Petaling Jaya spend marginally more on locational attributes than structural attributes. In contrast, buyers in Wangsa Maju-Maluri area spent more on structural attributes than locational attributes as stated in the previous discussion.

### 8.3.2.4 Value of Socio-economic and Ethnic Attributes

Among variables explaining socio-economic and ethnic attributes, the percentage of Malay ethnics is the only variable that produces a significant positive effect on house prices. Globally, for every 1 per cent increase in percentage of Malay ethnics, house prices are estimated to increase by approximately MYR3500 and this value is assumed to be constant over space, ignoring the nature of spatial process. An examination of t-values and parameter estimates of the local model proved that this is only the case in some sections in Petaling Jaya and one housing estate in Wangsa Maju-Maluri, in which for every 1 per cent increase in percentage of Malay ethnics is estimated to increase house prices of around MYR3,700 to MYR13,600 (light-green and dark-green dots) for houses located in Section 4, Section 7, Section 8, Section 14, Section 20 and Section 22 of Petaling Jaya and MYR1 to MYR3,700 (yellow dots) in Taman Bunga Raya in Wangsa Maju-Maluri (see Figure 8.23).

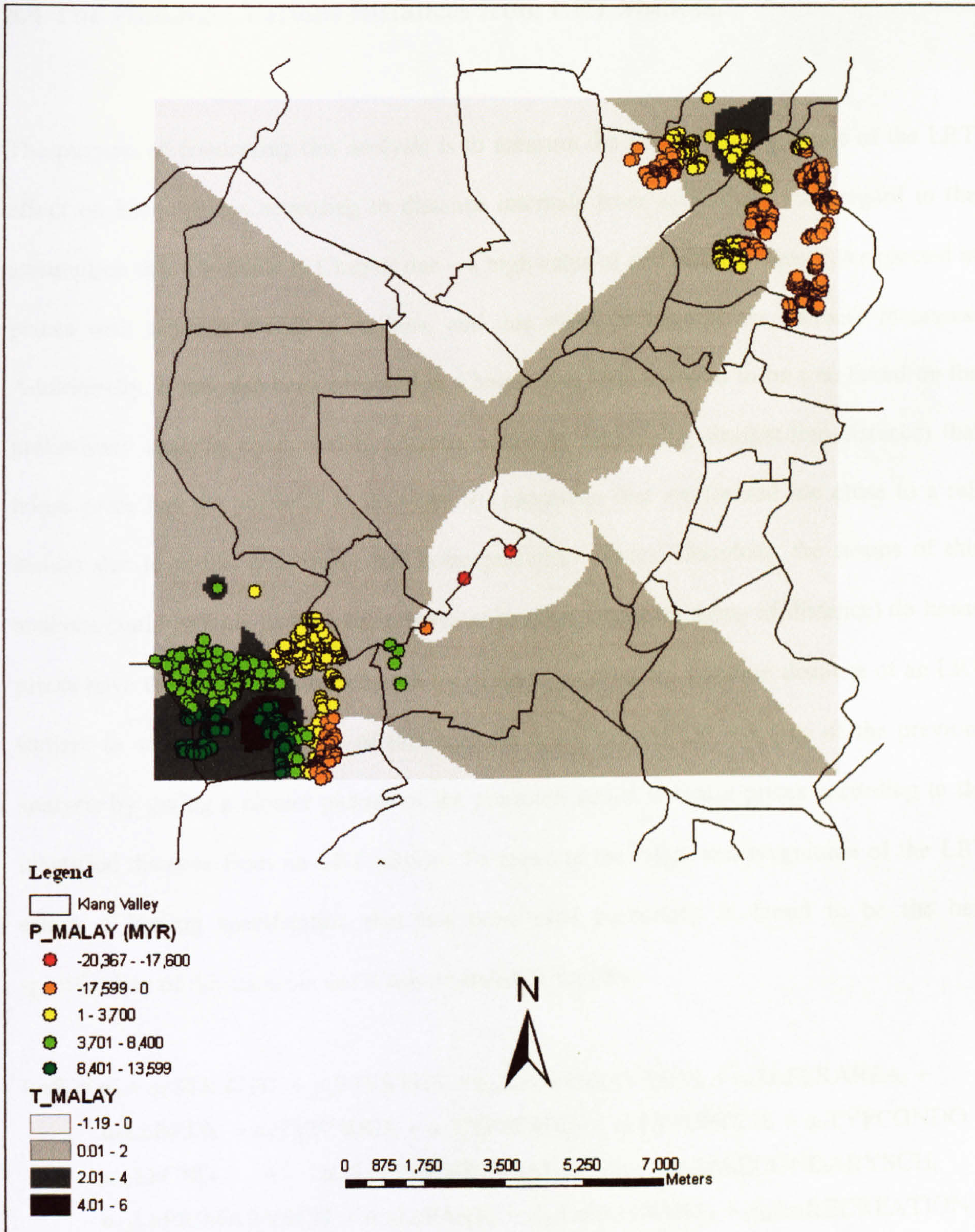



**Figure 8.23**: Map of t-values and parameter estimates associated with variable MALAY

## 8.4 The Findings: Various Distances from LRT Stations

The purpose of conducting this analysis is to measure the range and magnitude of the LRT effect on house prices according to distance intervals from its stations with regard to the assumption that was made in Chapter one – a high value of residential property is expected in places with superior access to stations, and this value declines as the distance increases. Additionally, it has also been assumed in Chapter one (and is found to be true based on the preliminary analysis conducted in Chapter seven by employing straight-line-distance) that house price has the potential to decrease for properties that are located too close to a rail station due to traffic congestion and noise pollution effects. Therefore, the results of this analysis could provide us with the answer of to what extent (in terms of distance) do house prices have the potential to be affected by being located within a certain distance of an LRT station. In addition, the results of this analysis could support the outcome of the previous analysis by giving a clearer picture of the premium added to house prices according to the identified distance from an LRT station. To measure the range and magnitude of the LRT effect, a log-log specification that has been used previously is found to be the best specification of this analysis and it can be stated as follows:

$$\begin{aligned}LnP_i = {} & \alpha_0 + \alpha_1 STRSTN1_i + \alpha_2 STRSTN3_i + \alpha_3 LnTIMESAVINGS_i + \alpha_4 LnFLRAREA_i + \\ & \alpha_5 LnBEDS_i + \alpha_6 TYPTRRD_i + \alpha_7 TYPSEMID_i + \alpha_8 TYPDETCH_i + \alpha_9 TYPCONDO_i + \\ & \alpha_{10} LnCBD_i + \alpha_{11} LnCOMMERCIAL_i + \alpha_{12} LnSECONDARYSCH_i + \\ & \alpha_{13} LnPRIMARYSCH_i + \alpha_{14} LnPARK_i + \alpha_{15} LnHOSPITAL_i + \alpha_{16} LnRECREATION_i + \\ & \alpha_{17} LnINDUSTRY_i + \alpha_{18} LnMALAY_i + \varepsilon_i \qquad (8.4)\end{aligned}$$

where $i$ is the subscript denoting each property; $P_i$ is the price of property $i$ in Malaysia Ringgit (MYR); Ln is natural logarithm; STRSTN1 is 1 if the property located within 500 metres of an LRT station measured in straight-line-distance, 0 otherwise; STRSTN3 is 1 if the property located within 1,001-1,500 metres of an LRT station measured in straight-line-distance, 0 otherwise; TIMESAVINGS denotes travel-time savings to the CBD when people travel with the LRT system; FLRAREA is the floor area of the property in square foot; BEDS is the number of bedrooms of the property; TYPxxx is a set of dummy variables that illustrate the type of house as follows:

TYPTRRD is 1 if the property is terraced, 0 otherwise;
TYPSEMID is 1 if the property is semi-detached, 0 otherwise;
TYPDETCH is 1 if the property is detached, 0 otherwise;
TYPCONDO is 1 if the property is condominium, 0 otherwise.

CBD, COMMERCIAL, SECONDARYSCH, PRIMARYSCH, PARK, HOSPITAL, RECREATION, and INDUSTRY are the network-distance from the property to Kuala Lumpur's city centre, commercial areas, secondary schools, primary schools, parks, hospitals, recreational areas and industrial areas measured in metres. Finally, MALAY is the percentage of Malay ethnics at Mukim level; $\alpha$ denotes a parameter to be estimated; and $\varepsilon$ denotes standard error of the estimation.

Consequently, the model for network-distance can be stated as:

$$LnP_i = \alpha_0 + \alpha_1 NETSTN1_i + \alpha_2 NETSTN2_i + \alpha_3 NETSTN3_i + \alpha_4 NETSTN4_i + \alpha_5 LnTIMESAVINGS_i + \alpha_6 LnFLRAREA_i + \alpha_7 LnBEDS_i + \alpha_8 TYPTRRD_i + \alpha_9 TYPSEMID_i + \alpha_{10} TYPDETCH_i + \alpha_{11} TYPCONDO_i + \alpha_{12} LnCBD_i + \alpha_{13} LnCOMMERCIAL_i + \alpha_{14} LnSECONDARYSCH_i + \alpha_{15} LnPRIMARYSCH_i + \alpha_{16} LnPARK_i + \alpha_{17} LnHOSPITAL_i + \alpha_{18} LnRECREATION_i + \alpha_{19} LnINDUSTRY_i + \alpha_{20} LnMALAY_i + \varepsilon_i \quad (8.5)$$

where the difference between perceived distance to a station and actual-distance to a station is given by given NETSTN1, NETSTN2, NETSTN3 and NETSTN4: are 1 if the property located within 500, 501-1,000, 1,001-1,500 and 1,501-2,000 metres of an LRT station respectively measured in network-distance; 0 otherwise.

As indicated before, there are various dummy variables of straight-line-distance and network-distance indicating distances of an LRT station which are employed in order to measure the effect of the LRT system on house price. However, the above equations solely include the distance from LRT station measures with significant levels at 0.05 and 0.01 per cent. It should be highlighted that there are two straight-line-distance measures which are not significant, namely STRSTN1 (501-1,000m) and STRSTN3 (1,501-2,000m), whilst NETSTN5 (beyond 2,000m) is not significant for network-distance measures. Do note that most of the network-distance measures are found to be statistically significant for the final model and this obviously shows that network-distance (actual-distance that people travel to reach an LRT station) can be considered as an appropriate measure in determining a premium added to house prices due to the existence of the LRT system. Therefore, the house price differences can be expected for various distances of an LRT station. The results of the analysis will be examined in the next subsection.

### 8.4.1 The Results of Global Model

Table 8.5 presents the summary of the parameter estimates of Models 8.4 and 8.5 concerning the effect of the LRT system on house price for various specified distances from the station. Overall, the results of both models show that most of the predictor variables that have been used to estimate the range and magnitude of the LRT effect on house prices according to various specified distances from its stations, have indeed produced similar signs to those obtained in the previous models (Models 8.1 and 8.2) with high $R^2$ – 78.6 per cent for straight-line-distance model and 78.5 per cent for network-distance model. Both of these models have explained the variation of house prices reasonably well but as observed in the previous model, it still leaves 22 per cent of the variance in house prices unexplained. To avoid a repetition of Section 8.3.1, the discussion in this section will concentrate on the LRT parameters.

#### 8.4.1.1 Value of the LRT system

The results of focus variables establish that the location of a property within 500 metres (STRDIST1) of an LRT station adds a premium of approximately MYR20,000 (straight-line-distance model) to house price. However, as distance from an LRT station increases, a premium added to a property located within 1,001-1,500 metres (STRDIST3) of an LRT station increases to MYR37,000 more than of a house located in the previous distance, and more than 1500 metres from an LRT station. For the network-distance variables, the location of a property within 500 metres (NETSTN1) of an LRT station adds a premium of MYR27,800 to house price.

**Table 8.5**: The traditional hedonic specification of various distances from stations of Model 8.4 and Model 8.5

| Vector | Predictor | Straight-line distance (Model 8.4) | | | | Network distance (Model 8.5) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Coefficient | Standard error | t-value | VIF | Coefficient | Standard error | t-value | VIF |
| | Constant | 21162.80 | 1.77 | 17.45 | | 30730.16 | 1.75 | 18.47 | |
| Focus variables | *STRSTN1* | 20003.54 | 7870.24 | 2.57 | 1.81 | | | | |
| | *STRSTN3* | 37055.74 | 6230.61 | 5.98 | 1.66 | | | | |
| | *NETSTN1* | | | | | 27873.79 | 10873.66 | 2.67 | 1.77 |
| | *NETSTN2* | | | | | 47877.33 | 10493.66 | 4.51 | 3.90 |
| | *NETSTN3* | | | | | 20659.39 | 8298.17 | 2.58 | 1.51 |
| | *NETSTN4* | | | | | 35088.18 | 7542.32 | 4.66 | 2.06 |
| | *TIMESAVINGS* | 1319.25 | 296.01 | 4.48 | 3.29 | 2638.49 | 376.92 | 6.78 | 5.70 |
| Structural variables | *FLRAREA* | 309.63 | 12.58 | 24.23 | 6.22 | 310.15 | 13.09 | 24.29 | 6.32 |
| | *BEDS* | 29197.48 | 3922.04 | 7.47 | 1.89 | 30504.83 | 3922.05 | 7.82 | 1.88 |
| | *TYPTRRD* | 77062.83 | 9509.88 | 8.17 | 4.32 | 76079.05 | 9837.81 | 7.79 | 4.60 |
| | *TYPSEMID* | 154125.83 | 22626.95 | 6.86 | 1.42 | 155109.441 | 22626.95 | 6.83 | 1.44 |
| | *TYPDETCH* | 180031.89 | 17052.20 | 10.64 | 6.06 | 179048.10 | 17052.20 | 10.44 | 6.20 |
| | *TYPCONDO* | 184294.94 | 9837.80 | 18.52 | 2.98 | 190525.55 | 10165.73 | 18.78 | 3.08 |
| Locational variables | *CBD* | -15.87 | 1.55 | -10.26 | 3.34 | -18.43 | 1.58 | -11.56 | 3.52 |
| | *PRIMARYSCH* | 26.25 | 3.93 | 6.77 | 1.94 | 24.61 | 3.94 | 6.21 | 2.01 |
| | *SECONDARYSCH* | -12.91 | 4.66 | -2.81 | 1.37 | -12.19 | 4.66 | -2.58 | 1.44 |
| | *COMMERCIAL* | -15.21 | 3.28 | -4.52 | 2.64 | -9.24 | 3.57 | -2.60 | 2.86 |
| | *PARK* | -1.13 | 0.30 | -3.19 | 1.24 | -1.13 | 0.31 | -3.09 | 1.25 |
| | *HOSPITAL* | 3.22 | 1.28 | 2.47 | 3.28 | 2.94 | 1.38 | 2.17 | 3.54 |
| | *RECREATION* | -6.56 | 1.70 | -3.86 | 6.04 | -6.06 | 1.70 | -3.54 | 6.09 |
| | *INDUSTRY* | 27.35 | 3.50 | 7.65 | 1.69 | 24.06 | 3.72 | 6.45 | 1.82 |
| Socio-economic and ethnic variables | *MALAY* | 4302.31 | 613.52 | 7.00 | 7.80 | 4317.65 | 628.86 | 6.88 | 8.08 |
| | | $R^2$ (adj.) = 78.6 per cent | | | | $R^2$ (adj.) = 78.5 per cent | | | |

A premium added to the house price increases simultaneously with the increase of distance (within 501-1,000 metres as indicated by NETSTN2) by approximately (MYR47,800) than it is in the previous distance. For further distance, namely within 1,001-1,500 metres (NETSTN3) and 1,501-2,000 metres (NETSTN4), they add a premium of approximately MYR20,600 and MYR35,000 to house price, although the latter provides a slightly higher premium than the former which is an unexpected result. It can be seen that house prices have the potential to decrease for properties that are located too close to a rail station due to traffic congestion and noise pollution effects, whilst properties radiating out from the station and within easy walking and driving distance have increased in prices, thus confirming the assumption that was made earlier, at least in the context of this study. In other words, the easy access to transit stations conveniently and quickly have capitalised into property values.

Figure 8.24 illustrates the estimated distance decay curves for various specified distances of an LRT station by using network-distance. It can be seen from Figure 8.24 below how the effect of the LRT system (with respect to the distance from its station and greatest effect) can be found within 501-1,000 metres of an LRT station. Previously, it has been highlighted that the capitalisation of house price can be expected if the LRT system has truly improved accessibility from residential areas to the CBD – this can be shown in the form of travel-time savings. Evidently, the travel-time savings variable in the analysis shows that for every one minute saved commuting to the CBD, it adds a premium of an average of MYR1,319.25 (straight-line-distance model) and MYR2,638.49 (network-distance model) to house price.

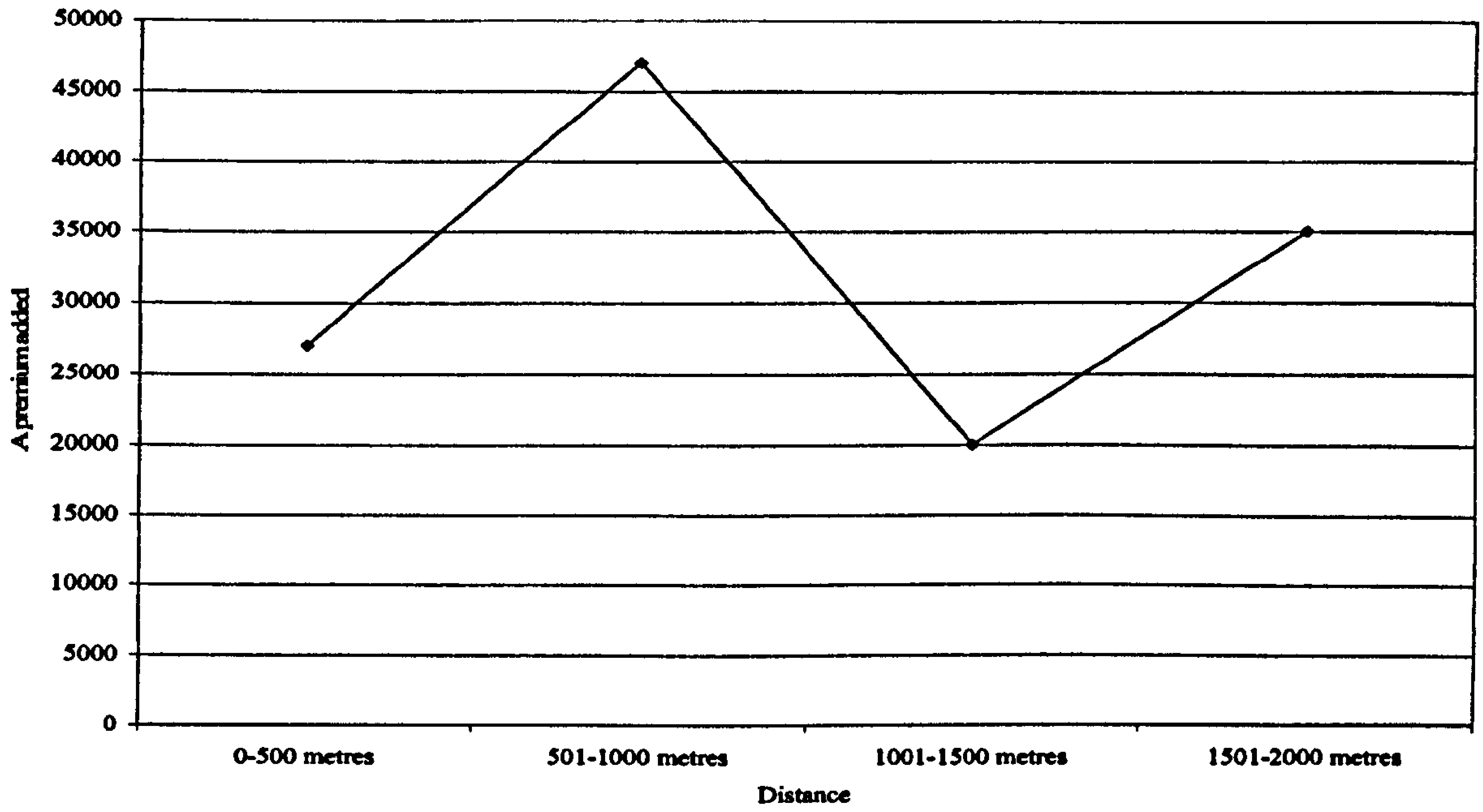



**Figure 8.24:** Distance decay relationship between house price and distance from a LRT station

Based on the above discussion, several conclusions can be drawn with respect to the distance decay relationship between house price and various specified distances to an LRT station. Firstly, the effect of the LRT on house prices is well measured by employing network-distance measures, since most of the variables are statistically significant with a positive sign which is contrary to the previous conclusion. Secondly, the distance variables respond according to the theory where the highest premium added to house price is to be found for a distance within 1,001-1,500 metres and 501-1,000 metres of an LRT station for straight-line-distance and network-distance model respectively – properties radiating out from the station and within walking and driving distance gain higher price premiums compared to properties located closer to an LRT station (500 metres) or further away from an LRT station (beyond 1,500 metres for straight-line-distance model and beyond 1,000 metres for network-distance model). Similarly, the premiums added decrease as the distance from the LRT station increases. This result can obviously be seen for the network-distance model. To verify whether straight-line and network-distance measures do not overestimate a premium added to the house price, further analysis needs to be conducted by employing a local model (GWR). This is due to the nature of the local model having the ability to identify spatial variation that is always generalised over space by the global model. Next, the discussion will be focused on the results of GWR model.

### 8.4.2 The Results of GWR Model

The discussion in this subsection follows the strategy of interpreting the GWR results that have been obtained in the preceding subsection. Table 8.6 and 8.7 illustrate diagnostic information of the GWR estimation for Models 8.4 and 8.5. As can be seen from Table 8.6 and 8.7 above, the adjusted $R^2$ has increased from 78.6 per cent and 78.5 per cent for both models in a global model to 88.1 per cent and 88.3 per cent respectively for both models in the GWR model. After considering degrees of freedom, the conclusion can be reached that the GWR model provides a better explanation of house price variation in this study. In addition, the reduction in the AIC from 414.85 and 424.15 for both models in a global model to -404.90 and -401.61 respectively for both models in the GWR model suggests that the local model is better than a global model, after taking into account degrees of freedom.

**Table 8.6**: The results of GWR estimation for Model 8.4

| Global Estimation | |
|---|---|
| *Diagnostic information* | |
| Residual sum of squares | 117.23 |
| Effective number of parameters | 19.00 |
| Sigma | 27.40 |
| Akaike Information Criterion | 414.85 |
| Coefficient of determination | 78.85 |
| Adjusted $R^2$ | 78.59 |

| GWR Estimation | |
|---|---|
| *Fitting geographically weighted regression model* | |
| Number of observations | 1580 |
| Number of independent variables (intercept is variable 1) | 19 |
| Number of locations to fit model | 1580 |
| | |
| *Diagnostic information* | |
| Residual sum of squares | 60.99 |
| Effective number of parameters | 117.53 |
| Sigma | 20.42 |
| Akaike Information Criterion | -401.61 |
| Coefficient of determination | 88.99 |
| Adjusted $R^2$ | 88.11 |

| Source | *ANOVA* | | | |
|---|---|---|---|---|
| | Sum of squares | Degrees of freedom | MS | F-value |
| OLS residuals | 117.20 | 19.00 | | |
| GWR improvement | 56.20 | 98.53 | 0.57 | |
| GWR residuals | 61.00 | 1462.47 | 0.04 | 13.68 |

**Table 8.7:** The results of GWR estimation for Model 8.5

| Global Model | |
|---|---|
| *Diagnostic information* | |
| Residual sum of squares | 117.62 |
| Effective number of parameters | 21.00 |
| Sigma | 27.46 |
| Akaike Information Criterion | 424.15 |
| Coefficient of determination | 78.78 |
| Adjusted $R^2$ | 78.49 |

| GWR Estimation | |
|---|---|
| *Fitting geographically weighted regression model* | |
| Number of observations | 1580 |
| Number of independent variables (intercept is variable 1) | 21 |
| Number of locations to fit model | 1580 |
| | |
| *Diagnostic information* | |
| Residual sum of squares | 58.84 |
| Effective number of parameters | 140.06 |
| Sigma | 20.21 |
| Akaike Information Criterion | -404.90 |
| Coefficient of determination | 89.38 |
| Adjusted $R^2$ | 88.35 |

| Source | *ANOVA* | | | |
|---|---|---|---|---|
| | Sum of squares | Degrees of freedom | MS | F-value |
| OLS residuals | 117.60 | 21.00 | | |
| GWR improvement | 58.80 | 119.07 | 0.49 | |
| GWR residuals | 58.80 | 1439.93 | 0.04 | 12.08 |

Once again, to avoid a repetition of Section 8.3.2 above, the discussion in this subsection concentrates solely on variables associated with the LRT system which are represented by STRSTN1, STRSTN2, NETSTN1, NETSTN2, NETSTN3 and NETSTN4. In the subsequent maps, the t-value of the abovementioned variables is classified into four. Similarly, in the following maps, the parameter estimates are classified by five bands indicating the positive and negative premium added to the house price in Malaysia Ringgit (MYR).

#### 8.4.2.1 Value of the LRT System

This section provides evidence of the existence of spatial variability of premium added for the properties located within various distances of an LRT station which could not be able to be identified in a global model. In response to that, findings from the GWR model of house prices within various distances of an LRT station are mapped in Figures 8.25 to 8.29. These findings are vital to support the previous outcome and they are also useful in helping us make a conclusive judgement of the effect of the LRT system on house prices in the Klang Valley, Malaysia. This objective can be achieved by comparing these findings with the results from a global model. The following discussion commences by addressing the premium for those properties located within 500 metres of an LRT station of straight-line-distance measures.

##### 8.4.2.1.1 Houses within 500 metres of an LRT Station (STRSTN1)

The global model shows that positive premium added of each unit of the houses located within 500 metres of an LRT station is estimated at an average of MYR20,300 and this value has been applied for the entire area being studied. However, examination of Figure 8.25

indicates that such a positive premium that is associated with it only occurs for high-rise units in Bangsar and Kerinchi, but with insignificant t-values. For those houses in Bangsar and Kerinchi (dark-green dots) located within 500 metres of the LRT station adds premium value of up to MYR41,800 to its price. This value is even greater than the value that has been obtained from a global model.

Figure 8.22 also reveals that no positive significant t-value and parameter estimates are found in any house located within 500 metres of the LRT station in Petaling Jaya and Wangsa Maju-Maluri. In the case of houses located in Wangsa Maju-Maluri, being located within 500 metres of an LRT station decreases the house price between MYR40,000 and MYR68,800 (orange and red dots). The trend illustrated in this analysis can be used to confirm the results from the previous analysis in which it has indicated that the existence of the LRT system is not/not yet adding to positive premium of house prices in Wangsa Maju-Maluri. It should be noted that this spatial variability is completely unseen in a global model. Any observation made solely and based on a global model can be associated with the overestimation as well as underestimation problem of the entire areas and, therefore it could produce a misleading conclusion.

### 8.4.2.1.2 Houses within 1,001-1,500 metres of an LRT Station (STRSTN3)

In the case of houses located within 1,001-1,500 metres of an LRT station, a global model has yielded positive house price premium at an average of MYR37,000 compared to houses located closer or further away from this distance. To confirm whether the estimation given by a global model represents the reality of the house price-LRT relationship with regards to being located within 1,001-1,500 metres of an LRT station, the results of t-values and parameter estimates from local model estimation are mapped in Figure 8.26. As clearly shown in Figure 8.26, significant positive price premiums are recorded in Section 3, Section 4, Section 6, Section 7, Section 8, Section 11 and Section 12 of Petaling Jaya, where houses located within 1,001-1,500 metres of an LRT station experience capitalisation of significant positive premiums of between MYR15,500 and MYR68,300 (light-green and dark-green dots).

Figure 8.26 also illustrates that in Petaling Jaya area, non-significant positive price premiums of between MYR1 and MYR15,500 (yellow dots) are found for some houses in Section 14 and Section 21, whilst non-significant negative premiums up to MYR25,000 (orange dots) are found in Section 14 and Section 22. Yet, no positive significant t-value is found in any house located within 1,001-1,500 metres of an LRT station in Wangsa Maju-Maluri. Although there is no significant t-value found in Wangsa Maju-Maluri, Figure 8.26 shows that there is non-significant positive premium of between MYR1 and MYR15,500 (yellow dots) and is capitalised into house prices in Taman Wangsa Melawati, Taman Bunga Raya, Taman Ibu Kota and Danau Kota. It is clear that the effect or impact of the LRT system on the majority of the houses that are located in Wangsa Maju-Maluri is not significant at the time the data for this study was collected.

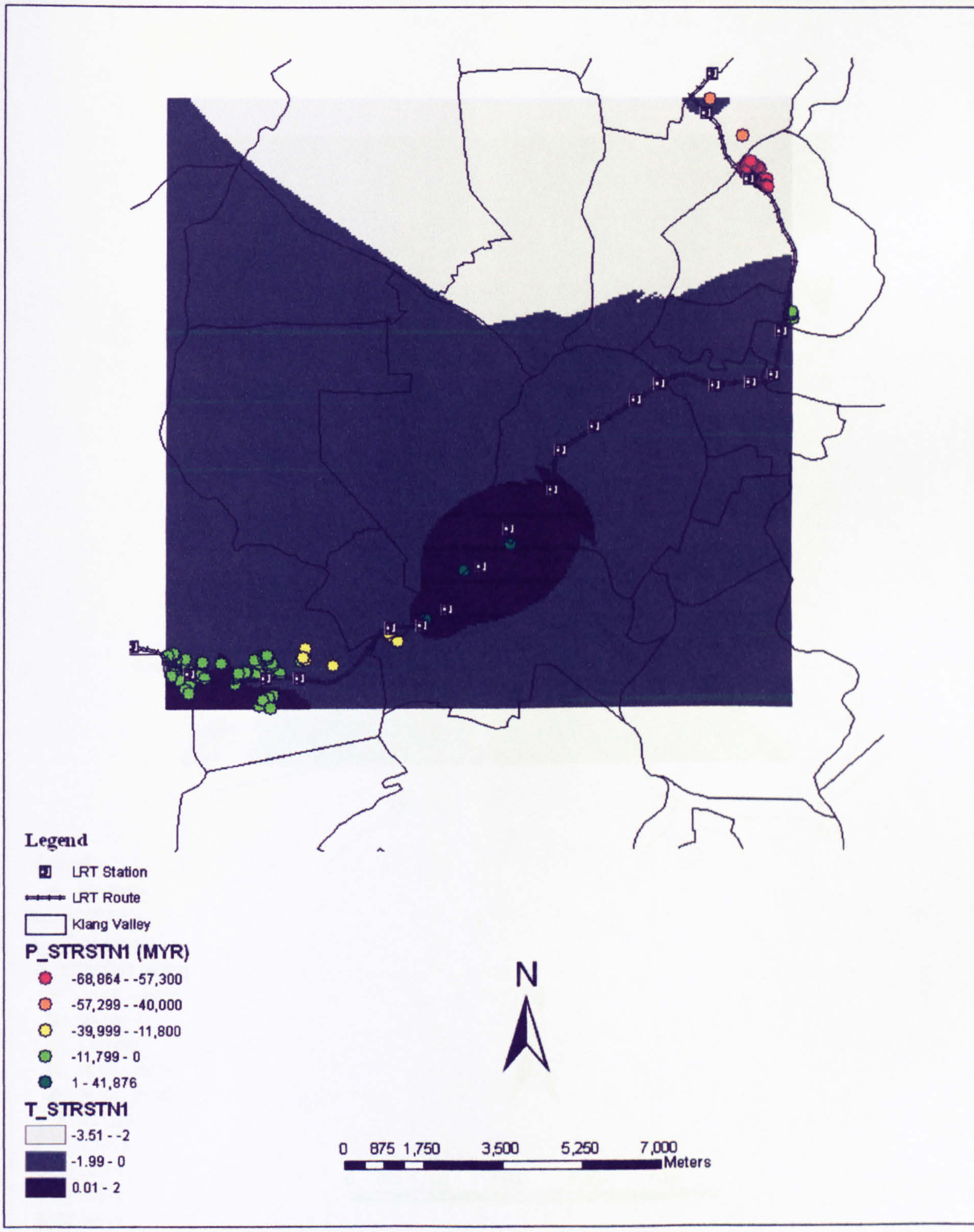



**Figure 8.25**: Map of t-values and parameter estimates associated with variable STRSTN1

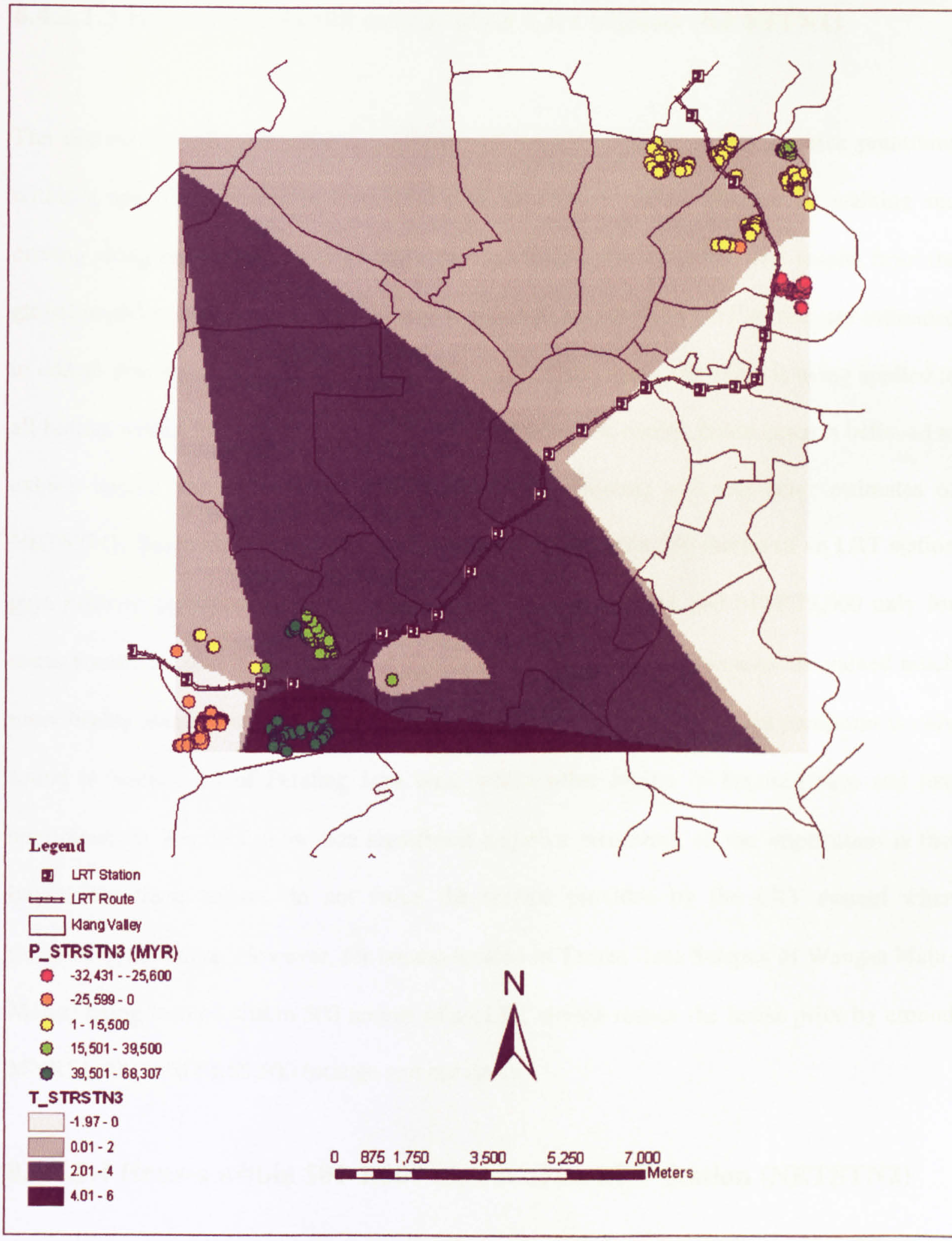



**Figure 8.26**: Map of t-values and parameter estimates associated with variable STRSTN3

#### 8.4.2.1.3 Houses within 500 metres of an LRT Station (NETSTN1)

The discussion will now address the effect of the LRT system on house price premiums within a specified distance measured by network-distance: actual distance by walking and driving along the shortest route to reach the transit station from home. The results from the global model revealed that houses located within 500 metres of an LRT station are estimated to add an average of MYR27,800 to the house price. Once again, the value is being applied to all houses within 500 metres of an LRT station, although in reality, house price is believed to exhibit spatial variation. Figure 8.27 illustrates the t-values and parameter estimates of NETSTN1. Based on Figure 8.27 below, houses located within 500 metres of an LRT station gain positive significance in price premiums of between MYR1 and MYR79,000 only for some houses located in Section 14 of Petaling Jaya. It appears that houses are valued much more highly than in the global model. Yet, the positive significance in price premiums is only found in Section 14 of Petaling Jaya area, whilst other houses in Petaling Jaya and two apartments in Kerinchi show non-significant negative premiums, so the implication is that buyers for these houses do not value the service provided by the LRT system when purchasing the house. However, for houses located in Taman Desa Setapak of Wangsa Maju-Maluri being located within 500 metres of an LRT station reduce the house price by around MYR51,400 to MYR68,500 (orange and red dots).

#### 8.4.2.1.4 Houses within 501-1,000 metres of an LRT Station (NETSTN2)

Results of t-values and parameter estimates from GWR model for houses located within 501-1,000 metres of an LRT station are shown in Figure 8.28. In the global model, the positive significant house price premium is estimated at an average MYR47,800 for houses located within 501-1,000 metres of an LRT station. However, as shown in Figure 8.28, houses located within the same distance appear to have significant positive premiums of between MYR1 and MYR62,900 (yellow and light-green dots) in some areas of Petaling Jaya, and of between MYR62,900 and MYR221,900 (dark-green dots) in Taman Setiawangsa of Wangsa Maju-Maluri. Again, most houses located in Wangsa Maju-Maluri, Bangsar and Kerinchi area are found to exhibit significant negative premiums of between MYR17,000 and MYR30,300 (orange and red dots).

The significant positive premium for those houses in Petaling Jaya is examined further by comparing further between sections. As can be seen from Figure 8.28, the parameter estimate in Petaling Jaya area differs between one location and another adding to the spatial variability of house prices. For example, houses located in Section 6, Section 7, Section 14 and Section 20, Section 22 and Section 52 add between MYR44,100 and MYR62,900 (light-green dots) in price premiums. In contrast, houses located in Section 20 add between MYR1 and MYR44,100 (yellow dots) in price premiums which is lower than the previously mentioned sections. In this example, there is clearly spatial variation of house prices between different locations, suggesting that ignoring this spatial process would result in misleading conclusions of the effect of the LRT system on house prices.

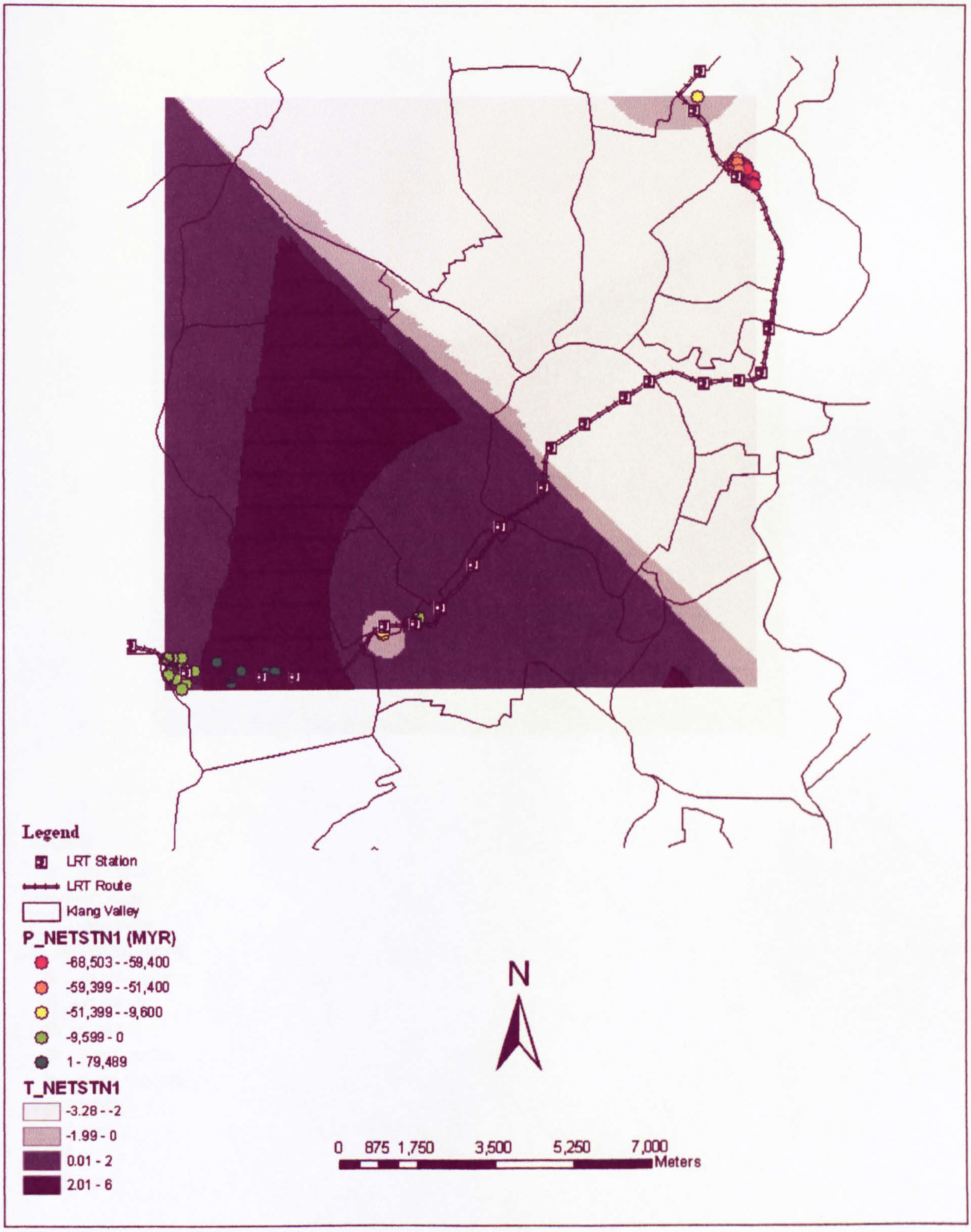



**Figure 8.27**: Map of t-values and parameter estimates associated with variable NETSTN1

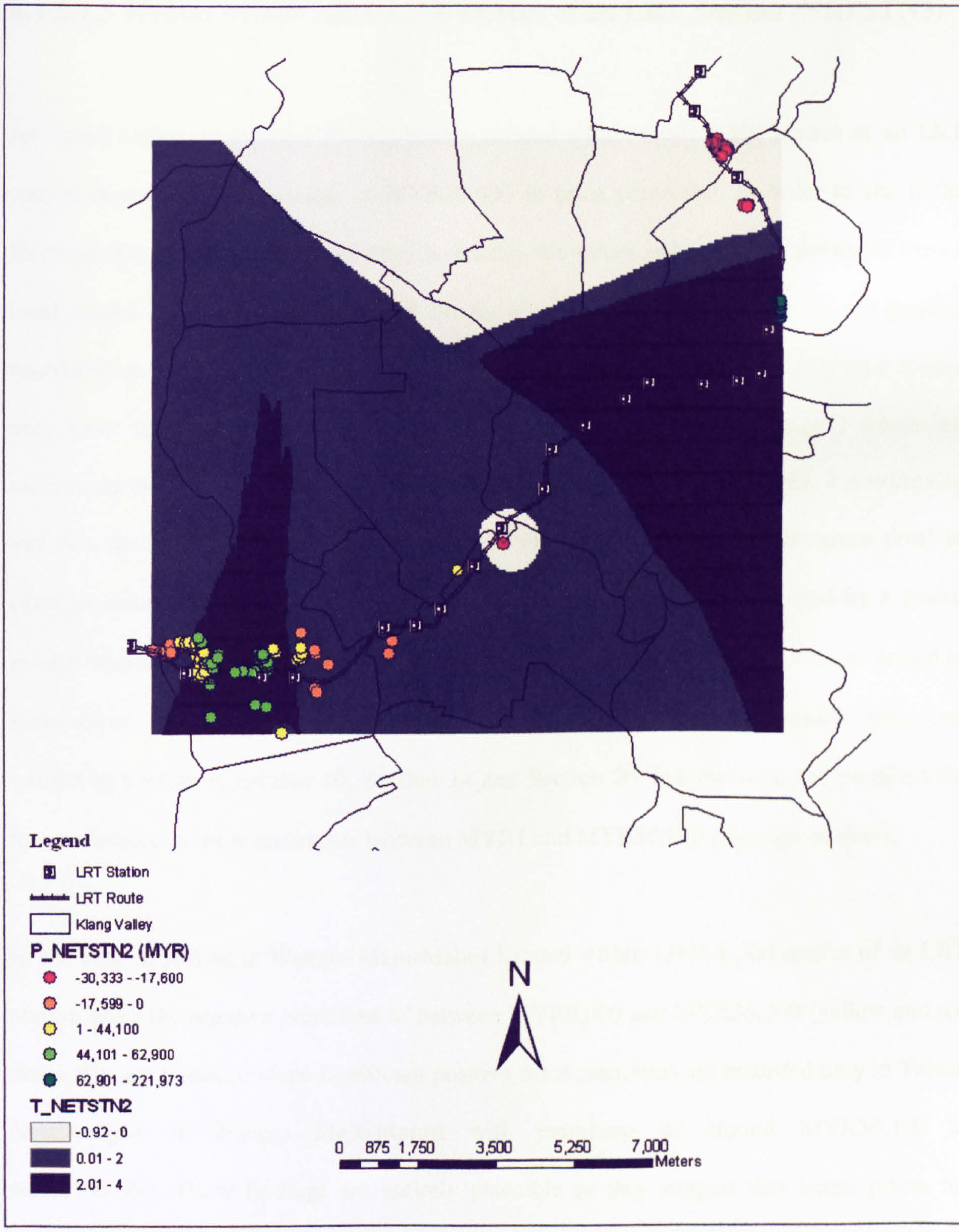



**Figure 8.28**: Map of t-values and parameter estimates associated with variable NETSTN2

### 8.4.2.1.5 Houses within 1,001-1,500 metres of an LRT Station (NETSTN3)

As stated earlier, in a global model, houses located within 1,001-1,500 metres of an LRT station increased at an average of MYR20,600 in price premiums. In order to see if the findings of a global model are reliable, the results of t-values and parameter estimates from a local model are presented in Figure 8.29. As can be seen from Figure 8.29, the positive significant price premiums for houses located within 1,001-1,500 metres of an LRT station only exist in Section 21 of Petaling Jaya, in contrast to the global model where the aforementioned value has been applied over space. As depicted in Figure 8.29, it is estimated that few houses in Section 21 gain between MYR1 and MYR38,100 (light-green dots) in price premiums and these premiums seem to be greater than those estimated by a global model. Moreover, it must be stressed that despite being non-significant for houses located in other areas, there is strong evidence of the considerable differentials positive premiums exhibit in Section 9, Section 10, Section 14 and Section 20. For instance, the premium for houses located in these sections is between MYR1 and MYR38,100 (light-green dots).

In the case of houses in Wangsa Maju-Maluri located within 1,001-1,500 metres of an LRT station gives the negative premiums of between MYR8,000 and MYR36,700 (yellow and red dots). The areas that produce significant positive price premiums are recorded only in Taman Setiawangsa of Wangsa Maju-Maluri with premiums of around MYR38,100 to MYR105,300. These findings are entirely plausible as they suggest that house prices for those houses located in Wangsa Maju-Maluri are not affected by the existence of the LRT system at the time of data collection. The findings in this subsection also suggest that the house premium differences exist when the nature of spatial process is taken into consideration. Most importantly, the results from a local model strongly suggest that the

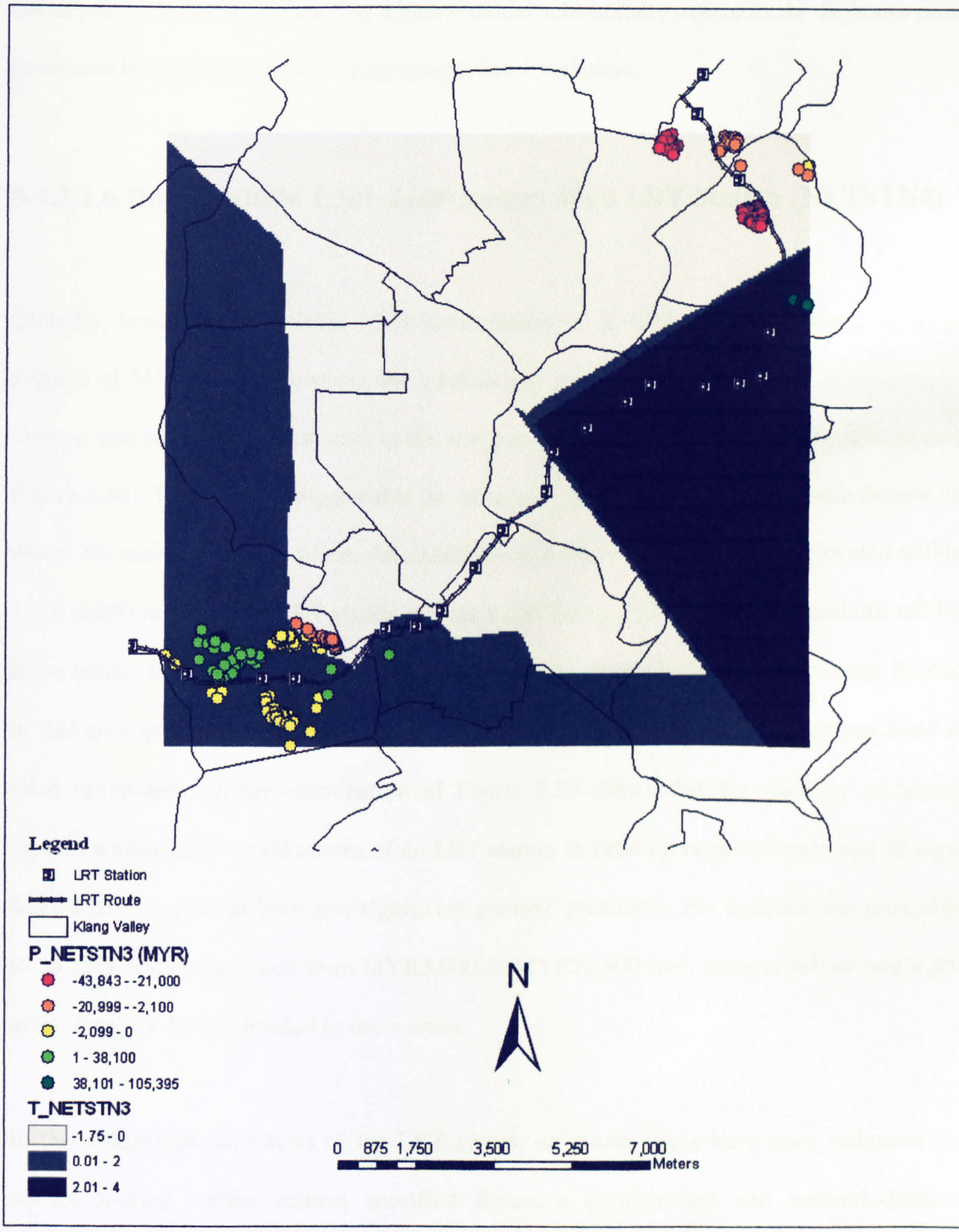



**Figure 8.29**: Map of t-values and parameter estimates associated with variable NETSTN3

house price premiums estimated by a global model substantially overestimate the house price premiums by ignoring the underlying geographical variations.

### 8.4.2.1.6 Houses within 1,501-2,000 metres of an LRT Station (NETSTN4)

Globally, houses located within 1,501-2,000 metres of an LRT station are estimated at an average of MYR35,000. However, the t-values and parameter estimates from a local model showed that house price premiums in the study area operate in a non-stationary fashion (see Figure 8.30). These results suggest that the difference house price premiums make depend on where the estimation takes place. An examination of the t-values for houses located within 1,501-2,000 metres of an LRT station indicates that the significant positive premiums are for those houses located in Section 14 of Petaling Jaya. As shown in Figure 8.30, houses located in this area gain an average of between MYR26,400 and MYR39,400 (dark-green dots) in price premiums. Further examination of Figure 7.30 shows that the majority of houses located within 1,501-2,000 metres of an LRT station in Petaling Jaya, Kerinchi and Wangsa Maju-Maluri appear to have non-significant positive premiums. For instance, the proximity to an LRT station increases from MYR3,000 to MYR26,400 (red, orange, yellow and light-green dots) for houses located in these areas.

In this subsection the effects of the LRT system on house prices have been estimated for houses located within various specified distances (straight-line and network-distance measures) from an LRT station. The GWR technique has been employed to estimate the benefits that residents gain (in terms of house price premiums) in having superior access to an LRT station for both straight-line and network-distance measures. The major benefit of

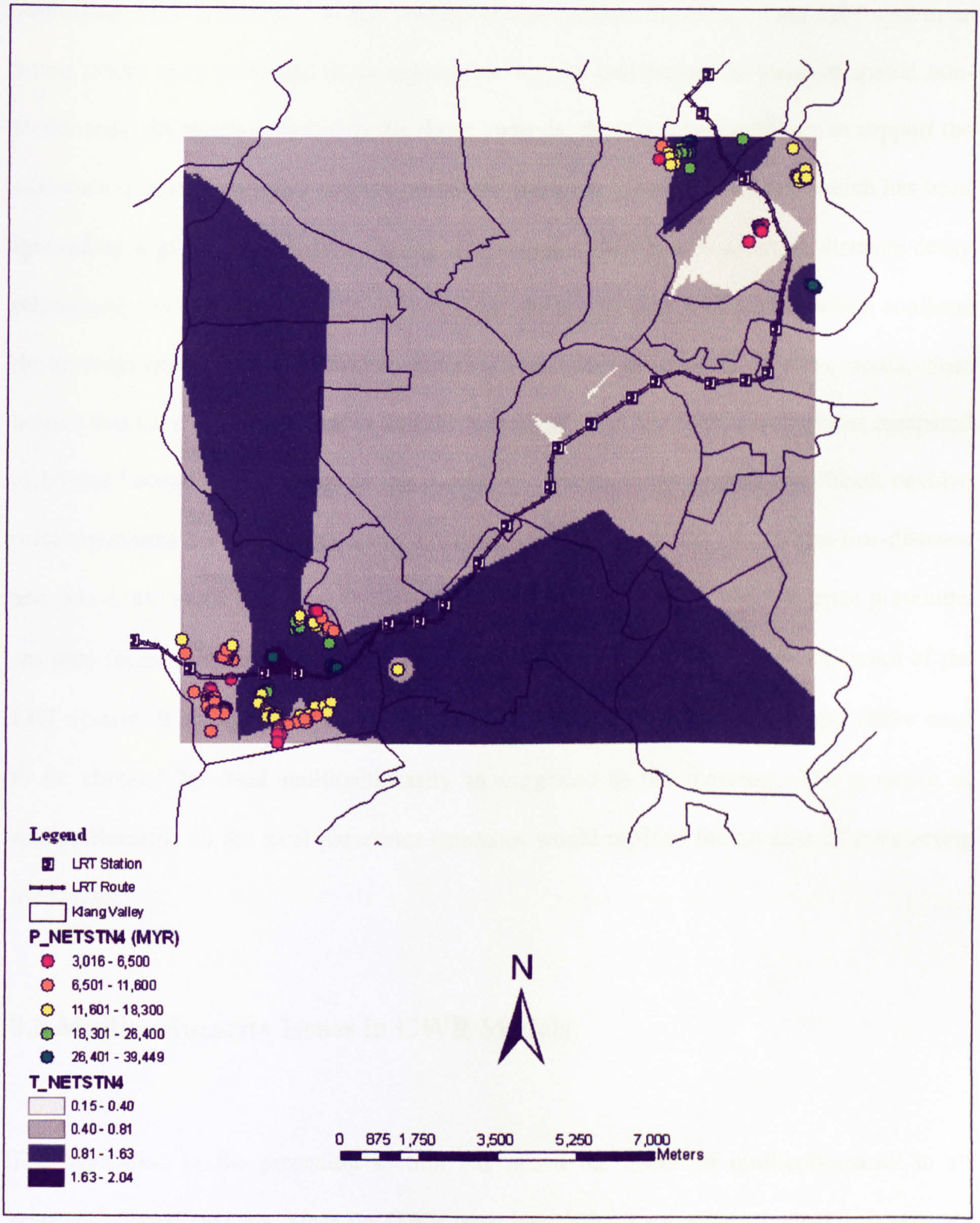



**Figure 8.30**: Map of t-values and parameter estimates associated with variable NETSTN4

employing a GWR technique in this analysis is that it allows the effect of the LRT system on house prices to be measured in an appropriate way by addressing the issue of spatial non-stationarity. As clearly revealed in the above analysis, there is strong evidence to support the existence of spatial variation in price premiums from one location to another which has been ignored by a global model. This finding also suggests that there is a strong distance decay relationship between the values of the house and the access to an LRT station which confirms the findings from a global model but of course with better description. In other words, those houses that have superior access to an LRT station are paid higher price premiums compared to houses located further away. In the context of this study, the highest significant positive price premiums are for houses located within 1,001-1,500 metres of straight-line-distance and 501-1,000 metres of network-distance. However, note that the positive price premiums are only found in some areas, whilst other areas are not yet affected by the existence of the LRT system. It is important to note that the local parameter estimates discussed above need to be checked for local multicollinearity as suggested in the literature. The presence of multicollinearity in the local parameter estimates would mislead the process of interpreting the results.

## 8.5 Multicollinearity Issues in GWR Models

The discussion in the preceding section has raised the issues of multicollinearity in all regression based analysis. Since the GWR technique follows a similar principal, it is sensible to expect the presence of multicollinearity among variables that have been estimated in the GWR model. According to Wheeler and Tiefelsdorf (2005) and Du (2006), multicollinearity is more likely to be found in GWR models than global models. Wheeler and Tiefelsdorf

(2005: pp. 163) argue further that 'evaluating data in GWR for local multicollinearities and pair-wise correlations between sets of local coefficients is even more important than in the traditional global regression model due to the increased complexities of the GWR estimation procedure that potentially induces interrelationships among the local estimates'. These issues have been raised and explored by Wheeler and Tiefelsdorf (2005) and later by Du (2006). Wheeler and Tiefelsdorf (2005) have carried out an analysis based on bladder cancer mortality data. The findings from their analysis showed that the presence of multicollinearity in the GWR model is much stronger than in global models. Du (2006) has arrived at a similar conclusion in the context of the effects of transportation services on house prices in Tyne and Wear in the UK, where she found two parameter estimates to be strongly associated in the GWR model, although it did not occur in the global model.

Based on the two studies mentioned above, there is strong evidence to suggest that mullticollinearity is an issue that can potentially occur in the GWR model. As noted above, ignoring this issue would mislead the interpretations of the local parameter estimates. In relation to this point, the main objective of this section is to examine the potential local multicollinearity in the GWR model as presented in Section 8.3.2 and Section 8.4.2. The question is how to detect the presence of multicollinearity in the GWR model since the current GWR software is not equipped with the diagnostics tool for the above purpose.

Wheeler and Tiefelsdorf (2005) list five multicollinearity detection measures for the GWR model; scatter plots between the local parameter estimates, histograms of local parameter correlations, maps of the local parameter correlations or the local variance inflation factors, scatter plots of correlation between two local kernel weighted independent variables and the local parameter correlations. It has been argued by Du (2006) that the last two approaches require specialised computational procedures. To detect the presence of multicollinearity among transport variables in the GWR model of her study, Du employed scatter plots between the local parameter estimates incorporated into correlation matrix, together with a check of local standard errors. The scatter plots between the local parameter estimates approach seem to be more convenient and proved to be effective to use as demonstrated by Du, and so will be employed in this study.

### 8.5.1 The Examination of Local Multicollinearity in Models 8.1-8.2 and 8.4-8.5

The presence of multicollinearity among local parameter estimates in Models 8.1-8.2 and 8.4-8.5 is detected first by using correlation analysis in SPSS. As mentioned previously, the correlation coefficients above 8.0 indicated serious multicollinearity. The results of a high correlation between local parameter estimates are summarised in Tables 8.8-8.11, whereas the results of other variables are shown in Tables A8.2-8.5 of Appendix G.

**Table 8.8**: Results of highly correlated local parameter estimates in Model 8.1

| Variable 1 | Variable 2 | Correlation coefficient |
|---|---|---:|
| INTERCEPT | CBD | -8.08 |
| FLRAREA | TYPDETCH | -8.15 |
| TYPTRRD | TYPSEMID | 9.39 |
| TYPTRRD | TYPDETCH | 8.85 |
| FLRAREA | PRIMARYSCH | -8.10 |
| TYPSEMID | SECONDARYSCH | -8.03 |
| TYPSEMID | COMMERCIAL | -8.68 |
| TYPSEMID | TYPDETCH | 9.51 |
| TYPDETCH | COMMERCIAL | -8.71 |

**Table 8.9**: Results of highly correlated local parameter estimates in Model 8.2

| Variable 1 | Variable 2 | Correlation coefficient |
|---|---|---|
| TYPTRRD | TYPSEMID | 9.43 |
| FLRAREA | TYPDETCH | -8.10 |
| TYPTRRD | TYPDETCH | 8.87 |
| FLRAREA | PRIMARYSCH | -8.42 |
| TYPSEMID | TYPDETCH | 9.52 |

It can be seen that the presence of multicollinearity between the local parameter estimates is strongly found among intercept and free variables (structural and locational attributes) in Models 8.1 and 8.2 (see Table 8.8). Yet, there no strong correlation is found between focus and other variables in these two models. However, since free variables were also used as the determinants of house prices in this study, the presence of multicollinearity between local parameter estimates among these variables should also be examined in order to avoid incorrect interpretation the spatial patterns of local GWR parameters. In relation to this point, the local parameter estimates of the variables listed above are examined further in scatter plots (see Appendix H). As can be seen from Figures H.1 to H.12, there is a strong linear relationship between the two parameters, confirming the finding from the correlation analysis.

In the case of the Models 8.4 and 8.5 (various specified distance from an LRT station), the correlation between a pair of variables can be found among intercept, focus and free variables. As shown in Table 8.11 below, there is a strong relationship between parameters of NETSTN3 and NETSTN4 ($r = 0.85$) and also between other parameters. For this, scatter plots are employed to further examine the pattern of relationships between these variables as highlighted in the pair-wise correlation matrix (see Appendix I).

**Table 8.10**: Results of highly correlated local parameter estimates in Model 8.4

| Variable 1 | Variable 2 | Correlation coefficient |
|---|---|---|
| INTERCEPT | CBD | -8.08 |
| FLRAREA | TYPDETCH | -8.05 |
| FLRAREA | PRIMARYSCH | 8.23 |
| TYPTRRD | TYPSEMID | 9.39 |
| TYPTRRD | TYPDETCH | 9.02 |
| TYPTRRD | CBD | 8.44 |
| TYPTTRD | COMMERCIAL | 8.30 |
| TYPSEMID | TYPDETCH | 9.54 |
| TYPSEMID | COMMERCIAL | -9.22 |
| TYPDETCH | COMMERCIAL | -9.34 |
| PARK | RECREATION | -8.91 |

**Table 8.11**: Results of highly correlated local parameter estimates in Model 8.5

| Variable 1 | Variable 2 | Correlation coefficient |
|---|---|---|
| NETSTN2 | NETSTN3 | 8.99 |
| NETSTN4 | MALAY | 8.16 |
| FLRAREA | TYPDETCH | 8.48 |
| TYPTRRD | TYPSEMID | 9.36 |
| TYPTRRD | TYPDETCH | 8.93 |
| TYPTRRD | CBD | 8.10 |
| TYPSEMID | TYPDETCH | 9.56 |
| TYPSEMID | COMMERCIAL | 8.57 |
| TYPDETCH | COMMERCIAL | 8.61 |

Acknowledging the presence of multicollinearity between a pair of local parameter estimates, the next subsection will examine the effects of the LRT system on house prices with fewer variables. The logic behind this approach is that since the local parameter estimates are found to be affected by serious multicollinearity, the removal of a few independent variables from the final model might help to overcome this problem. Note that the results of this analysis will be compared to the results from the previous models. However, the attention will be paid to interpreting the results of GWR model since it has suffered from local multicollinearity.

### 8.5.2 The Findings: Models 8.1-8.2 vs. Models 8.6-8.7

As noted above, the examination of the effects of the LRT system on house prices in this subsection is carried out with fewer variables. Using the same approach that has been set out in the previous model, the model for straight-line distance can be stated as:

$$LnP_i = \alpha_0 + \alpha_1 STRDIST_i + \alpha_2 FLRAREA_i + \alpha_3 BEDS_i + \alpha_4 LnSECONDARYSCHi + \alpha_5 LnHOSPITAL_i + \alpha_6 LnINDUSTRY_i + \varepsilon_i \qquad (8.6)$$

where $i$ is the subscript denoting each property; $P_i$ is the price of property $i$ in Malaysia Ringgit (MYR); Ln is natural logarithm; STRDIST is the straight-line distance from the property to an LRT station measured in metres; FLRAREA is the floor area of the property in square feet; BEDS is the number of bedrooms of the property; SECONDARYSCH, HOSPITAL, and INDUSTRY are the network-distance from the property to Kuala Lumpur's secondary schools, hospitals and industrial areas. These variables are all measured in metres. Finally, $\alpha$ denotes a parameter to be estimated; and $\varepsilon$ denotes standard error of the estimation.

Similarly, the model for network-distance can be stated as:

$$LnP_i = \alpha_0 + \alpha_1 NETDIST_i + \alpha_2 FLRAREA_i + \alpha_3 BEDS_i + \alpha_4 LnSECONDARYSCHi + \alpha_5 LnHOSPITAL_i + \alpha_6 LnINDUSTRY_i + \varepsilon_i \qquad (8.7)$$

where the difference between perceived distance to a station and actual distance to a station is given NETDIST: the network-distance from the property to an LRT station measured in metres. Finally, note that the variables used above are free from global multicollinearity after examining with pair-wise correlation matrix. The next stage of the analysis is to examine the presence of multicollinearity between a pair of local parameter estimates.

### 8.5.2.1 The Examination of Local Multicollinearity in Models 8.6-8.7

The collinearity index between a pair of local parameter estimates for both models (straight-line and network-distance) is presented in Table A8.6 and 8.7 of Appendix J. The findings from this analysis show that there no serious multicollinearity exists between a pair of local parameter estimates used in this analysis. This suggests that when fewer variables were used to estimate the effects of the LRT on house prices, the local parameter estimates seems to be less affected by multicollinearity.

### 8.5.2.2 The Results of Global Model

The discussion in this subsection provides a comparison between Models 8.1 and 8.2, and Models 8.6 and 8.7 in which the latter has fewer variables. Table 8.12 presents the summary of the parameter estimates of Models 8.6 and 8.7 – basic models for straight-line and network-distance measures.

**Table 8.12:** The traditional hedonic specification of Model 8.6 and Model 8.7

| Vector | Predictor | Straight-line distance (Model 8.6) | | | | Network distance (Model 8.7) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Coefficient | Standard error | t-value | VIF | Coefficient | Standard error | t-value | VIF |
| | Constant | 1303.52 | 1.24 | 32.95 | | 1306.79 | 1.25 | 33.46 | |
| | | *(35667.67)* | *(1.74)* | *(18.85)* | | *(43739.2)* | *(1.76)* | *(18.89)* | |
| Focus variables | *STRDIST* | -16.17 | 5.28 | -3.05 | 1.32 | | | | |
| | | *(-10.56)* | *(4.95)* | *(-2.16)* | *(1.85)* | | | | |
| | *NETDIST* | | | | | -25.40 | 4.55 | -5.98 | 1.50 |
| | | | | | | *(-6.61)* | *(3.03)* | *(-2.31)* | *(1.70)* |
| Structural variables | *FLRAREA* | 350.41 | 9.06 | 39.30 | 1.82 | 353.43 | 8.55 | 40.32 | 1.79 |
| | | *(310.63)* | *(13.09)* | *(24.07)* | *(6.23)* | *(312.65)* | *(13.09)* | *(23.99)* | *(6.35)* |
| | *BEDS* | 31373.39 | 4466.77 | 6.94 | 1.52 | 32247.96 | 4466.77 | 7.23 | 1.50 |
| | | *(31485.34)* | *(3922.05)* | *(8.01)* | *(1.87)* | *(31594.29)* | *(3922.04)* | *(8.06)* | *(1.87)* |
| Locational variables | *SECONDARYSCH* | -41.24 | 5.37 | -7.51 | 1.21 | -37.65 | 5.37 | -7.12 | 1.15 |
| | | *(-11.11)* | *(4.66)* | *(-2.40)* | *(1.41)* | *(-11.11)* | *(4.66)* | *(-2.36)* | *(1.41)* |
| | *HOSPITAL* | 4.87 | 1.10 | 4.38 | 1.48 | 7.36 | 1.19 | 6.09 | 1.74 |
| | | *(3.40)* | *(1.29)* | *(2.64)* | *(3.27)* | *(3.58)* | *(1.28)* | *(2.73)* | *(3.32)* |
| | *INDUSTRY* | 42.44 | 3.72 | 11.43 | 1.09 | 39.60 | 3.72 | 10.71 | 1.10 |
| | | *(28.22)* | *(3.72)* | *(7.74)* | *(1.70)* | *(26.91)* | *(3.71)* | *(7.23)* | *(1.80)* |
| | | $R^2$ (adj.) = 65.0 per cent<br>*($R^2$ (adj.) = 78.2 per cent)* | | | | $R^2$ (adj.) = 65.0 per cent<br>*($R^2$ (adj.) = 78.2 per cent)* | | | |

To aid comparison, the results of the parameters in the previous models will be shown in brackets. Using a similar approach that has been set out in describing the previous models, continuous independent variables were deviated around their means. That is, the models were estimated with respect to the average property size of 651.35 square feet. It can be seen from Table 8.12 that the results of both models show that most of predictors have produced correct signs (positive or negative) as theoretically expected and significance at the 0.01 and 0.05 level.

In terms of the $R^2$ statistic, the model explains the variation of the house price within two kilometres of an LRT station in the Klang Valley for both straight-line and network-distance models with 65.0 per cent, which is less than Models 8.1 and 8.2. This is due to the number of variables used in Models 8.6 and 8.7 being fewer than variables used in Models 8.1 and 8.2.

### 8.5.2.2.1 Value of the LRT System

As can be seen from Table 8.12, for every metre away from an LRT station, the value of a residential property reduces by MYR16.17 of straight-line-distance model and MYR25.40 of network-distance model which is greater than Models 8.1 and 8.2 (in the Models 8.1 and 8.2 for every metre away from an LRT station, the value of a residential property was reduced by MYR10.56 and MYR6.61 for both straight-line and network-distance models respectively). As for the magnitude of effect, the LRT system has significantly contributed at -3.05 and -5.98 (t-value of straight-line-distance and network-distance models respectively) as compared to the -2.16 and -2.31 (t-value of straight-line-distance and network-distance models respectively in Models 8.1 and 8.2) in determining house prices in the study area.

#### 8.5.2.2.2 Value of Structural Attributes

In Models 8.6 and 8.7, for every square-foot increase in the floor area, the house price increases on average around MYR350.41 for straight-line-distance model and of approximately MYR353.43 for network-distance model which is slightly higher than Models 8.1 and 8.2 by MYR310.63 and MYR312.65 for both straight-line and network-distance models respectively. In the case of the number of bedrooms, for one additional bedroom of a property, for both Models 8.6 and 8.7, positive premiums can add on average MYR31,000 to the house prices which is equivalent to the Models 8.1 and 8.2.

#### 8.5.2.2.3 Value of Locational Attributes

The parameter estimates for proximity to secondary schools is statistically significant with the correct sign for both models. The interpretation that can be made is for every metre away from secondary schools, house prices are reduced at an average of MYR41.24 of straight-line-distance model and MYR37.65 of network-distance model, which is also found to be higher than Models 8.1 and 8.2 where it has been estimated at an average of MYR11. The implicit price for proximity to hospitals suggests that for every metre away from hospitals, house prices would generally increase by about MYR4.87 for straight-line-distance model and MYR7.36 for network-distance model – once again this is higher than the value estimated in Models 8.1 and 8.2 – house prices are estimated to increase by around MYR3.40

and MYR3.58. Proximity to industrial areas is also to be found statistically significant in determining house prices with expected signs. House prices increase at an average of MYR42.44 for every metre away from industrial areas of straight-line-distance model and MYR39.60 of network-distance model which is also higher than the value estimated for the previous two models. Next, the effects of the LRT system on house prices is analysed further in the local model.

### 8.5.2.3 The Results of GWR Model

Tables 8.13 and 8.14 illustrate diagnostic information of the GWR estimation for Models 8.6 and 8.7. Since the main objective of conducting this analysis is to compare with the previous models, the results of GWR estimation in the previous models are shown in brackets. As illustrated in Tables 8.13 and 8.14 below, the adjusted $R^2$ has increased from 65.0 per cent for both models in a global model to 83.0 per cent for both models in the GWR model.

However, these values are obviously lower than the values obtained for Models 8.1 and 8.2. In other words, Models 8.1 and 8.2 are better than Models 8.6 and 8.7 in explaining house price variations in the study. In addition, the reduction in the AIC from 1205.42 and 1213.69 for straight-line-distance model and network-distance model – in that order in a global model to 60.47 and 53.51 for both models in the GWR model suggests that the local model is better than a global model, after taking into account degrees of freedom. In contrast, Models 8.1 and 8.2 have a lower AIC for both global and GWR models, suggesting that it is better than Models 8.6 and 8.7. As noted previously, this is due to the fewer number of variables used to estimate the LRT-house price relationship in Models 8.6 and 8.7. Although the former models seem to be better than the latter, the local parameter estimates of the latter models are far less disturbed by multicollinearity, particularly for the free variables. Hence, as far as local multicollinearity is concerned, Models 8.6 and 8.7 are better than Models 8.1 and 8.2.

**Table 8.13**: The results of GWR estimation for Model 8.6

| Global Model Estimation | |
|---|---|
| *Diagnostic information* | |
| Residual sum of squares | 196.37 (119.66) |
| Effective number of parameters | 7.00 (18.00) |
| Sigma | 35.33 (27.80) |
| Akaike Information Criterion | 1205.42 (445.15) |
| Coefficient of determination | 64.58 (78.40) |
| Adjusted $R^2$ | 65.00 (78.20) |

| GWR estimation | |
|---|---|
| *Fitting geographically weighted regression model* | |
| Number of observations | 1580.00 |
| Number of independent variables (intercept is variable 1) | 7.00 |
| Number of locations to fit model | 1580.00 |
| *Diagnostic information* | |
| Residual sum of squares | 88.42 (60.35) |
| Effective number of parameters | 62.22 (118.93) |
| Sigma | 24.23 (20.32) |
| Akaike Information Criterion | 60.47 (-415.17) |
| Coefficient of determination | 84.05 (89.10) |
| Adjusted $R^2$ | 83.39 (88.20) |

| Source | ANOVA | | | |
|---|---|---|---|---|
| | Sum of squares | Degrees of freedom | MS | F-value |
| OLS residuals | 196.40 (119.70) | 7.00 (18.00) | | |
| GWR improvement | 108.00 (59.30) | 55.22 (100.93) | 1.95 (0.58) | |
| GWR residuals | 88.40 (60.30) | 1517.78 (1461.07) | 0.05 (0.04) | 33.55 (14.22) |

**Table 8.14**: The results of GWR estimation for Model 8.7

| Global Estimation | |
|---|---|
| *Diagnostic information* | |
| Residual sum of squares | 197.40<br>(119.61) |
| Effective number of parameters | 7.00<br>(18.00) |
| Sigma | 35.42<br>(27.67) |
| Akaike Information Criterion | 1213.69<br>(444.38) |
| Coefficient of determination | 64.39<br>(78.40) |
| Adjusted $R^2$ | 65.00<br>(78.20) |

| GWR Estimation | |
|---|---|
| *Fitting geographically weighted regression model* | |
| Number of observations | 1580.00 |
| Number of independent variables (intercept is variable 1) | 7.00 |
| Number of locations to fit model | 1580.00 |
| *Diagnostic information* | |
| Residual sum of squares | 88.04<br>(61.18) |
| Effective number of parameters | 62.12<br>(118.85) |
| Sigma | 24.08<br>(20.29) |
| Akaike Information Criterion | 53.51<br>(-419.89) |
| Coefficient of determination | 84.11<br>(89.10) |
| Adjusted $R^2$ | 83.46<br>(88.20) |

| Source | *ANOVA* | | | |
|---|---|---|---|---|
| | Sum of squares | Degrees of freedom | MS | F-value |
| OLS residuals | 197.40<br>(119.60) | 7.00<br>(18.00) | | |
| GWR improvement | 109.40<br>(59.40) | 55.13<br>(100.85) | 1.98<br>(0.58) | |
| GWR residuals | 88.00<br>(60.20) | 1517.87<br>(1461.15) | 0.05<br>(0.04) | 34.19<br>(14.31) |

Using the similar format that has been set out in the preceding models, the t-values of STRDIST, NETDIST, FLRAREA, BEDS, SECONDARYSCH, HOSPITAL and

INDUSTRY are classified into four bands. The darkest areas indicate significant negative t-values while the lightest areas indicate significant positive t-values.

However, the areas between these two indicate non-significant negative and positive t-values. Similarly in the subsequent maps, the parameter estimates are classified by five bands using coloured dots indicating negative and positive premium added to the house price in Malaysia Ringgit (MYR). As mentioned previously, negative parameter estimates for STRDIST, NETDIST, SECONDARYSCH, HOSPITAL and INDUSTRY should be interpreted as positive premiums for house prices, while a positive parameter should be interpreted as negative premiums. However, negative and positive parameter estimates for FLRAREA and BEDS should be interpreted as they are.

Since the focus of this subsection is to compare with the previous models, Figures 8.27 to 8.32 will be interpreted against their counterparts in the previous models. However, before addressing this issue, let us first examine the results from a global model as compared to the local model that has been investigated in this subsection.

### 8.5.2.3.1 Value of the LRT System

The global results show for every metre away from an LRT station, house prices decrease at an average of MYR16.17 of straight-line-distance model and MYR25.40 of network-distance model. Once again, Figures 8.31 and 8.32 below demonstrate that the significant negative t-values are found in some areas, whilst other areas show insignificant t-values. However, as clearly depicted in Figure 8.31, the rent gradient for each unit of house from an LRT station is found to be lower in value when it was measured by straight-line-distance as compared to the network-distance measures. This implies that network-distance measures (actual distance that people travel to reach an LRT station from home) is found to be more effective in measuring the effects of the LRT system on house prices, at least in the context of this study.

The figure shows a slightly different distribution of t-values and parameter estimates between Models 8.1 and 8.2, and Models 8.6 and 8.7. In the case of Models 8.6 and 8.7, the significant negative t-values are found in several sections in Petaling Jaya, Kerinchi, Bangsar and houses located in the Taman Setiawangsa housing estate in Wangsa Maju-Maluri area. However, in the case of Models 8.1 and 8.2, the significant negative t-values were only found in the Petaling Jaya area. The figure also shows that the distribution of the parameter estimates between Models 8.6 and 8.7 is different from Models 8.1 and 8.2. For instance, several of the high-rise units located in the Bangsar and Kerinchi area were estimated either not or not yet affected by the existence of the LRT system (see Figures 8.8 and 8.9). Yet, the local parameter estimates of Models 8.6 and 8.7 show these high-rise units are estimated to decrease in value for every metre away from an LRT station (see Figures 8.31 and 8.32). This is somehow capturing the reality of the area after considering the background of demography and transportation facilities of the area. This is the same approach adopted to understand the effect of the LRT systems towards the houses located in Wangsa Maju-Maluri – in which, it has been observed that there is no effect accounted by the existence of the LRT system towards the prices of these houses. However, further examination of Figures 8.31 and 8.32 found that the positive house price premiums indicated by red, orange and yellow dots appear in greater numbers than the previous figures in Wangsa Maju-Maluri with significant t-values found for the Taman Setiawangsa housing estate.

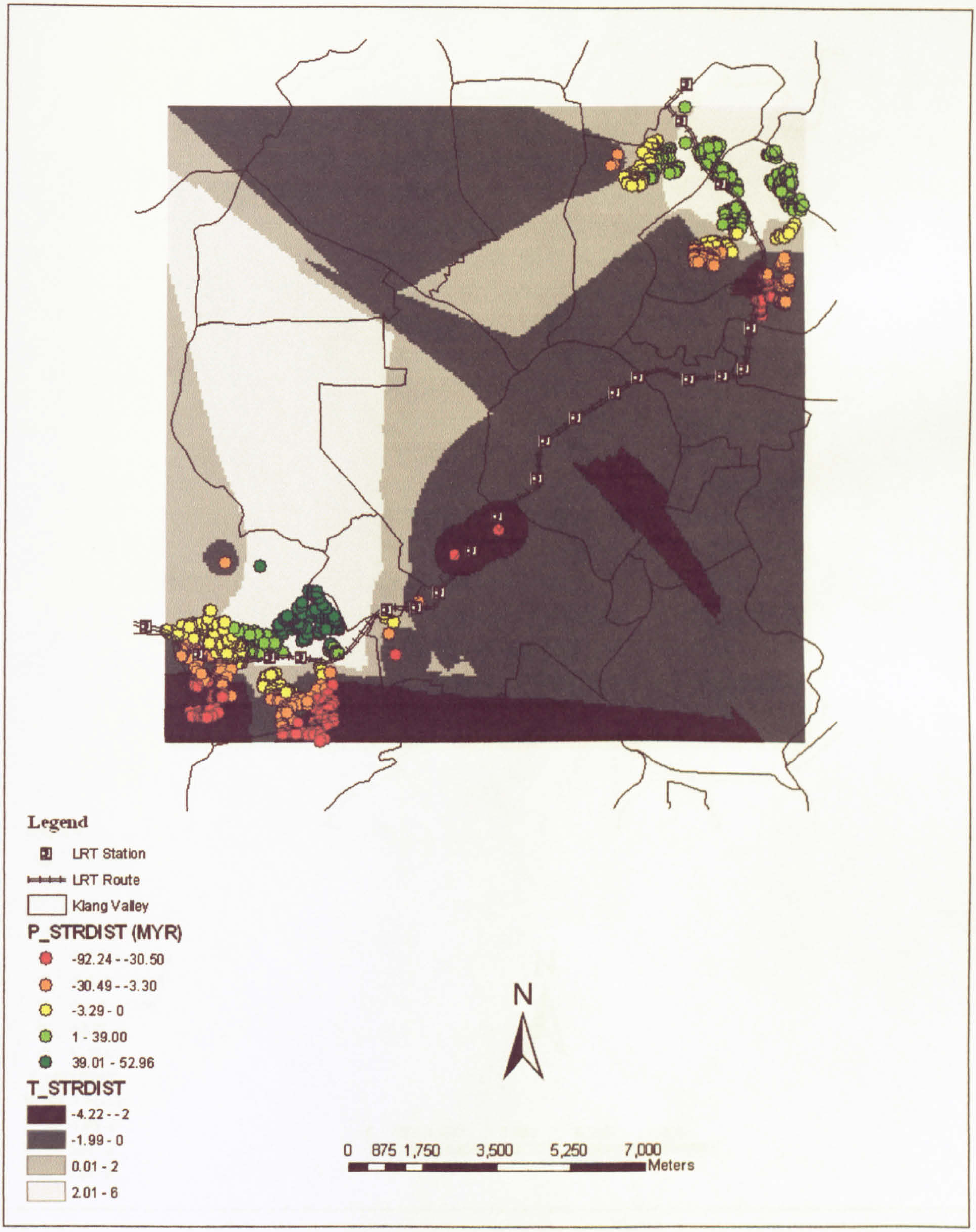



**Figure 8.31**: Map of t-values and parameter estimates associated with variable STRDIST

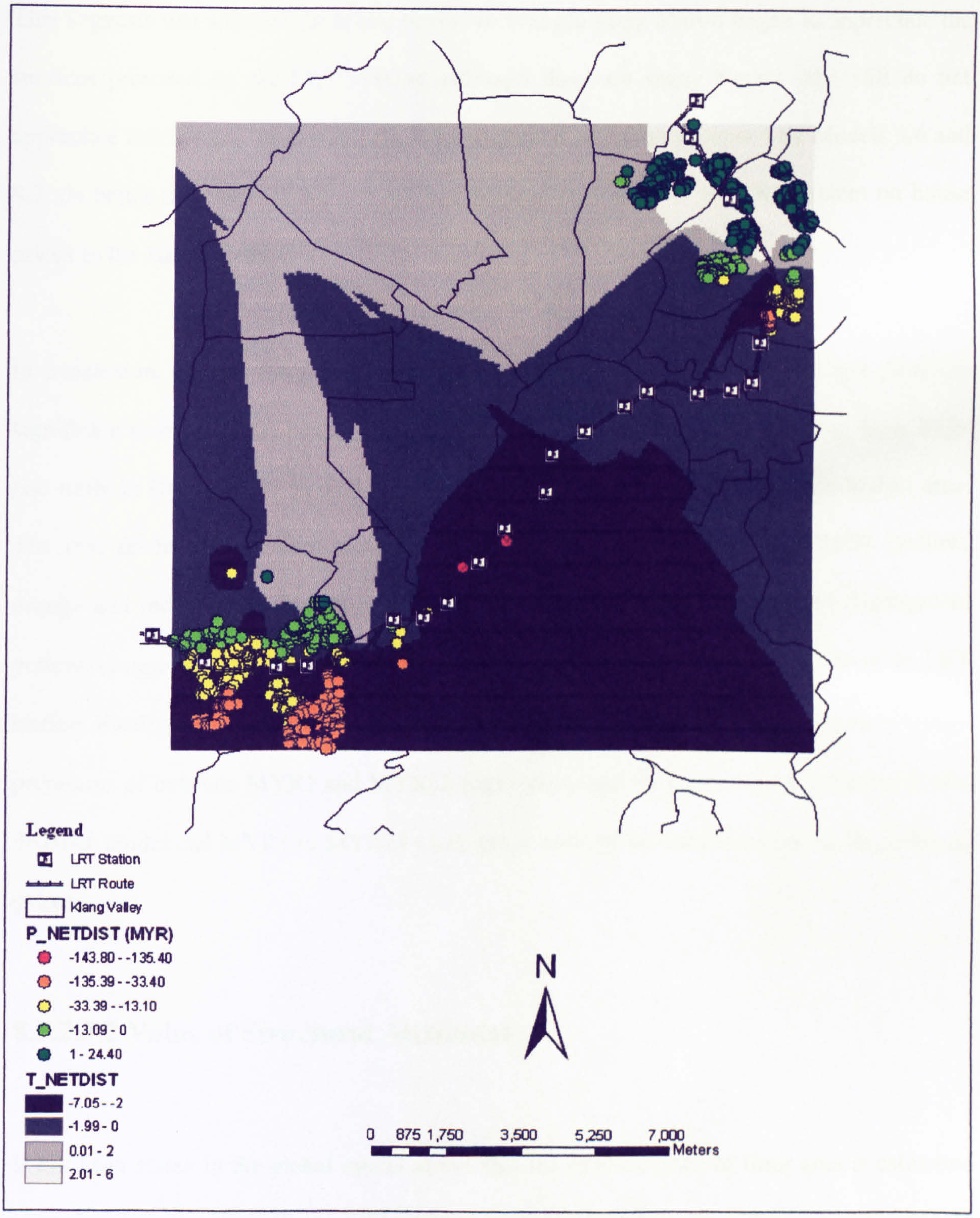



**Figure 8.32**: Map of t-values and parameter estimates associated with variable NETDIST

This suggests that some of the house buyers in Wangsa Maju-Maluri began to appreciate the services provided by the LRT system, although there are many buyers who still do not appreciate this service. In general, the local parameter estimates produced by Models 8.6 and 8.7 are better than Models 8.1 and 8.2 in capturing the effects of the LRT system on house prices in the Klang Valley.

In conclusion, Models 8.6 and 8.7 suggest that the existence of the LRT system produces significant positive house price premiums for the majority of houses in Petaling Jaya, high-rise units in Bangsar and Kerinchi, and some houses located in Wangsa Maju-Maluri area. The rent gradient for houses located in these areas are from MYR3 to MYR92 (yellow, orange and red dots) of straight-line-distance model and MYR13 to MYR143 (light-green, yellow, orange and red dots) of network-distance model for every metre away from an LRT station. Finally, note that most of the houses located in Wangsa Maju-Maluri exhibit negative premiums of between MYR1 and MYR52 (light-green and dark-green dots) of straight-line-distance model and MYR1 to MYR24 (dark-green dots) of network-distance model on house prices.

### 8.5.2.3.2 Value of Structural Attributes

It has been stated in the global model above that the implicit price of floor area is estimated at approximately MYR350.41 and MYR353.43 for both straight-line-distance and network-distance models respectively. In contrast to the global model, the implicit price of floor area is estimated to vary between locations in which some locations exhibit lower implicit prices than a global model and others exhibit higher implicit prices than a global model. For instance, the implicit price of floor area for two high-rise units located in Petaling Jaya is estimated at an average of between MYR216 and MYR243 (red dots) for every square-foot increase. However, it can be seen from Figure 8.33 that the implicit price of floor area for the majority of houses located in Petaling Jaya is estimated at around MYR243 to MYR400 (orange dots) which is in line with the estimation made in a global model. It can also be seen in the figure below that the implicit price of floor area for the majority of houses located in Wangsa Maju-Maluri area is estimated to be around MYR400 to MYR689 (yellow, light-green and dark-green dots) for every square-foot increase which is obviously greater than the estimation made in a global model.

In comparison to Figure 8.11, it is clear that a similar pattern of implicit price of floor area demonstrated in Figure 8.33 in which the floor area for houses located in the Wangsa Maju-Maluri area is estimated higher than in the Petaling Jaya. However, the only difference that can be pointed out is that the implicit price of floor area for the majority of houses located in Section 14, Section 20 and Section 21 of Petaling Jaya are estimated at approximately MYR243 to MYR400 (orange dots) which is higher than in the previous models where it has been estimated at around MYR16 to MYR155 for every square-foot increase. These differences can be associated to the less number of variables that are using in the latter model.

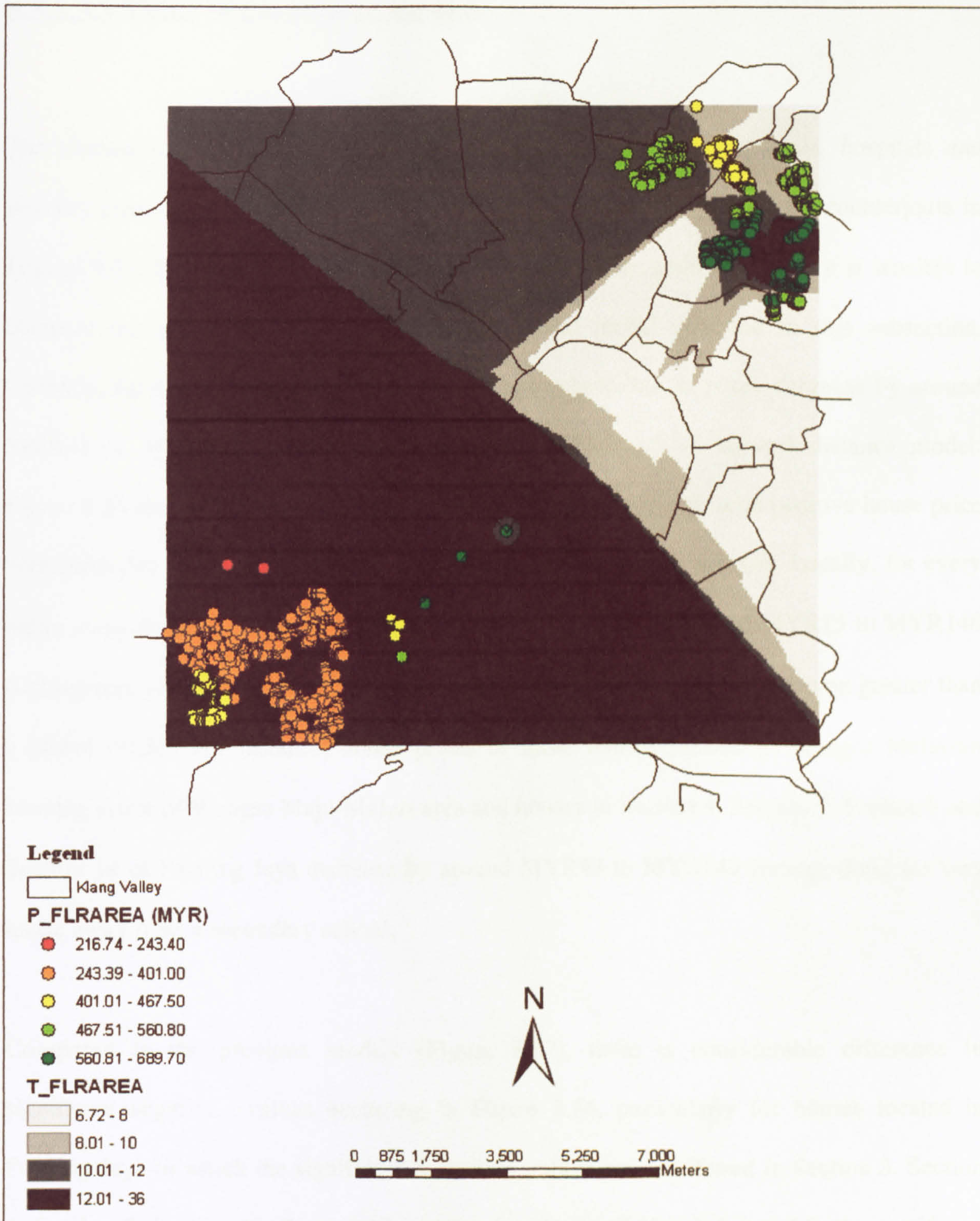



**Figure 8.33**: Map of t-values and parameter estimates associated with variable FLRAREA

#### 8.5.2.3.3 Value of Locational Attributes

The discussion continues by comparing the effects of secondary schools, hospitals and industry areas on house prices (as shown in Figures 8.34-8.37) against their counterparts in Figures 8.17, 8.19 and 8.22 – in that order. However, before addressing this, it is sensible to compare the results of local models with a global model obtained in this subsection. Globally, for every metre away from a secondary school, house prices decrease by around MYR41.24 of straight-line-distance model and MYR37.65 of network-distance model. Figure 8.34 shows that the majority of houses in the region emerge with positive house price premiums due to the educational service provided by secondary schools. Locally, for every metre away from a secondary school house prices decrease by around MYR15 to MYR148 (light-green, yellow, orange and red dots), and the effects for some areas is even greater than a global model. For instance, house prices of those houses located in Wangsa Melawati housing estate of Wangsa Maju-Maluri area and houses in Section 4, Section 7, Section 8 and Section 14 of Petaling Jaya decrease by around MYR44 to MYR148 (orange dots) for very metre away from a secondary school.

Compared to the previous models (Figure 8.17), there is considerable difference in significant negative t-values occurring in Figure 8.34, particularly for houses located in Petaling Jaya in which the significant negative t-values are only found in Section 3, Section 4, Section 7, Section 11, Section 12 and Section 52. In Models 8.6 and 8.7, the significant negative t-values are also found in Section 14 and Section 22 of Petaling Jaya, together with the aforementioned areas. Yet, there is no difference in the patterns shown for houses located in the Wangsa Maju-Maluri area.

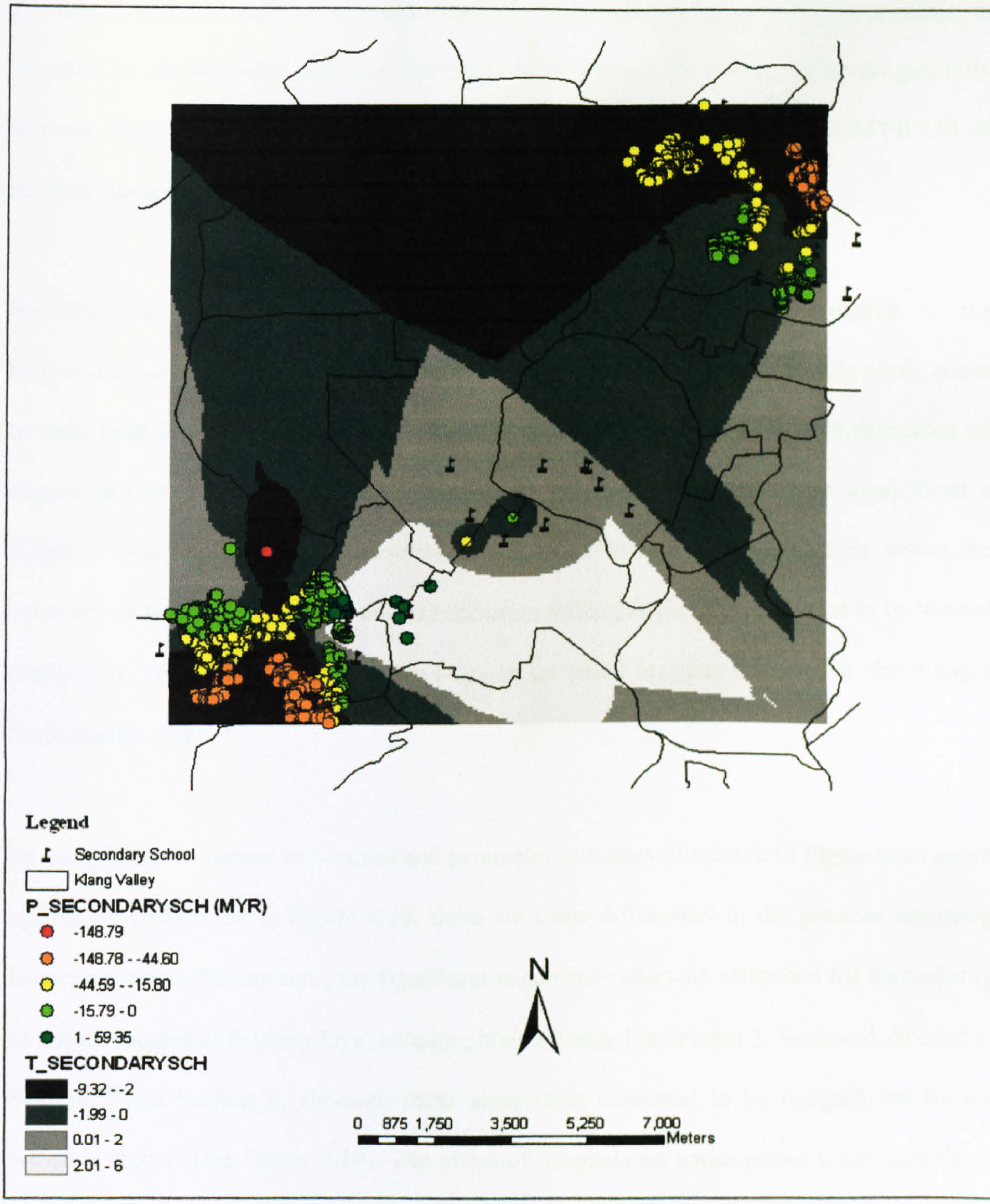



**Figure 8.34**: Map of t-values and parameter estimates associated with variable SECONDARYSCH

The other locational attributes that also contribute to determining house prices is proximity to hospitals. A global model indicates that every metre away from a hospital would generally increase house prices around MYR4.87 of straight-line-distance model and MYR7.36 of network-distance model.

However, the results of local models show that the existence of hospitals in the neighbourhood is bringing about positive premiums to the house prices in some areas. It can be seen from Figure 8.35 above that houses located in the Petaling Jaya have decreased by around MYR4 to MYR53 (yellow, orange and red dots) for every metre away from a hospital. This implies that the majority of buyers of houses in Petaling Jaya assess the existence of hospitals positively, and are therefore willing to pay a higher price to be located closer to it. Yet no significant negative t-values are found for houses located in the Wangsa Maju-Maluri area.

By comparing the pattern of t-values and parameter estimates illustrated in Figure 8.36 above against its counterpart in Figure 8.19, there are some differences in the patterns occurring between the two. For instance, the significant negative t-values are estimated for the majority of houses located in Petaling Jaya including houses located in Section 3, Section 4, Section 6, Section 7 and Section 8, although these areas were estimated to be insignificant by the previous models (see Figure 8.19). The effect of hospitals on house prices is not significant for houses located in the Wangsa Maju-Maluri area which is similar to the outcome in the previous models.

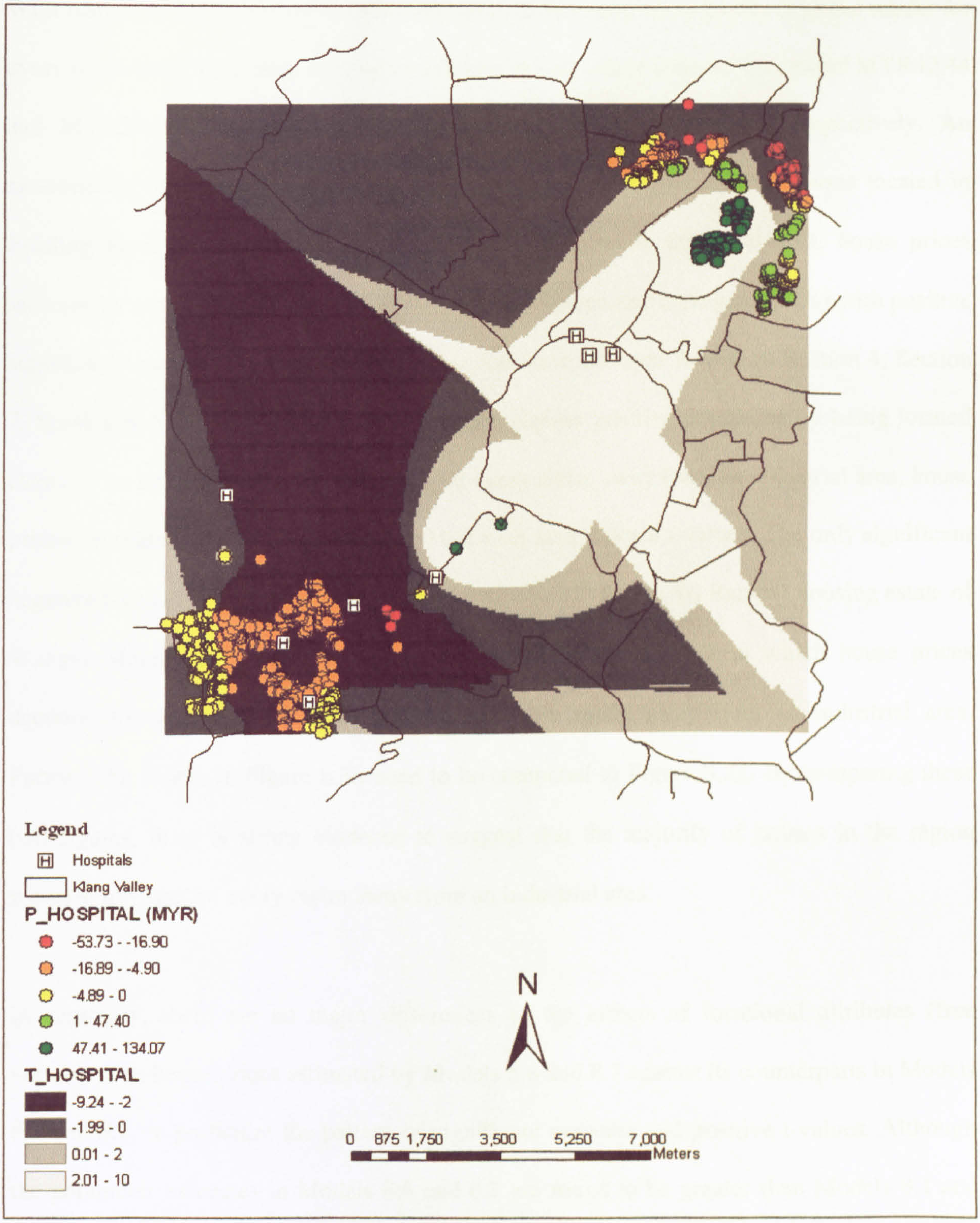



**Figure 8.35**: Map of t-values and parameter estimates associated with variable HOSPITAL

With respect to the proximity to industrial areas, it has been estimated by a global model for every metre away from an industrial area, house prices would increase by around MYR42.44 and MYR39.60 of straight-line-distance and network-distance models respectively. An examination of Figure 8.36 suggests that this is true for the majority of houses located in Petaling Jaya. For instance, for every metre away from an industrial area, house prices increase by around MYR1 to MYR98 (yellow, light-green and dark-green dots) with positive significant t-values. The result also suggests that there are some houses in Section 4, Section 7, Section 8, Section 14 and Section 22 which capture positive premiums by being located closer to an industrial area. For instance, for every metre away from an industrial area, house prices decrease by MYR25 (orange dots) but with insignificant t-values. The only significant negative t-values are estimated for houses located in the Taman Sri Rampai housing estate of Wangsa Maju-Maluri and two high-rise units located in Bangsar in which house prices decrease by around MYR25 to MYR64 for every metre away from an industrial area. Further, the results in Figure 8.36 need to be compared to Figure 8.22. By comparing these two figures, there is strong evidence to suggest that the majority of houses in the region increase in value for every metre away from an industrial area.

In summary, there are no major differences in the effects of locational attributes (free variables) on house prices estimated by Models 8.6 and 8.7 against its counterparts in Models 8.1 and 8.2, in particular the pattern of significant negative and positive t-values. Although the parameter estimates in Models 8.6 and 8.7 are found to be greater than Models 8.1 and 8.2, this is due to the fact that the number of variables used to estimate house prices in the latter models are fewer than the former models, hence it would affect the value and magnitude of the effect. The discussion in the subsection is continued by examining the effects of the LRT system on house prices for various specified distances.

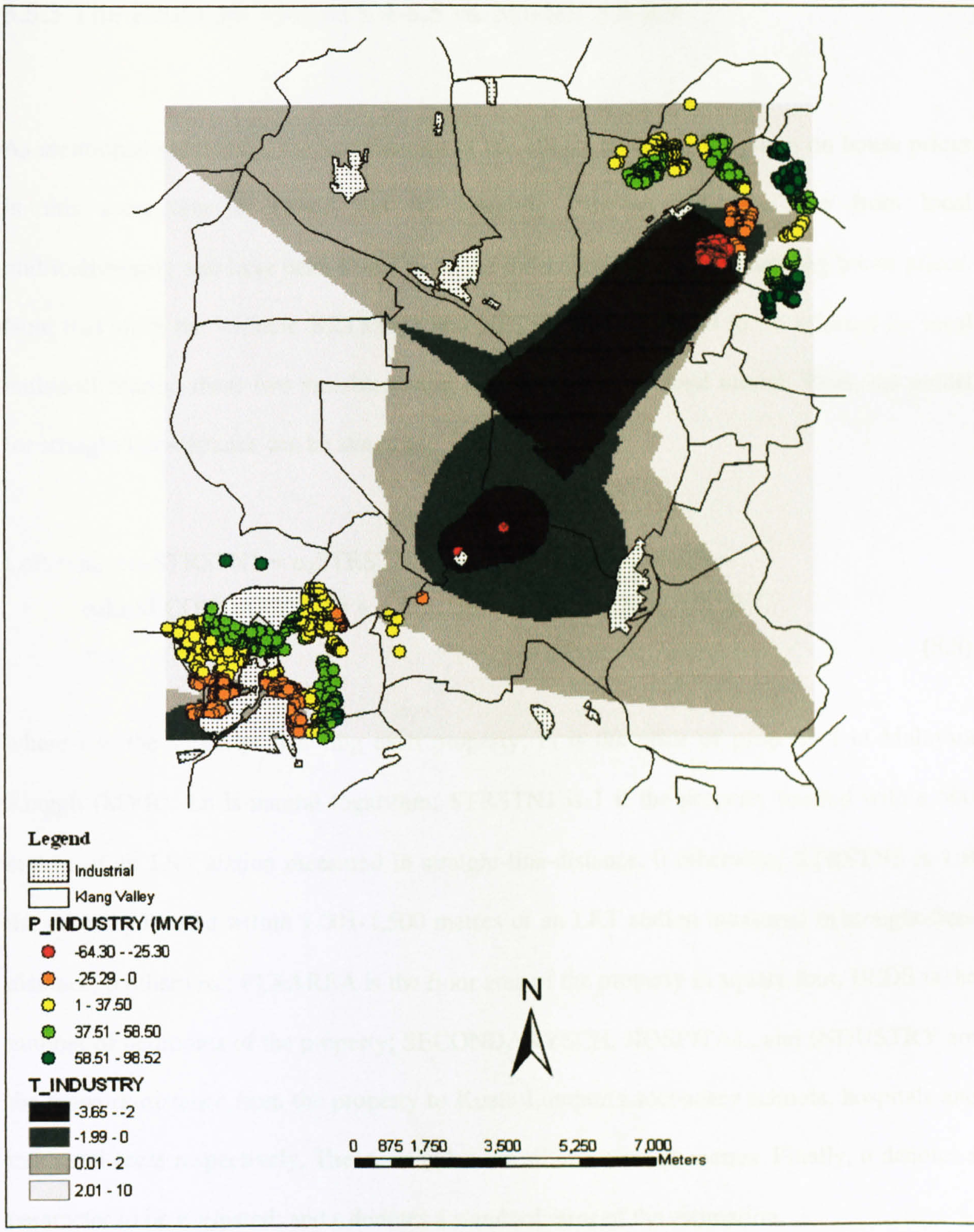



**Figure 8.36**: Map of t-values and parameter estimates associated with variable INDUSTRY

### 8.5.3 The Findings: Models 8.4-8.5 vs. Models 8.8-8.9

As mentioned previously, the examination of the effects of the LRT system on house prices in this subsection is carried out by selecting variables that are free from local multicollinearity and have been found to be the most significant in determining house prices. Note that since the variable NETSTN3 and NETSTN4 were found to be affected by local multicollinearity, these two variables were excluded from the final model. Thus, the model for straight-line-distance can be stated as:

$$LnP_i = \alpha_0 + \alpha_1 STRSTN1_i + \alpha_2 STRSTN3_i + \alpha_3 FLRAREA_i + \alpha_4 BEDS_i + \alpha_5 LnSECONDARYSCHi + \alpha_6 LnHOSPITAL_i + \alpha_7 LnINDUSTRY_i + \varepsilon_i \qquad (8.8)$$

where $i$ is the subscript denoting each property; $P_i$ is the price of property $i$ in Malaysia Ringgit (MYR); Ln is natural logarithm; STRSTN1 is 1 if the property located within 500 metres of an LRT station measured in straight-line-distance, 0 otherwise; STRSTN3 is 1 if the property located within 1,001-1,500 metres of an LRT station measured in straight-line-distance, 0 otherwise; FLRAREA is the floor area of the property in square foot; BEDS is the number of bedrooms of the property; SECONDARYSCH, HOSPITAL, and INDUSTRY are the network-distance from the property to Kuala Lumpur's secondary schools, hospitals and industrial areas respectively. These variables are all measured in metres. Finally, $\alpha$ denotes a parameter to be estimated; and $\varepsilon$ denotes a standard error of the estimation.

Consequently, the model for network-distance can be stated as:

$$LnP_i = \alpha_0 + \alpha_1 NETSTN1_i + \alpha_2 NETSTN2_i + \alpha_3 FLRAREA_i + \alpha_4 BEDS_i + \alpha_5 LnSECONDARYSCHi + \alpha_6 LnHOSPITAL_i + \alpha_7 LnINDUSTRY_i + \varepsilon_i \quad (8.9)$$

where the difference between perceived distance to a station and actual distance to a station is given by NETSTN1 and NETSTN2: are 1 if the property is located within 500 and 501-1,000 metres of an LRT station respectively measured in network-distance; 0 otherwise.

### 8.5.3.1 The Examination of Local Multicollinearity in Model 8.8-8.9

The collinearity index between a pair of local parameter estimates for both models (straight-line and network-distance) is presented in Table A8.3 of Appendix K. The findings from this analysis show that there no serious multicollinearity exists between a pair of local parameter estimates used in this analysis. As mentioned previously, when fewer variables were used to estimate the effects of the LRT on house prices, the local parameter estimates seems to be less affected by multicollinearity.

### 8.5.3.2 The Results of Global Model

Table 8.15 presents the summary of the parameter estimates of Models 8.8 and 8.9 concerning the effects of the LRT system on house prices for various specified distances from the station. Overall, the results of both models show that most of the predictor variables that have been used to estimate the range and magnitude of the LRT effect on house prices (according to various specified distances from its stations), have indeed produced similar signs as obtained in the previous models (Models 8.4 and 8.5) with $R^2$ of 65.2 per cent for both straight-line-distance and network-distance models. Both of these models have explained the variation of house prices reasonably well but as observed in the previous model, it still leaves 35 per cent of the variance in house prices unexplained. To avoid a repetition of Section 8.5.2.2, the discussion in this section will concentrate on the LRT parameters.

**Table 8.15**: The traditional hedonic specification of various distances from stations of Model 8.8 and Model 8.9

| Vector | Predictor | Straight-line distance (Model 8.8) | | | | Network distance (Model 8.9) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Coefficient | Standard error | t-value | VIF | Coefficient | Standard error | t-value | VIF |
| | Constant | 714.38 | 1.26 | 28.04 | | 932.08 | 1.26 | 26.37 | |
| | | *(21162.80)* | *(1.77)* | *(17.45)* | | *(30730.16)* | | *(18.47)* | |
| Focus variables | *STRSTN1* | 56403.43 | 8526.10 | 6.57 | 1.35 | | | | |
| | | *(20003.54)* | *(7870.24)* | *(2.57)* | *(1.81)* | | | | |
| | *STRSTN3* | 17708.05 | 6886.46 | 2.56 | 1.24 | | | | |
| | | *(37055.74)* | *(6230.61)* | *(5.98)* | *(1.66)* | | | | |
| | *NETSTN1* | | | | | 77718.68 | 16724.27 | 4.68 | 1.42 |
| | | | | | | *(27873.79)* | *(10873.66)* | *(2.67)* | *(1.77)* |
| | *NETSTN2* | | | | | 61978.19 | 7542.31 | 8.08 | 1.27 |
| | | | | | | *(35088.18)* | *(10493.66)* | *(4.51)* | *(3.90)* |
| Structural variables | *FLRAREA* | 362.49 | 9.06 | 40.01 | 1.92 | 354.94 | 9.06 | 39.69 | 1.91 |
| | | *(309.63)* | *(12.58)* | *(24.23)* | *(6.22)* | *(310.15)* | *(13.09)* | *(24.29)* | *(6.32)* |
| | *BEDS* | 25493.32 | 4684.67 | 5.49 | 1.63 | 35298.44 | 4466.77 | 7.88 | 1.55 |
| | | *(29197.48)* | *(3922.04)* | *(7.47)* | *(1.89)* | *(30504.83)* | *(3922.05)* | *(7.82)* | *(1.88)* |
| Locational variables | *SECONDARYSCH* | -39.80 | 5.37 | -7.59 | 1.13 | -32.27 | 5.37 | -6.10 | 1.17 |
| | | *(-12.91)* | *(4.66)* | *(-2.81)* | *(1.37)* | *(-12.19)* | *(4.66)* | *(-2.58)* | *(1.44)* |
| | *HOSPITAL* | 5.88 | 1.10 | 5.40 | 1.43 | 7.72 | 1.19 | 6.34 | 1.81 |
| | | *(3.22)* | *(1.28)* | *(2.47)* | *(3.28)* | *(2.94)* | *(1.38)* | *(2.17)* | *(3.54)* |
| | *INDUSTRY* | 43.10 | 3.71 | 11.47 | 1.14 | 40.03 | 3.71 | 10.98 | 1.09 |
| | | *(27.35)* | *(3.50)* | *(7.65)* | *(1.69)* | *(24.06)* | *(3.72)* | *(6.45)* | *(1.82)* |
| | | $R^2$ (adj.) = 65.2 per cent *($R^2$ (adj.) = 78.6 per cent)* | | | | $R^2$ (adj.) = 65.2 per cent *($R^2$ (adj.) = 78.5 per cent)* | | | |

#### 8.5.3.2.1 Value of the LRT system

The results of focus variables establish that the location of a property within 500 metres (STRSTN11) of an LRT station adds a premium of approximately MYR56,400 (straight-line-distance model) to house price. However, as distance from an LRT station increases, a premium added to a property located within 1,001-1,500 metres (STRSTN3) of an LRT station decreases to MYR17,700 less than a house located within the previous distance and more than 1500 metres from an LRT station. For the network-distance variables, the location of a property within 500 metres (NETSTN1) of an LRT station adds a premium at a value of MYR77,700 to house price. A premium added to the house price decreases simultaneously with the increase of distance (within 501-1,000 metres as indicated by NETSTN2) by approximately (MYR61,900) than it is in the previous distance. This obviously contradicts the results obtained in the previous models (Models 8.4 and 8.5) where house prices have a potential to decrease for properties that are located too close to a rail station, whilst properties radiating out from the station and within easy walking and driving distance have increased in price.

### 8.5.3.3 The Results of GWR Model

The discussion in this subsection follows the strategy of interpreting the GWR results that have been obtained in the preceding subsection. Tables 8.16-8.17 illustrate the diagnostic information of the GWR estimation for Models 8.8 and 8.9. As can be seen from Tables 8.16-8.17 above, the adjusted $R^2$ has increased from 65.2 per cent for both models in a global model to 83.5 per cent and 83.7 per cent respectively for both models in the GWR model.

After considering degrees of freedom, the conclusion that can be made is that the GWR model provides a better explanation of house price variation in this study. In addition, the reduction in the AIC from 1174.05 and 1167.40 for both models in a global model to 52.35 and 31.81 respectively for both models in the GWR model suggests that the local model is better than a global model, after taking into account degrees of freedom.

Once again, to avoid a repetition of Section 8.4.2 above, the discussion in this subsection concentrates solely on variables associated with the LRT system which is represented by STRSTN1, STRSTN2, NETSTN1 and NETSTN2. In the subsequent maps, the t-values of the aforementioned variables are classified into four. Similarly in the following maps, the parameter estimates are classified by five bands indicating the positive and negative premium added to the house price in Malaysia Ringgit (MYR).

**Table 8.16**: The results of GWR estimation for Model 8.8

| Global Estimation | |
|---|---|
| *Diagnostic information* | |
| Residual sum of squares | 192.27 |
| | *(117.23)* |
| Effective number of parameters | 8.00 |
| | *(19.00)* |
| Sigma | 34.97 |
| | *(27.40)* |
| Akaike Information Criterion | 1174.05 |
| | *(414.85)* |
| Coefficient of determination | 65.32 |
| | *(78.85)* |
| Adjusted $R^2$ | 65.20 |
| | *(78.59)* |
| **GWR Estimation** | |
| *Fitting geographically weighted regression model* | |
| Number of observations | 1580 |
| Number of independent variables (intercept is variable 1) | 19 |
| Number of locations to fit model | 1580 |
| *Diagnostic information* | |
| Residual sum of squares | 86.94 |
| | *(60.99)* |
| Effective number of parameters | 70.72 |
| | *(117.53)* |
| Sigma | 24.00 |
| | *(20.42)* |
| Akaike Information Criterion | 52.35 |
| | *(-401.61)* |
| Coefficient of determination | 84.32 |
| | *(88.99)* |
| Adjusted $R^2$ | 83.58 |
| | *(88.11)* |

| Source | *ANOVA* | | | |
|---|---|---|---|---|
| | Sum of squares | Degrees of freedom | MS | F-value |
| OLS residuals | 192.30 | 8.00 | | |
| | *(117.20)* | *(19.00)* | | |
| GWR improvement | 105.30 | 62.72 | 1.68 | |
| | *(56.20)* | *(98.53)* | *(0.57)* | |
| GWR residuals | 86.90 | 1509.28 | 0.06 | 29.15 |
| | *(61.00)* | *(1462.47)* | *(0.04)* | *(13.68)* |

**Table 8.17**: The results of GWR estimation for Model 8.9

| Global Model | |
|---|---|
| *Diagnostic information* | |
| Residual sum of squares | 191.46 *(117.62)* |
| Effective number of parameters | 8.00 *(21.00)* |
| Sigma | 34.89 *(27.46)* |
| Akaike Information Criterion | 1167.40 *(424.15)* |
| Coefficient of determination | 65.47 *(78.78)* |
| Adjusted $R^2$ | 65.20 *(78.49)* |

| GWR Estimation | |
|---|---|
| *Fitting geographically weighted regression model* | |
| Number of observations | 1580 |
| Number of independent variables (intercept is variable 1) | 21 |
| Number of locations to fit model | 1580 |
| *Diagnostic information* | |
| Residual sum of squares | 86.19 *(58.84)* |
| Effective number of parameters | 67.64 *(140.06)* |
| Sigma | 23.87 *(20.21)* |
| Akaike Information Criterion | 31.81 *(-404.90)* |
| Coefficient of determination | 84.45 *(89.38)* |
| Adjusted $R^2$ | 83.76 *(88.35)* |

| Source | *ANOVA* | | | |
|---|---|---|---|---|
| | Sum of squares | Degrees of freedom | MS | F-value |
| OLS residuals | 191.50 *(117.60)* | 8.00 *(21.00)* | | |
| GWR improvement | 105.30 *(58.80)* | 59.64 *(119.07)* | 1.76 *(0.49)* | |
| GWR residuals | 86.20 *(58.80)* | 1512.36 *(1439.93)* | 0.06 *(0.04)* | 30.97 *(12.08)* |

#### 8.5.3.3.1 Value of the LRT System

This section provides evidence on the existence of spatial variability of premium added to the properties located within various distances of an LRT station. The findings from the GWR model of house prices within various distances of an LRT station are mapped in Figures 8.37-8.40 and it will be interpreted against its counterpart in Figures 8.25-8.28. The following discussion commences by addressing the premium for those properties located within 500 metres of an LRT station of straight-line-distance measures.

##### 8.5.3.3.1.1 Houses within 500 metres of an LRT Station (STRSTN1)

It has been estimated in a global model that houses located within 500 metres of an LRT station have experienced a significant positive effect with premiums at an average of MYR56,400. To confirm this, the t-values and parameter estimates associated with variable STRSTN1 are mapped and shown in Figure 8.37. An examination of Figure 8.37 shows that there is no significant positive effect of house price premiums that can be found for houses located within 500 metres of an LRT station. The positive house price premium is only found for two high-rise units located in the Bangsar area, but with insignificant t-values. It can be seen in the figure below that high-rise units located within 500 metres of an LRT station in Bangsar adds the premium of up to MYR51,700 to its price. This value is slightly lower than the value that has been estimated in a global model. Figure 8.37 also reveals that houses located in the Wangsa Maju-Maluri and Petaling Jaya areas exhibit significant negative premiums of between approximately MYR57,000 and MYR79,000 (red dots) and MYR27,000 and MYR57,000 (orange dots) respectively.

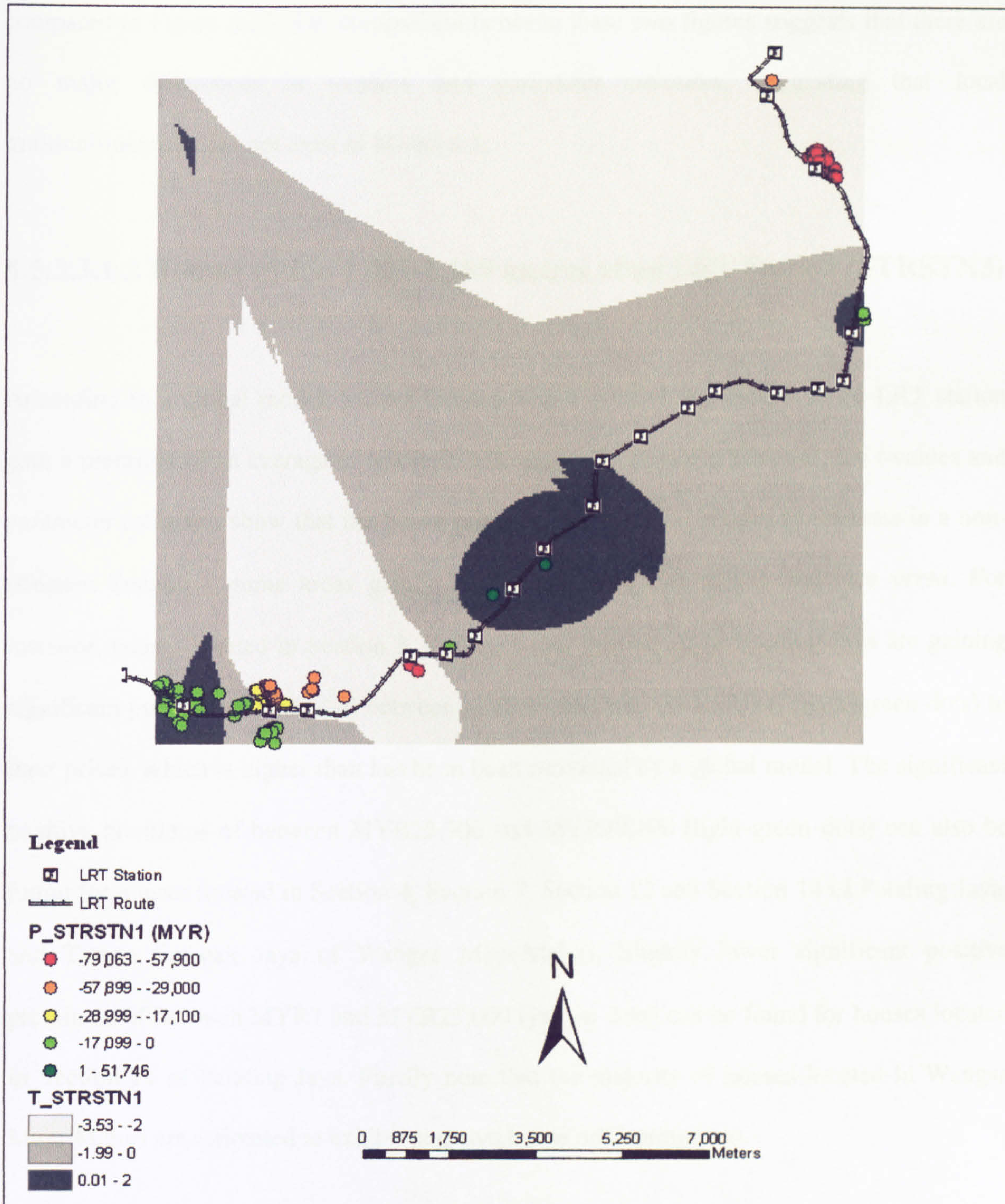



**Figure 8.37**: Map of t-values and parameter estimates associated with variable STRSTN1

As mentioned earlier, the t-values and parameter estimates of Figure 8.37 need to be compared to Figure 8.25. The comparison between these two figures suggests that there are no major differences in t-values and parameter estimates, suggesting that local multicollinearity does not exist in Model 8.4.

### 8.5.3.3.1.2 Houses within 1,001-1,500 metres of an LRT Station (STRSTN3)

According to a global model, houses located within 1,000-1,500 metres of an LRT station gain a premium of an average of MYR17,700. In the GWR model however, the t-values and parameter estimates show that the house price premium-LRT relationship operates in a non-constant fashion – some areas gain a higher premium than others and *vice versa*. For instance, houses located in Section 3, Section 6 and Section 20 of Petaling Jaya are gaining significant positive premiums of between MYR49,000 and MYR67,000 (dark-green dots) to their prices, which is higher than has been been estimated by a global model. The significant positive premiums of between MYR25,900 and MYR49,100 (light-green dots) can also be found for houses located in Section 4, Section 7, Section 12 and Section 14 of Petaling Jaya, and Taman Setapak Jaya of Wangsa Maju-Maluri. Slightly lower significant positive premiums of between MYR1 and MYR25,000 (yellow dots) can be found for houses located in Section 14 of Petaling Jaya. Finally note that the majority of houses located in Wangsa Maju-Maluri are estimated to exhibit negative house price premiums.

Let us now compare the results shown in Figure 8.38 against its counterpart in Figure 8.26. Compared to Model 8.4 (as depicted in Figure 8.26), the distribution of positive significant t-values obtained in Model 8.8 (see Figure 8.38) are found have a slightly different pattern in those areas that have been identified in the previous models as not being affected by the existence of the LRT system are estimated to have significant positive t-values.

For instance, houses located in Section 14 and Section 20 of Petaling Jaya and Taman Setapak Jaya of Wanga Maju-Maluri are estimated to have significant positive premiums in Model 8.8 although it has been estimated not to be affected by the existence of the LRT system in Model 8.4. The pattern of parameter estimates is also found to be slightly different between Model 8.8 and Model 8.4. It can be seen from Figure 8.38 that the distribution of non-significant positive parameter estimates (yellow and light-green dots) is found for most of the areas in Petaling Jaya. For instance, houses located in Section 14 of Petaling Jaya are estimated to have negative house price premiums in Model 8.4, yet in Model 8.8 these houses exhibit positive house price premiums. This result is in line with the estimation made in Models 8.1 and 8.2 and Models 8.6 and 8.7 in which house prices is estimated to increase in premiums by being located closer to an LRT station for the majority of houses located in Petaling Jaya. In the case of houses located in Wangsa Maju-Maluri, it can be seen in Figure 8.26 that the non-significant positive parameter estimates in Model 8.4 is estimated for the majority of houses (yellow dots). However, an examination of Figure 8.38 shows that the non-significant positive parameter estimates can only be found in the Taman Sri Rampai and Danau Kota housing estates (yellow dots). This implies that Model 8.4 is affected slightly by local multicollinearity.

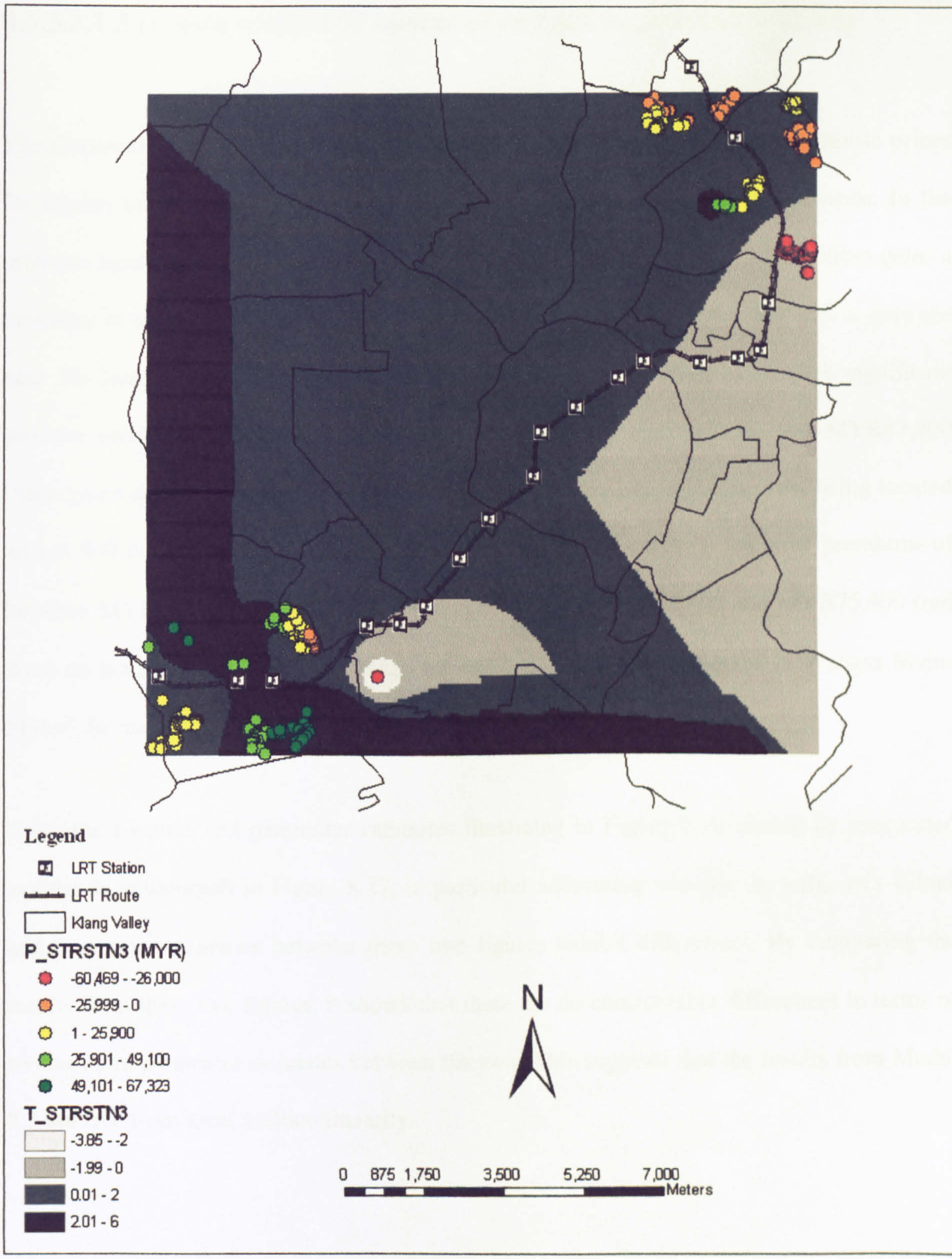



**Figure 8.38**: Map of t-values and parameter estimates associated with variable STRSTN3

#### 8.5.3.3.1.3 Houses within 500 metres of an LRT Station (NETSTN1)

The discussion in this subsection focuses on the effects of the LRT system on house prices for houses located within 500 metres of a station measured by a network-distance. In the previous models (global model), houses located within 500 metres of an LRT station gains a premium of an average of MYR77,700 to its prices. Figure 8.39 shows that this is only the case for houses located in Section 14 and Section 22 of Petaling Jaya, with significant positive premiums that are estimated at an average of between MYR1 and MYR87,800 (dark-green dots). In the case of houses located in Wangsa Maju-Maluri area, being located within 500 metres of an LRT station is estimated to have significant negative premiums of between MYR68,800 and MYR72,300 (orange dots) and MYR72,400 and MYR75,400 (red dots) on house prices. Therefore, it can be concluded that houses located in Wangsa Maju-Maluri decrease in value by being located closer to an LRT station.

Next, the t-values and parameter estimates illustrated in Figure 8.39 should be interpreted against its counterpart in Figure 8.27, in particular addressing whether the value of t-values and parameter estimates between these two figures exhibit differences. By comparing the results from these two figures, it shows that there are no considerable differences in terms of t-values and parameter estimates between the two. This suggests that the results from Model 8.3 are free from local multicollinearity.

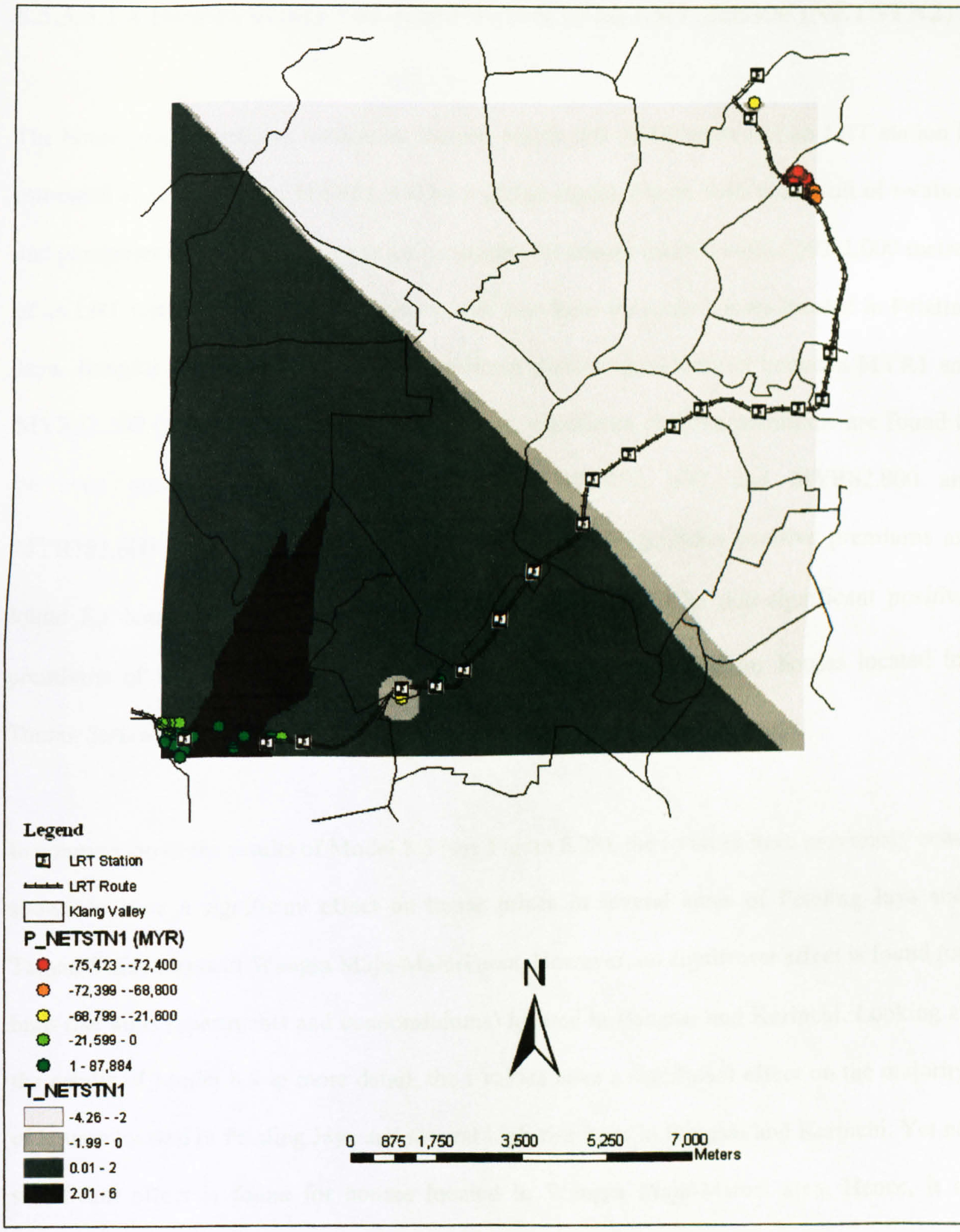



**Figure 8.39**: Map of t-values and parameter estimates associated with variable NETSTN1

#### 8.5.3.3.1.4 Houses within 501-1,000 metres of an LRT Station (NETSTN2)

The house price premiums for houses located within 501-1,000 metres of an LRT station is estimated at an average of MYR61,900 by a global model. Figure 8.40 is a result of t-values and parameter estimates of house price premiums for houses located within 501-1,000 metres of an LRT station of Model 8.9. It can be seen that there are some houses located in Petaling Jaya, Bangsar and Kerinchi that gain significant positive premiums of between MYR1 and MYR52,200 (yellow dots). In some other areas, significant positive premiums are found to be even greater – between MYR52,200 and MYR82, 800, and MYR82,800 and MYR181,800 (light-green and dark-green dots). Yet no significant positive premiums are found for houses located in the Wangsa Maju-Maluri area. The non-significant positive premiums of between MYR1 and MYR52,000 can only be found for houses located in Taman Setiawangsa.

In comparison to the results of Model 8.5 (see Figure 8.28), the t-values have previously been shown to have a significant effect on house prices in several areas of Petaling Jaya and Taman Setiawangsa of Wangsa Maju-Maluri area. However, no significant effect is found for high-rise units (apartments and condominiums) located in Bangsar and Kerinchi. Looking at the results of Model 8.9 in more detail, the t-values have a significant effect on the majority of houses located in Petaling Jaya and several high-rise units in Bangsar and Kerinchi. Yet no significant effect is found for houses located in Wangsa Maju-Maluri area. Hence, it is possible to arrive at a conclusion that the results from Model 8.5 are slightly affected by local multicollinearity.

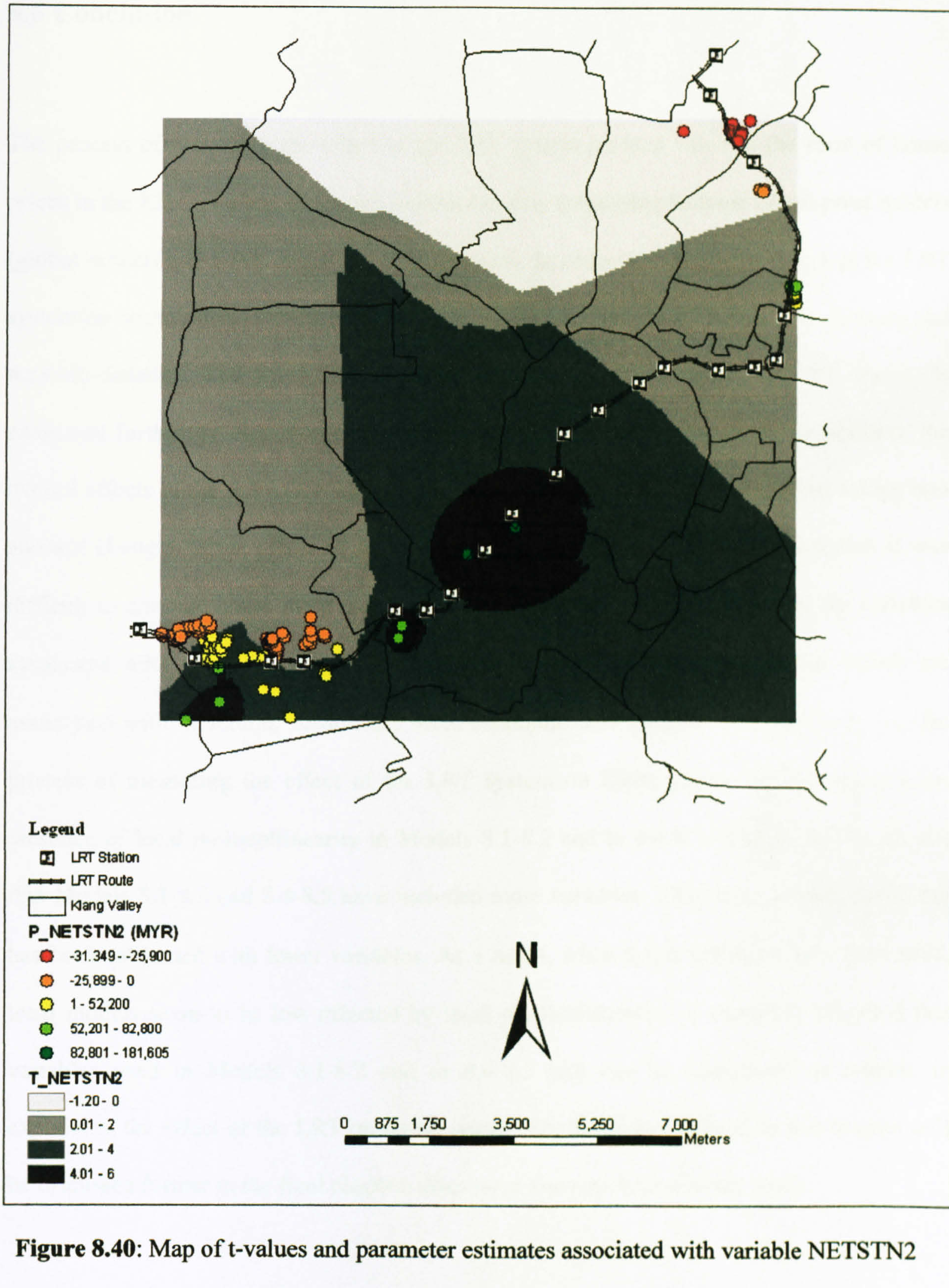



**Figure 8.40**: Map of t-values and parameter estimates associated with variable NETSTN2

## 8.6 Conclusion

The process of measuring the effect of the LRT system on land value in the form of house prices in the Klang Valley, Malaysia is carried out by employing hedonic house price models (global model) and GWR technique (local model). In order to capture the effect of the LRT system on house prices, two types of measurement were employed; straight-line-distance and network-distance. The proximity of each of the observations from an LRT station is examined further by classifying the distance for various catchment areas. In addition, the overall effects of the rail transit system on house prices can only be measured by taking into account changes in the prices of all housing attributes. This is due to the fact that it was difficult to attribute house price increases to the LRT system alone. Therefore, the variables associated with the LRT system are modelled together with other variables which are associated with structural, locational, socio-economic and ethnic variables. However, the process of measuring the effect of the LRT system on house prices has encountered the presence of local multicollinearity in Models 8.1-8.2 and to 8.4-8.5. This is due to the fact that Models 8.1-8.2 and 8.4-8.5 have included more variables. Therefore, Models 8.6 to 8.9 has been calibrated with fewer variables. As a result, when fewer variables have been used, local models seem to be less affected by local mutlicollinearity. It should to be noted that variables used in Models 8.1-8.2 and to 8.4-8.5 still can be considered as reliable in explaining the effect of the LRT on house prices. The findings obtained in this chapter will be discussed further in the final chapter; discussion and conclusion of the study.

# CHAPTER 9

## Conclusions and Discussion

### 9.1 Introduction

The purpose of this chapter is twofold. Firstly, this chapter will discuss the key findings of the empirical results with respect to micro-economic theories of the accessibility-transportation-house price relationship (Section 9.2). The main focus is to evaluate the empirical results presented in Chapter eight together with the discussion on hedonic house price models, GWR models and the role of GIS. Secondly, this chapter will conclude this study by discussing the policy implications of the study (9.3), highlighting the strengths of the study (Section 9.4), addressing limitations of the study and leading to suggestions for further studies (Section 9.5). The chapter ends with some closing statements for this study (Section 9.6).

### 9.2 Key Findings of the Study

As stated previously, the aim of this study is to critically investigate the effect of the LRT system on house prices in the Klang Valley, Malaysia. The theoretical foundation provided by micro-economic theories has been important in order to understand how land values for example, in the form of house prices can be affected by being located closer to transportation systems such as rail transit systems. As explained in micro-economic theories, the choice of residential location made by households is the result of the trade-off between land rent, accessibility to the CBD and the cost of all other goods and services, in particular housing attributes. The trade-off between these attributes over space resulted in a distance decay relationship between land rent and distance from the CBD. The greater distance a household lives from the CBD, the more it will have to spend on transportation and the less it will have to spend on housing. However, any significant improvement in the transportation system that increases accessibility and reduces transportation costs (time and money) should result in an increase in house prices for those houses that are located closer to a rail transit station. For instance, the introduction of rail transit systems (heavy and LRT systems) in many countries have proven to improve accessibility along the rail line corridors compared to areas that are not served by the systems. Since the accessibility has improved it would make houses located closer to a rail transit station much more attractive and hence more valuable than houses located further away. As a result, house price is expected to decrease for every metre away from a rail transit station. However, it must be noted that rail transit systems usually replace the existing bus service. As a result, their effect on accessibility can be quite small. Thus, it is extremely difficult to expect a greater effect of the rail transit system on the whole transportation network. This is because the rail transit system accounts for a very small portion of the entire transportation network. Even a large change in transit accessibility has little effect on the system as a whole. Therefore, the magnitude and range of effects of the rail transit system on house prices are only found in those with the closest proximity to a station.

It has been mentioned earlier that since the 1970s, more than thirty studies have been conducted in the UK and North America in order to provide empirical evidence of the effects of rail transit systems on land values such as property values. The evidence from empirical research both in the UK and North America provides inconsistent results and varying magnitude of the effects of heavy and LRT systems on property values. Twenty-four of the thirty-five studies on both heavy and light rail transit systems show a positive relationship between property values and access to rail transit systems. However, other studies found a negative relationship between property values and rail transit systems. For instance, eleven of the thirty-five studies show that there is no relationship between property values and access to rail transit systems.

The study in the Klang Valley however, has been carried out in order to provide empirical evidence for the estimation of the negative rent gradient with respect to the trade-off between the improvement of accessibility to the CBD and house prices. Hedonic house price models have therefore been employed – the role of hedonic house price models is to provide empirical evidence of a negative land rent gradient for a unit of house from an LRT station. In other words, it has been assumed that house prices would decrease for every metre further away from an LRT station. However, since the hedonic house price model is a global model which naturally has a tendency to assume that the relationship between house prices and housing attributes are stationary over space, and therefore may hide some very interesting and important local differences in the determinants of house prices, a new local model known as GWR has also been employed in this study. In addition, it is important to note that the process of measuring the effect of the LRT system on house prices would not have been successfully completed without using GIS, in particular for storing, managing, analysing and visualising the selling price, and the structural and locational attributes data. More importantly, GIS was used to construct locational attributes variables which are primarily important in identifying the determinants of house prices.

The measuring of the effects of the LRT system on house prices using hedonic house price models and GWR technique in this study reveals a number of key findings. Firstly, the hedonic house price models estimate that houses located within two kilometres of an LRT station in the Klang Valley decrease in price as the distance from an LRT station increases for both straight-line-distance and network-distance models reasonably well with 78.2 per cent of adjusted R-square. In other words, there is strong evidence to suggest that a distance decay relationship between house prices and the LRT system strongly exists. However, since hedonic house price models are a global model, the results produced by the models have been applied equally for the entire area. That is, the distance decay relationships between house prices and the LRT system have been generalised for all houses located within two kilometres of an LRT station. The generalisation of the effects of the LRT system on house prices is found to be true when it was examined further by employing GWR models. In terms of the estimation, the GWR gives a statistically significant improvement over the global model, with a higher adjusted R-square of around 88 per cent for both straight-line-distance and network-distance models even after taking into account the degrees of freedom. The results from GWR reveal that house prices decrease only for the majority of houses located in the Petaling Jaya area and high-rise units located in Bangsar and Kerinchi. Yet, the majority of houses located in Wangsa Maju-Maluri area were found not to be affected by the existence of the LRT system. In other words, house price increases for every metre away from an LRT station. The spatial variability of the effects of the LRT system on house prices is completely unseen in a global model, but it can clearly be seen in a local model. In addition, both hedonic house price models and GWR estimates the effects of the LRT system on house prices for various catchment areas from an LRT station. As clearly revealed in the discussion in Chapter eight, those houses that have superior access to an LRT station have paid higher price premiums as compared to houses located very close or further away from an LRT station. In the context of this study, the highest significant positive price premiums are for houses located within 1,001-1,500 metres of straight-line-distance and 501-1,000 metres of network-distance. Once again, the significant positive house price premiums is only to be found for houses located in the Petaling Jaya area and several high-rise units located in Bangsar and Kerinchi. In the case of the Wangsa Maju-Maluri area, significant positive premiums can be found for houses located in Taman Setiawangsa housing estate. One may ask the discussion in the previous chapters have mentioned about the idea that there may be negative locational externalities with living near to a station. However, this study were not be able to detect this potential negative externalities based on two reasons. First, the number of observations located within close distance such as 50 to 200 metres from a station is very small to be examined, therefore, large distance interval such as 500 metres have been used. Secondly, the number of distance intervals need to be minimised due to multicollinearity problems that occurred among focused variables when more distance intervals were using.

One of the main reasons why the majority of house buyers in Petaling Jaya value the existence of the LRT system and are willing to pay more to be located closer to it is due to the inefficiency of public transportation such as bus services that operate in the area. For instance, the waiting time for buses is between thirty to sixty minutes. The inefficiency of public transportation together with the serious traffic congestion from Petaling Jaya to Kuala Lumpur and *vice versa* (particularly during peak hours) has made travel time an extremely long affair in which people have to spend more time on the roads before they can reach their desired destination. However, the introduction of the LRT system in the late 1990s has brought great relief for many Petaling Jaya residents, particularly for those who have had to rely on public transportation. As mentioned earlier, the services provided by the LRT system in the area have truly improved the accessibility from and to the CBD (Kuala Lumpur's city centre). Therefore, it is reasonable to expect that buyers of houses in Petaling Jaya will pay a higher price to be located closer to an LRT station. In the case of the Wangsa Maju-Maluri area, public transportation serving that area was better even before the LRT system was introduced in the late 1990s. Moreover, Wangsa Maju-Maluri itself is located very close to the CBD, and therefore the role of the LRT system as a mode of transport to the CBD is less important. It might also be due to the fact that the effect of the LRT system on house prices appears to take a long time to occur as stated by Giuliano (2004).

Secondly, there are two groups of residents who benefit from being located closer to an LRT station. One group of residents benefit from being geographically closer to an LRT station and it has been measured by straight-line-distance. As noted by Hess and Almeida (2007), "these residents have a sense of proximity to an LRT and consider this proximity as a locational advantage to residential properties" (pp. 1061). The other group of residents benefit from having superior access to an LRT station calculated along the street network. By comparing these two measures, the conclusion that can be made is that network-distance models are more influencial than the straight-line-distance upon house prices at least in the context of this study.

Thirdly, the results also reveal that structural attributes of the house played a greater role in determining house prices in the study. As discussed above, the size of the floor area and the number of bedrooms have shown to contribute more greatly to the house price. This is of course in line with most of the hedonic house price analysis. More interestingly, the results from the GWR model reveal that the majority of housebuyers located in the Wangsa Maju-Maluri area are paying a higher price for structural attributes than housebuyers located in Petaling Jaya.

Fourthly, it has been estimated by the hedonic house price models that house prices decrease for every metre away from the CBD, secondary schools, commercial areas (local shops and shopping malls), parks and recreational areas. However, house prices are found to increase for every metre away from primary schools, hospitals and industrial areas. Further examination of the effects of locational attributes (free variables) on house prices is carried out by employing the GWR model. The results from the GWR model show that the effects of locational attributes on house prices vary from one location to another. For proximity to the CBD, the house price gradient for every metre away from the CBD is found for houses located in the Petaling Jaya area, yet the majority of houses located in the Wangsa Maju-Maluri area are not affected. In the case of proximity to secondary schools, not all secondary schools could produce positive effects on house prices. As has been discussed earlier, a house located closer to a good secondary school which performs very well in major examinations and co-curriculum is more expensive than a house located away from this facility. It has also been shown in the previous chapter that the majority of housebuyers in Petaling Jaya have valued locational attributes marginally more than structural attributes. In contrast, the majority of buyers of houses in Wangsa Maju-Maluri area have valued structural attributes marginally more than locational attributes. At this juncture, readers are advised that the failure to take into account the nature of spatial process, for example the interactions between house prices and its determinants that are not in homogenous fashion, may lead to misleading interpretation of the effects.

Finally, this study has shown the potential of GIS together with spatial analysis within hedonic house price research. This study has indeed utilised a GIS by combining its capabilities with spatial analysis. For instance, GIS has been used to organise and manage large spatial datasets (that is, units of houses) and of course its structural and locational attributes too, and most importantly GIS has been used to position each observation and locational attribute accurately on a local map by using their geographical coordinates. Moreover, the combination between GIS and spatial analysis has been particularly useful in this study in which the distance and proximity that has caused controversy in the preceding work has been measured accurately by measuring the distance from one point to another using network distance. More importantly, the significant role played by GIS is indeed accountable for the quality of the results of this study. Apart from this, GIS has also contributed significantly as a visualisation medium in which the results of the GWR modelling were able to be displayed on maps. Without this brilliant tool, a spatially varying relationship between house prices and the LRT system variables as well as other determinants (free variables) can never be revealed.

The following conclusions can be drawn from these findings. Firstly, the results of this study support the micro-economic theory of the bid-rent function and the trade-off between accessibility to the CBD, transportation and house prices. As extensively examined, the improvement of accessibility to the CBD through the introduction of the LRT system has increased house prices for those houses that have superior access to its station, however with considerable variation over space. Secondly, the strong empirical evidence of the increase of house prices due to the presence of the LRT system found in this study have implications for the government's decision to introduce the LRT system in other places. In other words, the introduction of new transport infrastructures such as an LRT system to improve the accessibility of city centres for those living in residential areas could also bring indirect benefits for example, can uplift land value for those areas that have been served by the system. Hence, it could increase government revenues through land value taxation. Thirdly, GWR specification is found to be the most efficient tool for measuring the effect of the LRT system on house prices. Fourthly, most locational attributes including the LRT variable that has been used in determining house prices in this study are local in their impact, with a distance decay effect in their extent and intensity. Fifthly, structural attributes of the houses still play a major role in determining house prices. Finally, there are some households that value locational attributes marginally more than structural attributes, particularly for higher income households in Petaling Jaya. Therefore, it is reasonable to suggest that higher income households are more likely to compete through the pricing system in the property market to be near positive externalities from locational attributes, and may become involved in political actions in order to protect their property from negative externality generators that may cause their property prices to decrease, since locational externalities represent a larger investment in the price of their property.

## 9.3 Policy Implications

The previous section has presented and discussed the results of the hedonic house price and GWR models of the effects of the LRT system on house prices in the Klang Valley, Malaysia. The findings suggest that on average, for houses that are located within a two-kilometre radius, prices decrease as the distance increases from the LRT station; for both straight-line-distance and network-distance. In other words, the majority of residents located within a two-kilometre radius of an LRT station are willing to pay a higher price in order to experience the improvement in accessibility due to the existence of the LRT system. It is clear that use values were found to be important determinants of willingness to pay.

The findings reported in the previous section have important implications for policy implementation. Firstly, the research findings provide justification for the potential implementation of a Land Value Capture (LVC) policy; a policy that can be implemented in order to provide a funding mechanism for the new transport infrastructure. This is due to the fact that the construction of rail transit systems should not be viewed as a subsidised service for the poor, but as an investment that returns a profit through increased land values. It is worthwhile to emphasise at the outset the strategies in a LVC policy that may be implemented in at least six respects. These six strategies include property and sales taxes, real estate lease and sales revenues, fees on everything from parking to business licenses, join development, tax increment financing, special assessment districts and public-private partnership (see Figure 9.1). This approach has become a common practice in more developed countries such as in the UK and the US. The discussion below focuses on various strategies that have been associated with a LVC policy as previously noted.

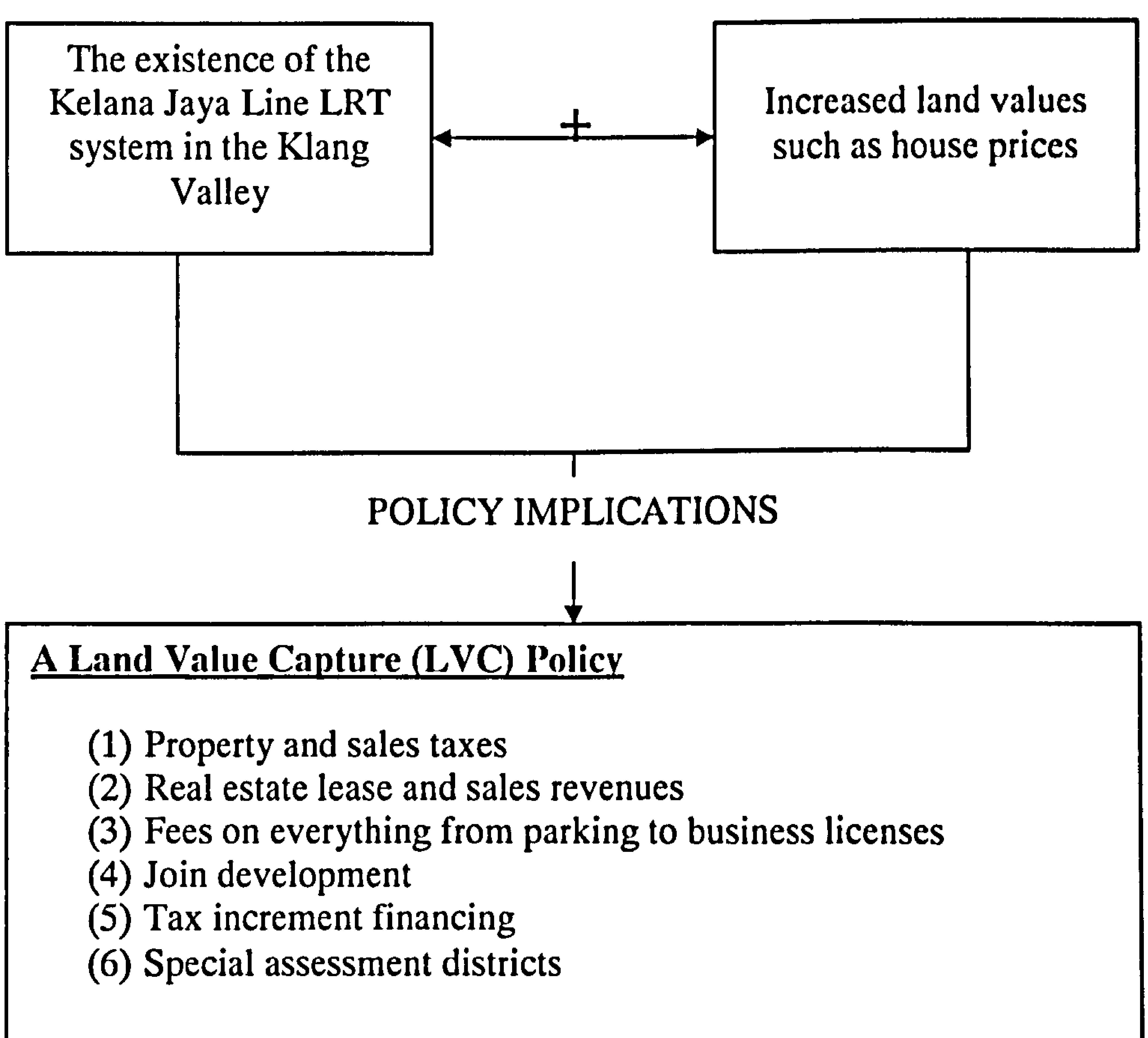



**Figure 9.1**: A potential implementation of a Land Value Capture (LVC) policy

First, the strategy that may be implemented in order to capture value is property and sales taxes. This strategy focuses on the tax revenues that can be generated over time for those properties that are located within close proximity to an LRT station, due to the fact that real estate around the station has become very valuable – it has been empirically proven by this research and some of other studies in the UK and North America. A study on the tax revenues that can be generated from property and sales in the US shows that a county that has been served by the rail transit system has generated high revenues for the county. Arlington County in Virginia has the most successful example of the tax revenues that can be generated from properties that are located around the Rosslyn-Ballston Corridor. As highlighted by Dittmar and Ohland (2003), in 2002 the assessed value of land and property in the corridor was US$8.88 billion, an 81 per cent increase over 1992 – it has contributes 33 per cent of county revenues, producing property taxes, hotel taxes, meal taxes, and business and household personal property taxes, although the corridor comprises just 8 per cent of county land. As a result, Arlington has one of the lowest real estate tax rates in Northern Virginia - as Robert Brosnan, Planning Director for Arlington County explains, "We have the lowest tax rate [in the region]. The tax burden is high, but the rates – we have been lowering them. We have AA bond rates. We can float bonds for schools, parks. You get a lot of service without raising taxes" (Dittmar and Ohland, 2003). Second, real estate lease and sales revenues may also provide another means to capture value. As mentioned earlier, areas that have been served by the rail transit systems are more convenient and vibrant compared to the areas that have not been served by the systems. Therefore, many cities have focused their real estate investments within close proximity to the rail transit stations in order to encourage greater use of transit, and reduce traffic congestion from and to the city centre as well as to reduce air pollution. For instance, the existence of rail transit systems in Arlington County, Virginia have contributed to the rapid development in real estate industry, particularly for those areas that are located around the stations. Evidently, office space in these areas has increased from 4.1 million square feet in 1969 to 30 million in 2003, whilst housing in the immediate vicinity has increased from 4,300 units to 34,000 units (Dittmar and Ohland, 2003). Once the development succeeds, real estate within close proximity to the stations can become very valuable. As a result, the city would earn millions of pounds in direct lease and sales revenues. It should be noted that by combining real estate development and public transit, a municipality can raise significant non-tax revenue through such enterprising government activity. Third, fees on everything from parking to business licenses may potentially be implemented in order to capture value. This is once again due to the increased activity around rail transit stations. Fourth, another strategy that has been widely implemented to capture value is join development. This strategy is found to be the most common practice in the last few years in the US. The main approach that has been employed in this strategy is transit agencies selling or leasing part of a station area for its development (Covarrubias, 2004). The developer usually pays for direct connections from the stations to the new buildings. Fifth, another strategy that may be implemented to capture value is through tax increment financing (TIF). As discussed earlier, the construction of rail transit systems has significantly increased the value of surrounding land for example, in the form of residential and commercial properties. The increase in surrounding land would generate increased tax revenues. In other words, the increased tax revenues are the tax increment (Dittmar and Ohland, 2003). Six, the special assessment district is another strategy in a LVC that may be implemented in order to capture value. In this strategy, property owners located within close proximity of a rail transit station may be levied due to the benefit that they have gained from the transportation project such as rail transit systems. This strategy has successfully been implemented in more developed countries such as the US. For instance, the Valley Transportation Authority (VTA) in Santa Clara County has used this strategy to fund the construction of a station in Sunnyvale. In addition, the VTA has also indicated that it will use special assessment districts to help pay for stations on the BART extension to San Jose (Dittmar and Ohland, 2003). Finally, having a method to measure rising land values due to the improvement in transportation service can allow alternative options or scenarios to be assessed. For example, different transport schemes for the same route may give rise to different land value capture potential, which may in turn help determine which transport scheme to pursue.

## 9.4 Strengths of the Study

The strengths of this study lie in the following headings. Firstly, this study uses a reasonable number of observations together with a good quality of data. Secondly, the study approach employed to measure the effect of the LRT system on house prices is found to be appropriate. Finally note that the study presents more accurate, robust and reliable empirical evidence.

### 9.4.1 A Reasonable Number of Observations and a Good Quality of Data

The discussion above shows that this study has produced reliable findings, indicated by a higher adjusted R-square for both straight-line-distance and network-distance models involving global and local models. As noted in the previous chapters, the adjusted R-square obtained for Models 8.1-8.2 and 8.4-8.5 was 78.2 per cent to 78.6 per cent for both straight-line-distance and network-distance models in the global models and of 88.1 per cent to 88.3 per cent for both straight-line-distance and network-distance models in the GWR models. This is apparently higher than many studies that have been conducted previously. The R-square from the previous studies can be summarised as follows; Damm et al. (1980) $R^2$s of 59 per cent to 79 per cent; Bajic (1983) $R^2$s of 63 per cent to 76 per cent; Laakso (1992) $R^2$s of 94 per cent; Gatzlaff and Smith (1993) $R^2$s of 67.6 per cent to 78.3 per cent; Cervero (1994) $R^2$s of 76 per cent to 80 per cent; Forrest et al. (1995) $R^2$s of 79 per cent; Chen et al. (1997) $R^2$s of 62.5 per cent; Henneberry (1997) $R^2$s of 71 per cent to 79 per cent; So et al. (1997) $R^2$s of 52 per cent; Knapp and Hopkins (1999) $R^2$s of 71 per cent; Cervero and Duncan (2002) $R^2$s of 65.8 per cent to 71.5 per cent; Cervero and Duncan (2004) $R^2$s of 44.2 per cent; Du (2006) $R^2$s of 60.4 per cent to 73.1 per cent; and Almeida and Hess (2007) $R^2$s of 77.0 per cent.

The reliable findings of this study can be attributed to a reasonable number of observations that have been used and the quality of data (selling price, structural, locational and socio-economic attributes) that has been prepared for the hedonic house price and GWR models estimation. In the case of the number of observations, this study has used 1,580 observations for the hedonic house price and GWR models together with a relatively large number of independent variables to estimate the effect of the LRT system on house prices; twenty-two independent variables in total. In the previous studies, a number of observations and independent variables range from 70 to 7,098 and 2 to 27 respectively, and this can be stated as follows; Damm et al. (1980) 286 and 22; Bajic (1983); 2000 and 17; Laakso (1992) 6,732 and 27; Gatzlaff and Smith (1993) 912 and 8; Cervero (1994) 1,131 and 15; Forrest et al. (1996) 795 of 21; Chen et al. (1997) 830 and 22; Henneberry (1997) 4,805 and 14; So et al. (1997) 1,234 and 14; Chau and Ng (1998) 70 and 2; Knapp and Hopkins (1999) 1,537 and 18; Cervero and Duncan (2002) 5,066 and 20; Cervero and Duncan (2004) 7,098 and 24; Du (2006) 2,837 and 17; and Almeida and Hess (2007) 7,357 and 18.

Most importantly, a reasonable number of observations and independent variables used in this study were supported by good quality secondary data. For instance, the selling price and structural attributes of the house that have been received from DVPS can be trusted since it has undergone some cleaning by the data provider, and it was also used by data provider for their own research as well as producing a property market report for the government. Locational attributes data are believed to be of high quality and reliability – they originate from the Centre of Spatial Analysis, University Science of Malaysia (USM). USM was actively involved in the GIS application of the Klang Valley project for the Prime Minister's Department of Malaysia. These data were then compared and updated with the latest set of inputs obtained from Kuala Lumpur City Hall and Department of Agriculture, Malaysia by the researcher for the purpose to increase their consistency and accuracy. Census data were extracted from the Malaysia Census Population Report. In addition, all of these data are carefully prepared by the researcher using the capabilities of GIS. In conclusion, the reliability of the findings in this study is due to the combination of a reasonable number of observations and independent variables used in the models together with good quality secondary data.

### 9.4.2 The Appropriate Study Approach

The study approach that was employed to measure the effect of an LRT system on house prices is found to be appropriate. As mentioned in Chapter six, this study employed the cross-sectional approach, but with focus on the relationships over space, rather than a before and after study. The principal analysis that has been carried out suggests that the relationships between the existence of the LRT system and its effect on house prices can clearly be seen over space by the successful use of GWR.

The selection of residential properties to be included in the principal analysis has also been conducted cautiously and it was guided by the previous studies as well as guidelines given by O'Sullivan and Morrall (2004). This effort paid off when the findings of the study accurately captured the effect of the LRT system on house prices and were also in line with the theoretical expectations. In addition, there were two methods of measuring the distance between a residential property and an LRT station; straight-line-distance and network-distance. By employing these two methods, it has permitted a useful comparison to be made between two groups of residents who benefit from being located closer to an LRT station; those geographically closer to an LRT station which has been measured by straight-line-distance, and those who have superior access to an LRT station, which was calculated along the street network. Finally, the effect of the LRT system on house prices has been estimated successfully by employing hedonic house price and GWR models. In the case of hedonic house price models, this study has selected the most appropriate functional form namely, log-log specification, after comparing it with several other functional forms in order to produce accurate, robust and reliable empirical evidence. However, as noted above, the hedonic house price models give an average result of house price decay for every metre away from an LRT station, whilst the GWR models reveal that the effect of the LRT system on house prices in the Klang Valley are varied over space due to several reasons which have been discussed in the previous section.

### 9.4.3 Accurate, Robust and Reliable Empirical Evidence

As stated previously, this study has produced more accurate, robust and reliable empirical evidence of the effect of the LRT system on house prices since it has considered the nature of spatial process in which the house prices-LRT relationship is believed to be heterogeneous over space. As has been extensively reviewed in the previous chapter, over the past forty years there have been many studies in the North America and UK on the effect of rail transit systems on property values, yet most of these studies have never addressed the issue associated with spatial heterogeneity, except a recent study conducted by Du and Mulley (2006) in their attempt to investigate the impact of the Metro on land values in Tyne and Wear in the UK. Thus, this study can be considered as a second study which has taken into account the nature of spatial process in measuring the effects of the LRT system on house prices. However, the main limitation with the study conducted by Du and Mulley is related to the selection of the factors that determine house prices. As clearly be seen from the variables selection in measuring the effects of the Metro on land values in Tyne and Wear, they did not take into account several important attributes of the house such as floor area and locational attributes within which houses are located. As a result, the adjusted $R^2$ for a global model that they obtained is about 61.5 per cent. In other words, there are still around 40 per cent of the variance in house prices unexplained. This study on the other hand has appropriately considered the determinants of house prices from various factors such as structural, locational and socio-economic attributes. This study also considers the multicollinearity in the global models as well as in the local models which makes the empirical evidence provided more accurate, robust and reliable.

## 9.5 Limitations of the Study and Avenues for Future Study

As with other studies, the present study has certain limitations. The limitations of this study can be associated with the following issues. The first issue is some of the data is not available. The second issue is the problem associated with spatial autocorrelation. The third issue is in-depth investigation of the basic socio-economic attributes of commuters can be carried out. The fourth issue is related with the limitations of GWR models. The final issue is the presence of local multicollinearity in GWR models. These limitations can be seen as potential avenues that need to be explored for future study in measuring the effect of the LRT or rail transit systems on house prices.

### 9.5.1 The Unavailability of the Data

As has been discussed in Chapter four, there are three main components of factors that determine house prices; structural, locational and socio-economic and ethnic attributes. Great efforts have been made to collect and prepare them for purpose of this study. However, some of the data that has been identified in the literature to be an important determinant of house prices are not available in this study. These missing data are discussed as follows;

*Structural attributes data*: It has been widely accepted in hedonic house price studies that structural attributes of the house are very important in determining house prices. Therefore, it is essential for every researcher to include them as much as possible in their study. Yet, this depends primarily on the availability of the data. In the context of this study, there were some structural attributes of houses that were not available; age of the house and level of the high-rise units (condominiums and apartments). These two structural attributes have been suggested in the literature to be highly significant for house prices. In most of the hedonic studies, the age of the house is usually used as a proxy to indicate the quality of a house. For instance, the quality of the house is likely to depreciate over time. When the quality of the house depreciates, it is reasonable to expect a house to decrease in value. As has been revealed in the principal analysis above, buyers of houses located in Wangsa Maju-Maluri area spent marginally more on structural attributes than buyers in Petaling Jaya. As has also been explained above, this is to be expected since most housing estates in Wangsa Maju-Maluri were developed in the late 1980s and early 1990s, compared to housing estates in Petaling Jaya area which were developed during the 1950s to 1970s. The contribution of the age of the house on house prices in this study could be accurately estimated if the data were available. Apart from the age of the house, the level of high-rise units has also been suggested to be an important determinant of house prices. The literature has shown that a unit of condominium or apartment located at the top of the building is more expensive than a unit located at the bottom of the building. This is due to the fact that a unit of condominium located at the top of the building would have a better view than the one at the bottom. Once again, data on the level of high-rise units were not available in this study. If these two variables were included in the principal analysis, it is likely that it will have resulted in a higher R-square. This implies that future research could be pursued by taking into account the age of the house and level of high-rise units in the analysis.

*Locational attributes data*: In the case of locational attributes data, there were several significant locational attributes in determining house prices that were not available in this study; the quality of the schools, crime rate and environmental quality. In the case of the relationships between the quality of local schools and house prices, various approaches have been used to measure the quality of local schools; performance of its pupils in examinations for example, performance in English, Mathematics and Science, pupil/teacher ratio, and school demographic composition. It should be noted that the availability of this data would make the estimation of the relationship between local schools and house prices in the previous chapter more accurate and meaningful. Hence, future study could pursue the effects of the quality of the schools. However, this does not mean that the results on the relationship between local schools and house prices obtained in the previous chapter were not reliable. This is because the negative significant house price gradient from local schools was clearly revealed in the GWR models – it has helped the researcher to interpret the results by referring to the additional information related to those particular schools.

House prices are also believed to be highly correlated with the crime rate. As was mentioned previously, houses located in the neighbourhoods with higher crime rates would decrease in value and *vice versa*. In Malaysia, the crime rate data can only be obtained from the Police Department and it is not available to the public unless an official request to the police department is made. This study managed to obtain the crime rate data for Kuala Lumpur and Selangor. However, these data only indicated the crime rate at state level rather than at the Mukim or Section level – the variable associated with crime rate was forced to be eliminated from this study. Therefore, as a suggestion it would be very useful for the researchers if the crime data could be made available at the Mukim or Section level in order to capture accurate effects of the crime rate on house prices.

As discussed in the preceding chapter, the better the quality of the environment, the more highly valued it is, and so is positively capitalised into house prices. Boyle and Kiel (2001) have classified measures used in previous studies on environmental quality into three distinct groups; measures of air quality, measures of water quality and measures of undesirable land uses. These three distinct groups can be classified as a measure of pollution levels. This study however, did not pursue environmental quality since it involved a high degree of work which was not realistic given the time constraints and focus of the study. However, it is worth noting that the effect of environmental quality on house prices would be interesting to look at in future study since no study has ever been conducted with respect to this attribute in Malaysia.

*Socio-economic and ethnic attributes*: Another important determinant of house prices is socio-economic and ethnic attributes. This is due to the fact that socio-economic and ethnic attributes were always used to determine the status of the neighbourhood. As has been mentioned previously, the determinants of socio-economic status in house prices relate to income levels, age, education, and car ownership of households. In other words, income levels, age, education and car ownership are commonly used as proxy to indicate the status of the neighbourhood. Unfortunately, data on income levels, education and car ownership that have been produced by the Department of Statistics, Malaysia were only indicated at the state level rather than at the Mukim or Section level – data at the state level cannot be used since the information provided is too general. The data related to these attributes can only be obtained by conducting a survey in those selected areas. However, once again this study did not pursue this because it would involve a great deal and this is of course not practical given the time constraints. Thus, future studies could include these variables in the analysis if data at the Mukim or Section level are available.

### 9.5.2 The Presence of Spatial Autocorrelation

> 'I invoke the first law of geography: everything is related to everything else, but near things are more related than distant things' (Tobler, 1970 cited by Miller, 2004: pp. 284)

Spatial dependence or spatial autocorrelation has been recognised as one of the issues in multiple regression models, particularly for evaluating hedonic house prices. There are two reasons why house prices are spatially autocorrelated (Basu and Thibodeau, 1998). Firstly, neighbourhoods tend to be developed at the same time. As a result, neighbourhood properties have similar structural attributes such as number of rooms, age, size and design features. Secondly, house prices are spatially autocorrelated when neighbourhood residential properties share common locational attributes such as access to the same amenities, and are served by the same municipal council. In other words, the existence of spatial dependence means that values for the same attribute measured at one particular location that are near to one another tend to be similar, and tend to be more similar than values separated by larger distances (Haining, 2003). In addition, values for the same variable (such as structural attributes) close in time tend to be similar and even more similar than values separated by longer time periods. For example, the prices of nearby houses are similar because they share common locational attributes and will tend to have similar structural attributes. Also, house prices are likely to be spatially autocorrelated in neighbourhoods where households follow similar commuting patterns (Gillen et al., 2001). Finally, the prices of nearby houses will have an absolute externality effect on each other. It is important to note that data points near to one another carry duplicate information about the parameter. If it were possible to include all these attributes as explanatory variables, the similarities in the selling prices of neighbouring houses would already be accounted for. However, some of the correlation between the prices of houses nearby is not explained in the estimated hedonic price equation.

In the context of a hedonic model, Orford (1999) argues that the presence of spatial dependence or spatial autocorrelation will violate the assumption of independent errors and the standard statistical tests will yield inaccurate conclusions. Orford has illustrated that spatial dependence could lead to misleading inferences about the significance of parameter estimates and could also negatively affect the validity of a wide range of standards diagnostics tests. If we take into account some of the similarities in the house prices nearby through spatial correlation, it will allow us to remove some of the white noise from the data and draw clearer inferences on the variables that we have included in our analysis. Thus, future studies could address this problem.

### 9.5.3 In-depth Investigation of Commuters

The discussion in the previous chapters explained that the value of the properties where they are located will be bid up if there is an apparent saving of commuting time from residential areas to the CBD. A relationship between access and property values is to be expected when a measure of access captures travel time savings. Although this study considers travel time savings to the CBD for those living in residential areas to be included in hedonic house prices and GWR models, it was not detailed enough to capture the socio-economic attributes of commuters who directly benefit from the introduction of an LRT system. A study conducted by Bajic (1983) on the effects of a New Subway Line on house prices in Metropolitan Toronto can be used as an example of this. In his study on Toronto, Bajic carried out the survey on the basic socio-economic attributes of commuters such as age, employment status, education, income in a normal year, number of children and number of adults in the household. He also went further by obtaining information on the location of the workplace, method of transit, the location of the nearest available parking facility adjacent to the workplace, the amount charged for parking and walking time from parking place to the work destination. The results from the survey were then incorporated into the hedonic house price model. The approach outlined above could be considered for future study in order to capture more accurate travel time savings with respect to the basic socio-economic of the household. From this we would expect that those households who experience travel time savings due to the improvement of the transportation system to bid up the house prices. This of course would reflect in the premium paid for houses located within closer proximity to a rail transit station.

### 9.5.4 The Limitation of GWR models

The discussion above highlights the importance of acknowledging the spatial effects such as spatial heterogeneity if multiple regression models are used in evaluating hedonic house prices. Evidently, the global regression model provides the basis in explaining house price variations, whilst the additional results from GWR clearly reveal a spatially varying relationship between the house prices and its determinants. The empirical evidence from this study suggests that the GWR model can be considered as an appropriate method to examine the relationship between house prices and its determinants, particularly by addressing the issue of spatial processes; spatial non-stationary. Although GWR is found to be a powerful tool in examining the relationship between house prices and its determinants over space, there is one main limitation with this method – based on the results from both global regression model and GWR, there is strong evidence that proximity to an LRT station can increase house price significantly. At the same time saving in travel time to CBD can also increase house prices. In addition, proximity to several other locational attributes such as commercial areas, secondary schools, parks and recreational areas can also add significant value to a house. On the other hand, the close distance to primary schools, hospitals and industrial areas can decrease house price significantly. The positive and negative effects from all of these locational attributes on house prices are varied over space in which it may have a positive effect on house price in some areas but negative effect in others. The main limitation with GWR is that, the variance of structural and locational effects on house prices is somewhat difficult to explain. In order to provide a more accurate, robust and reliable explanation for varying effects over space, in-depth investigations on socio-economic attributes of commuters and neighbourhood need to be carried out – perhaps by adding more variables into the model particularly socio-economic variables. However, it must be noted that adding more variables into the model would cause multicollinearity among the independent variables.

### 9.5.5 The Presence of Local Multicollinearity

The discussion in Chapter eight has highlighted the issues of multicollinearity that exist in GWR models. This local multicollinearity has been detected by employing scatter plots between the local parameter estimates in Models 8.1 to 8.4. This is due to the fact that Models 8.1 to 8.4 included more variables. Therefore, Models 8.5 to 8.8 has been calibrated with fewer variables. As a result, when fewer variables have been used, local models seem to be less affected by local mutlicollinearity. As has been noted by Du (2006; pp. 165), "this confirms that the best global model is not necessarily the best GWR model and so it is very necessary to diagnose local multicollinearity before conducting GWR analysis". However, during the time of conducting this study, the diagnostics tools for local multicollinearities were not readily available. It would be very useful for researchers if the diagnostic tools for local multicollinearities were available, and hence local multicollinearity can be shown on the map.

## 9.6 Closing Statements

It has been mentioned earlier that the evidence from empirical research both in the UK and North America shows inconsistent results and varying magnitude of the effects of rail transit systems on property values. However, if the methods that have been employed to measure the effects are an appropriate method, together with the quality of data, the positive relationship between rail transit systems and property values can be identified. These have proven to be true from the outcomes of this study – the increase in house prices results from an improvement in the transport system. In general, this study has achieved its aims to critically investigate the effects of the Kelana Jaya Line on house prices in the Klang Valley by employing two methods; the hedonic house price models and GWR models. The GWR models in particular have proven to be an appropriate technique to investigate the effect of the LRT system on house prices since it has produced meaningful results by addressing the nature of spatial process; spatial heterogeneity. This study has also shown the potential of GIS together with spatial analysis within hedonic house price research. This study has utilised a GIS by combining its capabilities with spatial analysis. Based on the case study of the Kelana Jaya Line of the Klang Valley, Malaysia, it has found that the existence of the LRT system has increased the value of houses that located within closer proximity of a station. This study has indeed contributed to the growing literature on the positive relationship between the existence of the LRT system and house prices by providing more accurate, robust and reliable empirical evidence.

# Bibliography


Abdul Aziz, A.R. (2007), 'Privatisation of fixed-rail transit systems: a case study of Malaysia's STAR and PUTRA'. *Canadian Journal of Civil Engineering*, **33** (7), pp. 846-853.

Aiken, S.R. and Leigh, C.H. (1975), 'Malaysia's Emerging Conurbation'. *Annals of the Association of American Geographers*, **65** (4), pp. 546-563.

Aiken, S.R. (1981) 'Squatters and squatter settlements in Kuala Lumpur'. *Geographical Review*, **71** (2), pp. 158-175.

Al-Mosaind, M.A., Dueker, K.J. and Strathman, J.G. (1993), 'Light rail transit stations and property values: A hedonic price approach'. *Transportation Research Record*, **1400**, pp. 90-94.

Alonso, W. (1964) *Location and Land Use: Towards a General Theory of Land Rent.* Cambridge, MA: Harvard University Press.

Anas, A., Arnott, R. and Small, J.A. (1998), 'Urban of spatial structure'. *Journal of Economic Literature*, **36**, pp. 1426- 1464.

Anderson, H., Jonsson, L. and Ogren, M. (2009), *Property prices and exposure to multiple noise sources: Hedonic regression with road and railway noise*, [online], Available: www.toulouse.inra.fr/ierna/seminaires/Anderson_etal_Noise_Hedonic_Lerun.pdf [26 July 2009]

Anderson, R.J. and Crocker, T.D. (1971), 'Air pollution and residential property values'. *Urban Studies*, **8** (3), pp. 171-180.

Anselin, L. (1988a), *Spatial Econometrics: Methods and Models.* Dordrecht: Kluwer Academic.

Anselin, L. (1998), Exploratory Spatial Data Analysis in a Geocomputational Environment. In: P.A. Longley, S. Brooks, B. Macmillan and R. McDonnell (eds.), *Geocomputation-A Primer*. New York: John Wiley, pp. 77-94.

Anselin, L. (1999), *Spatial Econometrics*. Dallas: University of Texas, [online], Available: http://www.csiss.org/learning_resources/content/papers/baltchap.pdf#search='spatial%20econometrics%20by%20Anselin' [5 May 2006].

Anselin, L., Varga, A. and Acs, Z. (2000), 'Geographical spillovers and university research: A spatial econometric perspective'. *Growth and Change*, **31** (4), pp. 501-515.

Apparicio, P. and Séguin, A.M. (2006), 'Measuring the accessibility of services and facilities for residents of public housing in Montréal. *Urban Studies*, **43** (1), pp. 187-211.

Armstrong, R. (1994), 'Impacts of commuter rail service as reflected in single-family residential property values'. *Transportation Research Record* **1466**, pp. 88-98.

Aronoff, S. (1989), *Geographic Information Systems: A Management Perspective.* Ottawa: WDC Publications.

Azevedo, C., Herriges, J. and Kling, C. (2003), 'Combining revealed and stated preferences: Consistency tests and their interpretations'. *American Journal of Agricultural Economics,* **85** (3), pp. 525-537.

Bajic, V. (1983), 'The effects of a subway line on housing prices in metropolitan Toronto'. *Urban Studies,* **20** (2), pp. 147-158.

Bajic, V. (1984), 'An analysis of the demand for housing attributes'. *Applied Economics,* **16,** pp. 597-610.

Bailey, T.C. (1994), A Review of Statistical Spatial Analysis in Geographic Information Systems. In: A.S. Fotheringham and P. Rogerson (eds.), *Spatial Analysis and GIS.* Taylor and Francis Ltd., pp. 13-44.

Balchin, P.N., Jeffrey, L.K. and Gregory, H.B. (1988), *Urban Economics and Public Policy.* Basingstoke : Macmillan Education.

Ball, M. (1973), 'Recent empirical work on the determinants of relative house prices'. *Urban Studies,* **11,** pp. 231-233.

Banister, D. (2007), Quatification of the non-transport benefits resulting from rail investment, [online], Available: www.tsu.ox.ac.uk/research/pubs/1029-banister.pdf

Banister, D. and Berechman, Y. (2000), *The economic development effects of transport investment.* Paper presented at the TRANS-TALK workshop, Brussels, [online], Available: www.iccr-international.org/trans-talk/docs/ws2-banister.pdf

Banister, D. and Banister, C. (1995), 'Energy consumption in transport in Great Britain: Macro level estimates'. *Transportation Research A: Policy and Practice,* **29A** (1), pp. 21-32.

Basu, S. and Thibodeau, T.G. (1998), 'Analysis of spatial autocorrelation in house prices'. *Journal of Real Estate Finance and Economics,* **17,** pp. 61-85.

Bateman, I., Day, B. Lake, I. and Lovett, A. (2001), *The Effect of Road Traffic on Residential Property Values: A Literature Review and Hedonic Pricing Study.* UEA, ESRC, UCL.

Baum-Snow, N. and Kahn, M.E. (2005), The effects of urban rail transit expansions: Evidence from sixteen cities, 1970-2000. Brookings papers on urban affairs, Brookings Institute, [online], Available: www.ewn.brown.edu/fac/Nathaniel_Baum-Snow/brook_final.pdf

Beaverstock, J.V., Taylor, P.J. and Smith, R.G. (1999), 'A raster of world cities'. *Cities*, **16**, pp. 445-458.

Benjamin, J.D., and Sirmans, G.S. (1994), 'Mass transportation, apartment rent and property values'. *Journal of Real Estate Research*, **12** (1), pp. 1-8.

Black, S.E. (1999), 'Do better schools matter? Parental valuation of elementary education'. *American Journal of Education*, **14** (2), pp. 577-600.

Bogart, W.T., and Cromwell, B.A. (2000), 'How much is a neighbourhood school worth?' *Journal of Urban Economics*, **47**, pp. 280-305.

Bogart, W.T. and Ferry, W.C. (1999), 'Employment centres in greater Cleveland: Evidence of evolution in a formerly monocentric city'. *Urban Studies*, **36** (12), pp. 2099-2110.

Bourassa, S.C., Hoesli, M. and Peng, V.S. (2003), 'Do housing submarkets really matter?' *Journal of Housing Economics*, **12**, pp. 12-28.

Bovaird, T. (1993), 'Analysing urban economic development'. *Urban Studies*, **30** (4/5), pp. 631-658.

Boyce, D.E., Bruce, A. Mudge, R.R. Slater, P.B. and Isserman, A. (1972), *Impact of Rapid Transit on Suburban Residential Property Values and Land Development: Analysis of the Philadelphia-Lindenwold High-speed Line.* Final Report. Philadelphia: University of Pennsylvania, Department of Regional Science.

Boyle, K.J. (2003), Introduction to revealed preference methods. In: P.A. Champ, K.J. Boyle and T.C. Brown (eds.), *A primer on non-market valuation.* Dordrecht: Kluwer Academic Publisher.

Boyle, M.A. and Kiel, K.A. (2001), 'A survey of house price hedonic studies of the impact of environmental externalities'. *Journal of Real Estate Literature*, **9** (2), pp. 117-144.

Briassoulis, H. (2000), *Analysis of Land Use Change: Theoretical and Modelling Approaches. The Web Book of Regional Science.* Morgantown, WV: West Virginia University, Regional Research Institute.

Briggs, C., Clapp, J.M., Nanda, A. and Ross, S.L. (2004), *Housing Prices, Test Scores and The Racial and Ethnic Composition of Public Schools.* University of Connecticut. Working Paper.

Brinkerhoff, P. (2001), *The Effect of Rail Transit on Property Values: A Summary of Studies.* NEOrail II, Cleveland, Ohio Research carried out for Project 21439S, Task 7 (Draft).

Brown, G.M. and Pollakowski, H.O. (1977), 'The economic valuation of shore line'. *Review of Economics and Statistics*, **59**, pp. 272-278.

Brunsdon, C., Fotheringham, A.S. and Charlton, M. (1996), 'Geographically weighted regression: A method for exploring spatial non-stationarity'. *Geographical Analysis*, **28**, pp. 281-289.

Brunsdon, C., Fotheringham, A.S. and Charlton, M. (1999), 'Some notes on parameteric significance tests for geographically weighted regression'. *Journal of Regional Science*, **39** (3), pp. 497-524.

Burrough, P.A. (1986), 'GIS and geostatistics: Essential partners for spatial analysis'. *Environmental and Ecological Statistics*, **8**, pp. 361-377.

Burton, R. and Knapp, F. (1965), 'Socio-economic change in vicinity of Capital Beltway in Virginia'. *Highway Research Record*, **75**, pp. 32-47.

Can, A. (1990), 'The measurement of neighbourhood dynamics in urban house price'. *Economic Geography*, **66**, pp. 254-272.

Can, A. (1992), 'Specification and estimation of hedonic house price models'. *Regional Science and Urban Economics*, **22**, pp. 453-474.

Carroll, T.M., Clauretie, T.M., Jensen, J. and Waddoups, M. (1996), 'The economic impact of a transient hazard on property values: The 1988 PEPCON Explosion in Henderson'. *Journal of Real Estate Finance and Economics*, **13**, pp. 143-167.

Carson, R.T., Flores, N.E., Martin, K.M. and Wright, J.L. (1996), 'Contingent valuation and revealed preference methodologies: Comparing the estimates for quasi-publoic goods'. *Land Economics*, **72** (1), pp. 80-99.

Carter, H. (1986), *The Study of Urban Geography*, 3rd edition. Newcastle upon Tyne: Athenaeum Press Ltd.

Carter, J. R. (1989), On defining the geographic information system. In *Fundamentals of Geographic Information Systems: A Compendium*. Virginia: ASPRS/ACSM) pp. 3-7.

Casetti, E. (1972), 'Generating models by the expansion method: Application to geographical research'. *Geographical Analysis*, **4**, pp. 81-91.

Casetti, E. (1997), 'The expansion method, mathematical modelling and spatial econometrics'. *International Regional Science*, **20**, pp. 81-91.

Castells, M. (1977), *The Urban Question*. London: Edward Arnold.

Cervero, R. (2004), 'Rail transit and join development: Land impacts in Washington, DC and Atlanta'. *APA Journal*, pp.83-93.

Cervero, R. and Duncan, M. (2001), *Rail Transit's Value Added: Effects of Proximity to Light and Commuter Rail Transit of Commercial Land Value in Santa Clara County, California*. Paper Prepared for the Urban Land Institute, National Association of Realtors, Washington, D.C.

Cervero, R. and Duncan, M. (2002), *Land Value Impacts of Rail Transit Services in Los Angeles County*. Report Prepared for the Urban Land Institute, National Association of Realtors, Washington, D.C.

Cervero, R. and Duncan, M. (2004), *'Residential self selection and rail commuting: A nested logit analysis'*. Berkeley: University of California Transportation Centre. Working Paper.

Cervero, R. and Landis, J. (1993), 'Assessing the impacts of urban rail transit on local real estate markets using quasi-experimental comparisons'. *Transportation Research Part A*, **27** (1), pp. 13-22.

Cervero, R. and Landis, J. (1997), 'Twenty years of the bay area rapid transit system: Land use and development impacts'. *Transportation Research A*, **31** (4), pp. 309-333.

Cervero, R. and Wu, K.L. (1997), 'Polycentrism, commuting and residential location in the San Francisco bay area'. *Environment and Planning A*, **29** (5), pp. 865-886.

Champ, P.A., Bishop, R.C., Brown, T.C. and McCollum, D.W. (1997), 'Using donation mechanisms to value non-use benefits from public goods'. *Journal of Environmental Economics and Management*, **33** (2), pp. 151-162.

Chapin, F.S. and Kaiser, E.J. (1979), *Urban Land Use Planning*. Urbana: University of Illinois Press.

Chen, H., Rufolo, A. and Dueker, K.J. (1997), *Measuring the Impacts of Light Rail Systems on Single Family Home Values: A Hedonic Approach with GIS Application*. Discussion Paper 97-3, Portland, Oregon: Portland State University.

Cheshire, P. and Sheppard, S. (1995), *Evaluating the Impact of Neighbourhood Effects on House Prices and Land Rents: Result from an Extended Model*. Discussion Papers in Urban and Regional Economics. University of Reading: Department of Economics.

Cheshire, P. and Sheppard, S. (2004), 'Capitalising the value of free schools: The impact of supply characteristics and uncertainty'. *The Economic Journal*, **114**, pp. 397-424.

Chesterton (2000), *Property Market Scoping Report*. Prepared for the Jubilee Line Extension Impact Study Unit. Impact Study Unit. London: University of Westminster, Working Paper No. 32.

Chung, H.K. (2008), 'The contingent valuation method in public libraries'. *Journal of Librarinship and Information Science*, **40** (2), pp. 71-80.

Church, R.L. and Marston, J.R. (2003), 'Measuring accessibility for people with a disability'. *Geographical Analysis*, **35** (1), pp. 83-96.

Clapp, J.M. and Ross, S.L. (2004), 'Schools and housing markets: An examination of school segregation and performance in Connecticut'. *The Economic Journal*, **114**, pp. 425-440.

Clark, C. (1967), 'Von Thunen's isolated state'. *Oxford Economic Papers, New Series*, 19 (3), pp. 370-377.

Collins A. and Evans, A. (1994), 'Aircraft noise and residential property values: An artificial neural network approach'. *Journal of Transport Economics and Policy*, **27-28**, pp. 175-198.

Covarrubias, A. (2004), *Using Land Value Capture to Fund Rail Transit Extensions in Mexico City and Santiago de Chile*. Master thesis (unpublished), Massachusetts Institute of Technology, Cambridge.

Cowen, D.J. (1988), 'GIS versus CAD versus DBMS: What are the differences?' *Photogrammetric Engineering and Remote Sensing*, **54**, pp. 1551-1554.

Cribbins, D., Hill, W. and Seagraves, H. (1965), 'Economic impact of selected sections of interstate routes on land value and use'. *Highway Research Record*, **75**, pp. 1-31.

Cropper, M.L., Deck, L.B. and McConnell, K.E. (1988), 'On the choice of functional form for hedonic price functions'. *The Review of Economics and Statistics*, **70** (4), pp. 668-675.

Cubbin, J.S. (1970), 'A hedonic approach to some aspects of the Coventry housing market'. *Warwick Economic Research Papers* 14.

CURDS, TORG and DTCP (1990), *The Longer Term Effects of the Tyne and Wear Metro.* A Report to the Transport and Roads Research Laboratory, Department of Transport by the Centre for Urban and Regional Development Studies, the Transport Operations Research Group and the Department of Town and Country Planning. University of Newcastle upon Tyne.

Cutler, D.M., Glaeser, E.L. and Vigdor, J.L. (1999), 'The rise and of the decline American ghetto'. *Journal of Political Economy*, **107** (3), pp. 455-506.

Dalvi, M.Q. (1978), *Behavioural modelling, accessibility, mobility and need: Concepts and measurement.* Croom Helm.

Daly, D.D. (1882), 'Surveys and explorations in the native states of the Malayan Peninsular, 1875-1882'. *Proceedings of the Royal Geographical Society and Monty Record of Geography.*

Damm, D., Lerman, S.R., Learner-Lam, E. and Young, J. (1980), 'Response of urban real estate values in anticipation of the Washington metro'. *Journal of Transport Economics and Policy*, **18** (4), pp. 315-36.

Daniels, C.B. (1975), 'The influence of racial segregation on housing prices'. *Journal of Urban Economics*, **2**, pp. 105-122.

Davies, G. (1974), 'An econometric analysis of residential amenity'. *Urban Studies*, **11**, pp. 217-226.

Davies, L.E. (2005), 'Not in my back yard! Sports stadia location and the property market'. *Area*, **37** (3), pp. 268-276.

Delaney, J. (1999), *Geographic Information Systems: An Introduction*. Oxford: Oxford University Press.

Delaware River Port Authority (2006), *The PATCO speedline system*, [online], Available: http://www.ridepatco.org/history.html [16 Dec 2006].

DeMers, M.N. (2000), *Exercises in GIS to Accompany Fundamentals of Geographic Information Systems*. New York: John Wiley and Sons.

Department of Statistics (1947), *The Malaysia Population and Housing Census*. Kuala Lumpur.

Department of Statistics (1957), *The Malaysia Population and Housing Census*. Kuala Lumpur.

Department of Statistics (1970), *The Malaysia Population and Housing Census*. Kuala Lumpur.

Department of Statistics (1980), *The Malaysia Population and Housing Census*. Kuala Lumpur.

Department of Statistics (1986), *The Malaysia Internal Migration Census*. Kuala Lumpur.

Department of Statistics (1991), *The Malaysia Population and Housing Census*. Kuala Lumpur.

Department of Statistics (2000), *The Malaysia Population and Housing Census*. Putrajaya.

Department of Valuation and Property Services (2006), *Property Market Report*. Putrajaya.

Department of Valuation and Property Services (2007), *Property Market Report*. Putrajaya.

Department of Valuation and Property Services (2000), The Malaysian House Price Index. Putrajaya.

Department of Valuation and Property Services (2001), The Malaysian House Price Index. Putrajaya.

Des Rosier, F., Lagana, A. and Theriault, M. (2001), 'Size and proximity effects of primary schools on surrounding house values'. *Journal of Property Research*, **18** (2), pp. 149.168.

Dewess, D.N. (1976), 'The effects of subway on residential property values in Toronto'. *Journal of Urban Economics*, **3** (4), pp. 357-69.

Diamond, B.D. (1980a), 'Income and residential location: Muth revisited'. *Urban Studies*, **17**, pp. 1-12.

Dittmar, H. and Ohland, G. (2003), *The New Transit Town: Best Practice in Transit-Oriented Development*. Washington: Island Press

Do, A.Q. and Grunditski, G. (1995), 'Golf-course and residential house prices: An empirical examination'. *Journal of Real Estate Finance and Economics*, **10** (3), pp. 261-270.

Du, H. (2006), *The Relationship Between Transport and Land Value: A Local Model Approach Using Tyne and Wear As A Case Study*. Ph.D Thesis (unpublished), University of Newcastle, Newcastle.

Du, H. and Mulley, C. (2006), 'Relationship between transport accessibility and land value: Local model approach with geographically weighted regression'. *Transportation Research Record*, **1977** (1), 197-205.

Dubin, R.A. and Sung, C.H. (1987), 'Spatial variation in the price of housing: Rent gradient in non-monocentric cities'. *Urban Studies*, **24**, pp. 193-204.

Dubin, R.A. (1998), 'Predicting house prices using multiple listing data'. *Journal of Real Estate Finance and Economics*, **17** (1), pp. 35-59.

Dueker, K.J. (1979), Land resource information systems: A review of fifteen years experience. *Geo-Processing*, **1**, pp. 105-128.

Dueker, K.J. and Bianco, M.J. (1999), *Light Rail Transit Impacts in Portland: The First Ten Years*. Paper Presented at the 78th Annual Meeting of the Transportation Research Board, Washington, D.C., [online], Available: http://www.upa.pdx.edu/CUS/publications/docs/DP98-9.pdf [17 Jan 2006].

Dunn, R., Longely, P.A. and Wringley, N. (1987), 'Graphical procedure for indentifying functional form in binary discrete choice models: A case study of revealed tenure choice'. *Regional Science and Urban Economics*, **17** (1), pp. 151-171.

Dvett, M., Dornbusch, D., Fajans, M., Falcke, C. Gussman, V. and Merchant, J. (1979), *Land Use and Urban Development Impacts of BART*. Report No. DOT-P-30-79-09. Washington DC: US Department of Transportation and US Department of Housing and Urban Development.

Earhart, D. (2001), 'Combining revealed and stated preference methods to value environmental amenities at residential locations. *Land Economics*, **77** (1), pp. 12-29.

Evans, A.W. (1973), *The Economics of Residential Location*. London: McMillan.

Evans, A.W. (1983), 'The determination of the price of land'. *Urban Studies*, **20**, pp. 119-129.

Eyerly, R. (1966), *Land Use and Land Value in Four Interchange Communities*. Institute For Research on Land and Water Resource. Research Report No. 7. Philadelphia: Pennsylvania State University.

Federal Transit Administration (2000), *Transit Benefits*. Washington, D.C: United States Department of Transportation.

Fisher, M.M. and Nijkamp, P. (1992), 'Geographic information systems and spatial analysis'. *The Annals of Regional Science*, **26**, pp. 3-17.

Fleming, M.C. and Nellis, J.G. (1984), *The Halifax House Price Index: Technical Detail.* Halifax: Halifax Building Society.

Fletcher, M., Gallimore, P. and Mangan, J. (2000), 'Heteroscedasticity in hedonic price models'. *Journal of Property Research*, **17** (2), pp. 93-108.

Follain, J.R. and Jimenez, E. (1985), 'Estimating the demand for housing characteristics: A critique and survey'. *Regional Science and Urban Economics*, **15**, pp. 77-107.

Follain, J.R. and Malpezzi, S. (1981), 'Flight to the suburbs: Insight gained from an analysis of central city vs. suburban price differentials'. *Journal of Urban Economics*, **9**, pp. 381-398.

Ford, A. and Barr, S. (2009), 'Accessibility analysis by generalised cost in a GIS framework'. In: D. Fairbairn (ed.), *Proceedings of the GIS Research UK 17th Annual Conference 1st-3rd April 2009*. Durham: University of Durham.

Forrest, D., Glen, J., Grime, J. and Ward, R. (1996), 'House price changes in greater Manchester 1990-1993 and the impact of metro link'. *Journal of Transport Economics and Policy*, **30** (1), pp. 15-29.

Fortney, J. (1996), 'A cost-benefit locational-allocation model for public facilities: An econometric approach'. *Geographical Analysis*, **28** (1), pp. 67-92.

Foster, S.A. (1991), 'The expansion method: Implications for geographical research'. *Professional Geographer*, **43** (2), pp. 131-142.

Fotheringham, A.S. (1997b), 'Trends in quantitative methods I: Stressing the local'. *Progress in Human Geography*, **21**, pp. 88-96.

Fotheringham, A.S., Charlton, M.E. and Brunsdon, C. (1997a), 'Two techniques for exploring non-stationarity in geographical data'. *Geographical Systems*, **4**, pp. 59-82.

Fotheringham, A.S. and Brunsdon, C. (1999), 'Local forms of spatial analysis'. *Geographical Analysis*, **31** (4), pp. 340-358.

Fotheringham, A.S., Brunsdon, C. and Charlton, M.E. (1998), 'Geographically weighted regression: A natural evolution of the expansion method for spatial data analysis'. *Environment and Planning A*, **30**, pp. 1905-1927.

Fotheringham, A.S., Charlton, M.E. and Brunsdon, C. (1996), 'The geography of parameter space: An investigation into spatial non-stationarity'. *International Journal of Geographic Information Systems*, **10**, pp. 605-627.

Fotheringham, A.S., Brundson, C. and Charlton, M.E. (2002), *Geographically Weighted Regression: The Analysis of Spatially Varying Relationships*. West Sussex: John Wiley and Sons Ltd.

Freeman, A.M. (1979b), 'Hedonic prices, property values and measuring environmental benefits: A survey of the issues'. *Scandinavian Journal of Economics*, **81**, pp. 154-173.

Freeman, A.M. (1985), Methods for Assessing the Benefits of Environmental Programmes. In: A.V. Kneese and J.L. Sweeney (eds.), *Handbook of Natural Resource and Energy Economics*, **1**, pp. 223-269.

Freeman, A.M. (1993), *The Measurement of Environmental and Resource Values. Washington*, DC: Resources for the future.

Fujita, M. (1989), *Urban Economic Theory: Land Use and City Size*. Cambridge: Cambridge University Press.

Gambled, H., Sauerlender, O. and Langley, J. (1974), 'Adverse and beneficial effects of highways on residential property values'. *Transportation Research Record*, **508**, pp. 37-48.

García, N., Gámez, M. amd Alforo, E. (2008), 'ANN+GIS: An automated system for property valuation'. *Neurocomputing*, **71**, pp. 733-742.

Garreau, J. (1991), *Edge City*. New York: Dounleday.

Garret, T.A. and Castelazo, M.D. (2004), 'Light rail transit in America: Policy issues and prospects for economic development', Federal Reserve Bank of St. Louis, [online], Available: www.cfte.org/news/garret.pdf

Garrod, G. and Willis, K. (1992b), 'The environmental economic impact of woodland: A two stage hedonic price model of the amenity value of forestry in Britain'. *Applied Economics*, **24**, pp. 715-728.

Gatzlaff, D. and Smith, M. (1993), 'The impact of the Miami metrorail on the value of residences near station locations'. *Land Economics*, **69** (1), pp. 54-66.

Gibbons, S. and Machin, S. (2003), 'Valuing English primary schools'. *Journal of Urban Economics*, **53**, pp. 197-219.

Gibbons, S. and Machin, S. (2006), 'Paying for primary schools: Admission constraints, school popularity or congestion'. *The Economic Journal*, **116** (510), pp. 77-92.

Gillen, K., Thibodeau, T. and Wachter, S. (2001), 'Anisotropic autocorrelation in house prices'. *Journal of Real Estate Finance and Economics*, **23** (1), pp. 5-30.

Giuliano, G. (2004), Land Use Impacts of Transportation Investments: Highway and Transit. In: S. Hanson and G. Giuliano (eds). *The Geography of* Urban *Transportation*. New York: Guilford Press.

Giuliano, G. (2001), 'The role of public transit in the mobility of low income households', Metranst Transportation Institute, [online], Available: www.metrans.org/research/final/99-11_final.pdf

Giuliano, G. and Small, K. (1991), 'Is the journey to work explained by urban structure?' *Urban Studies*, **30** (9), pp. 1485-1500.

Gleave, S.D. (2005), 'What light rail can do for cities: A review of the evidence', [online], Available: www.pteg.net/NR/rdonlyres/F37F7FEB-4756-4705-8185-EEEA79F6287E/0/WhatLightRailCanDoforCitiesAppendices_0105.PDF

Golden, J. (1968), *Land values in Chicago: Before and after expressway construction.* Chicago transportation area study. Washington, DC: US Department of Transportation.

Goldstein, H. (1987), *Multilevel Models in Educational and Social Research.* London: Charles Griffith.

Goldstein, G.S. and Moses, L.N. (1973), 'A survey of urban economics'. *Journal of Economic Literature*, **11** (2), pp. 471-515.

Goodchild, M.F. (1987), 'A spatial analytical perspective on geographical information systems'. *International Journal of Geographical Information Systems*, **1**, pp. 335-354.

Goodchild, M.F. (1988), Towards an enumeration and classification of GIS. In: R.T. Aaneenburg and Y.M. Schiffman (eds.), *International Geographic Information Systems (IGIS) Symposium: The Research Agenda*. pp. 67-77.

Goodchild, M.F. (1991), The Technological Setting of GIS. In: D.J. Maguire, M.F. Goodchild and D.W. Rhind (eds.), *Geographical Information Systems: Methodology and Potential Applications*. London: Longmans. pp. 45-54

Goodchild, M.F., Haining, R. and Wise, S. (1992), 'Integrating GIS and spatial data analysis: Problems and possibilities'. *International Journal of Geographical Information Systems*, **6**, pp. 407-423.

Goodman, A.C. and Thibodeau, T.G. (1998), 'Dwelling age heteroscedasticity in repeat sales house price equation'. *Real Estate Economics*, **26**, pp. 151-171.

Goodman, A.C. and Thibodeau, T.G. (2003), 'Housing market segmentation and hedonic prediction accuracy'. *Journal of Housing Economics*, **12** (3), pp. 181-201.

Gordon, P., Richardson, H.W. and Wong, H.L. (1986), 'The distribution of population and employment in a polycentric city: The case of Los Angeles'. *Environment and Planning A*, **18**, pp. 161-173.

Gould, M. I. and Fieldhouse, E. (1997), 'Using the 1991 census SAR in a multilevel analysis of male unemployment'. *Environment and Planning A*, **29**, pp. 611-628.

Graves, P., Murdoch, J.C., Thayer, M.A. and Waldman, D. (1988), 'The robustness of the hedonic price function: Urban air quality'. *Land Economics*, **64** (3), pp. 220-233.

Griffith, D.A. (1981), 'Evaluating the transformation from a monocentric to a polycentric city'. *Professional Geographer*, **32** (2), pp. 189-196.

Griliches, Z. (1971), *Price Indexes and Quality Change*. Cambridge MA: Harvard University Press.

Gujarati, D. (1999), *Essentials of Econometrics*, 2nd Edition, Boston: Irwin/McGraw-Hill.

GVA Grimley (2004), 'Developing a Methodology to Capture Land Value Uplift Around Transport Facilities', [online], Available: http://www.scotland.gov.uk/Publications/2004/11/20385/48337

Haining, R.P. (1994), Designing Spatial Data Analysis Modules for Geographical Information Systems. In: A.S. Fotheringham and P. Rogerson (eds.), *Spatial Analysis and GIS*. London: Taylor and Francis. pp. 45-64

Haining, R. (2003), *Spatial Data Analysis: Theory and Practice*. Cambridge: Cambridge University Press.

Halvorsen, R. and Pollakowski, H. (1981), 'Choice of functional form for hedonic price equations'. *Journal of Urban Economics*, **10**, pp. 37-49.

Handy, S.L. and Niemeir, D.A. (1997), 'Measuring accessibility: an exploration of issues and alternatives'. *Environment and Planning A*, **29** (7), pp. 1175-1194

Hanson, S. (2004), The Context of Urban Travel: Concepts and Recent Trends. In: S. Hanson and G. Giuliano (eds.), *The Geography of Urban Transportation*. New York: Guilford Press.

Han, S.S. and Basuki, A. (2001), 'The spatial pattern of land values in Jakarta'. *Urban Studies*, **38** (10), pp. 1841-1857.

Harris, D.R. (1999), 'Property values drop when black move in, because...: Racial and socioeconomic determinants of neighbourhood desirability'. *American Sociology Review*, **64** (3), pp. 461-479.

Harrison, D.J. and Rubinfield, D.L. (1978), 'Hedonic housing prices and the demand for clean air'. *Journal of Environmental Economics and Management*, **5**, pp. 81-102.

Harvey, D. (1973), *Social Justice and the City*. Edward Arnold Ltd.

Harvey, J. (2000), *Urban Land Economics*, 5th edition. London: Macmillan Press Ltd.

Haurin, D.R. and Brasington, D. (1996), 'School quality and real housing prices: Inter and intra-metropolitan effects'. *Journal of Housing Economics*, **5**, pp. 351-368.

Hayes, K.J. and Taylor, L.L. (1996), Neighbourhood school characteristics: What signals quality to homebuyers? *Economic Review: Federal Reserve Bank of Dallas*, **4**, pp. 2-9.

Heikkila, E. (1988), 'Multicollinearity in regression models with multiple distance measures'. *Journal of Regional Science*, **28**, pp. 345-361.

Heikkila, E., Gordon, P., Kim, J., Deiser, R.B. and Richardson, H.W. (1989), 'What happened to the CBD: Distance gradient? Land values in a polycentric city'. *Environment and Planning A*, **21** (2), pp. 221-232.

Henneberry, J. (1998), 'Transport investment and house prices'. *Journal of Property Valuation and Investment*, **16** (2), pp. 144-158.

Hess, D.B. and Almeida, T.M. (2007), 'Impact of proximity to light rail rapid transit on station-area property values in Buffalo, New York'. *Urban Studies*, **44** (5-6), pp. 1041-1068.

Hirschman, C. (1980), 'Demographic trends in Peninsular Malaysia 1947-1975'. *Population and Development Review*, **6**, pp. 103-125.

Hoch, I. and Waddell, P. (1993), 'Apartment rents: Another challenge to the monocentric model'. *Geographical Analysis*, **25** (1), pp. 20-34.

Huang, Y. and Leung, Y. (2002), 'Analysing regional industrialisation in Jiangsu province using geographically weighted regression'. *Journal of Geographical System*, **4**, pp. 233-249.

Hurd, R. M. (1924), *Principles of City Land Values*. New York: The Record and Guide.

Husin, A. (1990), *The Construction of Regression-based Mass Appraisal Models: A Methodological Discussion and An Application to Housing Submarkets in Malaysia*. Ph.D. Thesis (unpublished), University of Reading, Reading.

Ithnin, H. (2001), 'The 1998 Water Crisis in the Klang Valley Region, Malaysia'. *Journal of Malaysian Tropical Geography*, **32** (1 & 2), pp. 1-12.

Irwin, E.G. (2002), 'The effects of open space on residential property values'. *Land Economics*, **78** (4), pp. 465-480.

Ismail, S. (2005), *Hedonic Modelling of Housing Markets Using GIS and Spatial Statistics: A Case Study of Glasgow, Scotland*. Ph.D. Thesis (unpublished), University of Aberdeen, Aberdeen.

Jackson, J.R. (1979), 'Intraurban variations in the price of housing'. *Journal of Urban Economics*, **6**, pp. 464-479.

Jim, C.Y. and Chen, W.Y. (2009), 'Value of scenic views: Hedonic assessment of private housing in Hong Kong'. *Journal of Landscape and Urban Planning*, pp. 1-9.

Johnston, R.J., Gregory, D., Pratt, G. and Watts, M. (2000), *The Dictionary of Human Geography*, 4th edition. Oxford: Blackwell Publishers Ltd.

Johnston, R.J., Gregory, D. and Smith, D.M. (1994), *The Dictionary of Human Geography 3rd edition.* Oxford: Blackwell Publishers Ltd.

Jones, K. (1991), *Multilevel Models for Geographical Research.* Concepts and Techniques in Modern Geography 54. Norwich: Geo Books.

Jones, K. and Bullen, N. (1993), 'A multilevel analysis of the variations in domestic property prices: Southern England 1980-1987'. *Urban Studies*, **30** (8), pp. 1409- 1426.

Jones, K. and Bullen, N. (1994), 'Contextual models of urban house prices: A comparison of fixed-and-random-coefficient models developed by expansion'. *Economic Geography*, **70** (3), pp. 252-272.

Jones, J. and Casetti, E. (1992), *Application of the Expansion Method.* London: Routledge.

Kain, J.F. and Quiley, J.M. (1970a), 'Measuring the value of housing quality'. *Journal of the American Statistical Association.* **65** (330), pp. 532-548.

Kennedy, G., Dai, M., Henning, S. and Vandeveer, L. (1996), 'A GIS-based approach for including topographic and locational attributes in the hedonic analysis of rural land values'. *Paper presented at the annual meetings of the American Agricultural Economics Association*, San Antonio, July 28–31.

Kiel, K.A. (1995), 'Measuring the impact of the discovery and cleaning of hazardous waste sites on house values'. *Land Economics*, **71**, pp. 428-435.

Kiel, K.A. and McClain, K.T. (1996), House price recovery and stigma after a failed sitting. *Applied Economics*, **28**, pp. 1351-1358.

King, A.T. (1976), 'The demand for housing: A lancasterian approach'. *Southern Economics Journal*, **43**, pp. 1077-1087.

King, A.T. and Mieszkowski, P. (1973), 'Racial discrimination, segregation and the price of housing'. *Journal of Political Economy*, **81** (3), pp. 590-606.

Klossterman, R.C. and Musterd, S. (2001), 'The polycentric urban region: Towards a research agenda'. *Urban Studies*, **38** (4), pp. 623-633.

Knapp, G.J., Hopkins, L.D. and Ding, C. (1999), *Do plans matter? Effects of light rail plans on land values in station areas.* Lincoln Institute of Land Policy Working Paper.

Knight, R. and Trygg, L. (1977), 'Evidence of land use impacts of rapid transit systems'. *Transportation*, **6**, pp. 233-147.

Knowles, R.D. (1996), 'Transport impacts of greater Manchester's metrolink light rail system. *Journal of Transport Geography*, **4** (1), pp. 1-14.

Koshkariov, A.V., Tikunov, V.S. and Trofimov, A.M. (1989), 'The current state and trends in the development of geographical information systems in the USSR'. *International Journal of Geographical Information Systems*, **5** (4), pp. 257-272.

Kuala Lumpur City Hall (1984), *Kuala Lumpur Structure Plan*. Kuala Lumpur.

Kuala Lumpur City Hall (2000), *Kuala Lumpur Structure Plan 2020*. Kuala Lumpur

Laakso, S. (1992), *Public Transportation Investment and Residential Property Values in Helsinki*. Scandinavian Housing and Planning Research.

Ladd, H.F. and Wheaton, W. (1991), 'Causes and consequences of the changing urban form'. *Regional Science and Urban Economics*, **21** (2), pp. 157-162.

Lake, I.R., Lovett, A.A., Bateman, I.J. and Langford, I.H. (1998), 'Modelling environment influences on property prices in an urban environment'. *Computers, Environment and Urban Systems*, **22** (2), pp. 121-136.

Lake, I.R., Lovett, A.A., Bateman, I.J. and Day, B. (2000a), 'Using GIS and large scale digital data to implement hedonic pricing studies'. *International Journal of Geographical Information Science*, **14** (6), pp. 521-541.

Lake, I.R., Lovett, A.A., Bateman, I.J. and Day, B. (2000b), 'Improving land compensation procedures via GIS and hedonic pricing'. *Journal of Environment and Planning C*, **18** (6), pp. 681-696.

Lake, I.R., Jones, A., Jones, N., Panter, J., Harrison, F., van Sluijs, E. and Griffin, S. (2009), 'Using GIS derived variables to identify factors affecting physical activity levels in children'. In: D. Fairbairn (ed.), *Proceedings of the GIS Research UK 17th Annual Conference 1st-3rd April 2009*. Durham: University of Durham.

Lancaster, K. (1966), 'A new approach to consumer theory'. *Journal of Political Economy*, **74**, pp. 132-157.

Landis, J. and Loutzenheiser, D. (1995), *BART at 20: BART Access and Office Building Performance*. Institute of Urban and Regional Development. Berkeley: University of California.

Landis, J., Guhathakurta, S., Huang, W. and Zhang, M. (1995), *Rail Transit Investments, Real Estate Values and Land Use Change: A Comparative Analysis of Five California Rail Transit Systems*. UCTC Working Paper No. 285. Berkeley: University of California Transportation Centre.

Lane, R. (1970), *Some Findings on Residential Location, House Prices and Accessibility*. Paper given to Research and Intelligence Unit, Department of Planning and Transportation, Greater London Council.

Lansford, N.H. and Jones, L.L. (1995), 'Recreational and aesthetic value of water using hedonic price analysis'. *Journal of Agricultural and Resource Economics*, **20** (2), pp. 341-355.

Lerman, S., Damm, D., Lam-Lerner, E. and Young, J. (1978), *The Effects of the Washington Metro on Urban Property Values*. Final Report No. UMTA-MA-11-0004-79-1. Cambridge, MA: MIT Press.

Lerman, S.R. (1979), Neighbourhood Choice and Transportation Services. In: D. Segal (ed.), *Studies in Urban Economics*. New York: Academic Press. pp. 129-153.

Leung, Y., Mei, C.L. and Zhang, W.X. (2000a), 'Statistical test for spatial non-stationarity based on the geographical weighted regression model'. *Environment and Planning A*, **32**, pp. 9-32.

Leung, Y., Mei, C.L. and Zhang, W.X. (2000b), 'Testing for spatial autocorrelation among the residuals of the geographical weighted regression'. *Environment and Planning A*, **32**, pp. 871-890.

Levesque, T. (1994), 'Modelling the effects of airport noise on residential housing market'. *Journal of Transport Economics and Policy*. **28** (2), pp. 199-211.

Li, M.M. and Brown, H.J. (1980), 'Micro-neighbourhood externalities and hedonic house prices'. *Land Economics*, **56**, pp. 125-140.

Litman, T. (2003), 'Evaluating rail transit criticism', [online], Available: www.vtpi.org/tca

Litman, T. (2004a), 'Rail transit in America: A comprehensive evaluation of benefits', [online], Available: www.vtpi.org/railben.pdf

Litman, T. (2004b), 'Evaluating public transit benefits in St. Louis: Critique of 'light rail boon or boondoggle' citizens for modern transit', [online], Available: www.cmt.stl.org/images/litman.pdf

Litman, T. (2006), 'Guide to calculating mobility management benefits', [online], Available: www.vtpi.org/tdmben.pdf

Litman, T. (2007), 'Evaluating rail transit benefits: A comment'. *Transport Policy*, 14, pp. 94-97

Loftin, C. and Ward, S.K. (1983), 'A spatial autocorrelation model of the effects of population density and fertility'. *American Sociological Review*, 48, pp. 121-128.

London Underground Report (2006), *London travel report 2006*, [online], Available: http://www.tfl.gov.uk/assets/downloads/corporate/London-Travel-Report-2006-final.pdf [23 Nov 2006].

Longley, P.A. and Dunn, R. (1988), 'Graphical assessment of housing market models'. *Urban Studies*, **25** (1), pp. 21-33.

Longley, P.A., Goodchild, M.F., Maguire, D. and Rhind, D.W. (1999), *Geographical Information Systems, 2.* New York: John Wiley and Sons.

Longley, P.A., Goodchild, M.F., Maguire, D. and Rhind, D.W. (2001), *Geographic Information Systems and Science.* New York: John Wiley and Sons.

Longley, P.A. and Tobon, C. (2004), 'Spatial dependence and heterogeneity in patterns of hardship: An intra-urban analysis'. *Annals of the Association of American Geographers*, **94** (3), pp. 503-519.

Loomis, J., Brown, T., Lucero, B. and Peterson, G. (1996), 'Improving validity experiments of contingent valuation methods: Results of efforts to reduce the disparity of hypothetical and actual willingness to pay. *Land Economics*, **72** (4), pp. 450-461.

Maguire, D.J. and Dangermond, J. (1991), The Functionality of GIS. In: D.J. Maguire, M.F. Goodchild, D.W. Rhind (eds.), *Geographical Information Systems: Principles and Applications*, **1**. New York: John Wiley and Sons. pp. 319-335.

Maguire, D.J. (1991), An Overview and Definition of GIS, In: D.J. Maguire, M.F. Goodchild, D.W. Rhind (eds.), *Geographical Information Systems: Principles and Applications*, **1**. New York: John Wiley and Sons. pp. 9-20.

Manchester Metrolink (2007), An introduction to metrolink, [online], Available: http://www.lrta.org/Manchester/index.html.

McDonald, J.F. (1979), *Economic Analysis of an Urban Housing Market Studies in Urban Economics.* Academic Press.

McDonald, J.F. and Prather, P. (1994), 'Suburban employment centres: The case of Chicago'. *Urban Studies*, **31**, pp. 201-218.

McGee, T. (1967), *The Southeast Asian City: A Social Geography of the Primate Cities of Southeast Asian.* London: G. Bell.

McLeod, P.B. (1984), 'The Demand for Local Amenity: An hedonic price analysis'. *Environment and Planning A*, **16**, pp. 359-400.

McMillan, M. L. (1979), Estimates of households' preferences for environment quality and other housing charateristics from a system of demand equations. *The Scandinavian Journal of Economics*, **81** (2), pp. 174-187.

McMillen, D.P. (2003), 'The return of centralisation to Chicago: Using repeat sales to identify changes in house price distance gradients'. *Regional Science and Urban Economics*, **33**, pp. 287-304.

McMillen, D.P. and McDonald, J.F. (1997), 'A nonparametric analysis of employment density in a polycentric city'. *Journal of Regional Science*, **37**, pp. 591-612.

McMillen, D.P. (2004), 'Airport expansions and property values: The case of Chicago O'Hare airpor't. *Journal of Urban Economics*, **55** (3), pp. 627-640.

Megbolugbe, I.F. (1989), 'A hedonic index model: The housing market of Jos, Nigeria'. *Urban Studies*, **26**, pp. 486-494.

Mendelsohn, R., Hellerstein, D., Hughenin, M., Unseworth, R. and Brazee, R. (1992), 'Measuring hazardous waste damages with panel models'. *Journal of Environmental Economics and Management*, **22**, pp. 259-271.

Mennis, J. (2006), 'Mapping the results of geographically weighted regression'. *The Journal of Cartographic*, **43** (2), pp. 171-179.

Mieszkowski, P. and Mills, E.S. (1993), 'The causes of metropolitan suburbanisation'. *Journal of Economic Perspectives*, **7**, pp. 135-147.

Mikelbank, B.A. (2000), *Spatial Analysis of the Relationship between Transportation Infrastructure and Metropolitan Housing Values: Integrating Traditional, Spatial and Geostatistical Approaches*. Ph.D. Thesis (unpublished), The Ohio State University, Ohio.

Miller, H.J. (2004), 'Tobler's first law and spatial analysis'. *Annals of the Association of American Geographers*, **94** (2), pp. 284-289.

Mills, E.S. (1972), *Urban Economics*. London: Scott, Foresman and Company.

Miles, J.C, Mitchell, C.G.B and Perrett, K. (1981) 'Monitoring the Effects of the Tyne and Wear Metro', In: *TRRL Report SR 860*, Transport and Road Research Laboratory, Crowthorne, UK.

Mingche, M.L. and Brown, J.H. (1980), 'Micro-neighbourhood externalities and hedonic housing price'. *Land Economics*, **56**, pp. 125-141.

Mitchell, R.C. and Carson, R.T. (1989), *'Using surveys to value public good: The contingent valuation method'*. Washington, DC: Resources for the future.

Mohamad, J. and Kiggundu, A.T. (2007), 'The rise of the private car in Kuala Lumpur: Assessing the policy option'. *IATSS RESEARCH*, **31** (1), pp. 69-77.

Mohamad, J. (1994), 'Car use for work travel in Kuala Lumpur: The availability factor'. *Malaysian Journal of Tropical Geography*, **25** (2), pp. 91-98.

Murdock, J.C. and Thayer, M.A. (1988), 'Hedonic price estimation of variable urban air quality'. *Journal of Environmental Economics*, **15**, pp. 143-146.

Muth, R. (1969), *Cities and Housing: The Spatial Pattern of Urban Residential Land Use*. Chicago: Chicago University Press.

Muth, R.F. and Goodman, A.C. (1989), *The Economics of Housing Markets. Fundamental and Applied Economics 31*. Harwood Academic Publishers.

Myers, C.K. (2004), 'Discrimination and neighbourhood effects: Understanding racial differentials in US housing prices'. *Journal of Urban Economics*, **56**, pp. 279-302.

Nakaya, T. (2001), 'Local spatial interaction modelling based on the geographically weighted regression approach'. *GeoJournal*, **53**, pp. 347-358.

Navrud, S. (1992), *Willingness to pay for preservation of species: An experiment with actual payments in pricing the European environment.* Oxford: Oxford University Press.

Nelson, J.P. (1978), 'Residential choice, hedonic prices and the demand for urban air quality'. *Journal of Urban Economics*, **5**, pp. 357-369.

Nelson, J.P. (1980), 'Airport and property values'. *Journal of Transport Economics and Policy*, **14** (1), pp. 37-52.

Nelson, J.P. (1981), 'Three Mile Island and residential property values: Empirical analysis and policy implication'. *Land Economics*, **57** (3), pp. 363–372

Nelson, A. (1992), 'Effects of elevated heavy rail transit stations on house prices with respect to neighbourhood income'. *Transportation Research Record*, **1359**, pp. 127-132.

Nelson, A. and McClesky, S. (1990), 'Improving the effects of elevated transit stations on neighbourhood'. *Transportation Research Record*, **1266**, pp. 173-180.

'New LRT lines approved', *The Star* (7 July 2007), p. 6.

Ohsfeldt, R.L. (1988), 'Implicit markets and the demand for housing characteristics'. *Regional Science and Urban Economics*, **18**, pp. 321-343.

Okposin, S.B. and Yu, C.M. (2000), *Economic Crises in Malaysia: Causes, Implications and Policy Prescriptions*. Subang Jaya: Pelanduk Publications (M) Sdn. Bhd.

Olszewski, P. and Wibowo, S.S. (2005), 'Using equivalent walking distance to assess pedestrian accessibility to transit stations in Singapore'. *Transportation Research Record*, **1927**, pp. 38-45.

Openshaw, S. (1991), Developing Appropriate Spatial Analysis Methods for GIS. In: D.J. Maguire, M.F. Goodchild and D.W. Rhind (eds.), *Geographical Information Systems: Methodology and Potential Application*. London: Longmans, pp. 389-402.

Openshaw, S. (1994a), What is GISable Spatial Analysis? *New Tools for Spatial Analysis*. Luxembourg: Eurostat. pp. 36-44.

Openshaw, S. (1994b), 'Two exploratory space-time-attribute pattern analysers relevant to GIS'. In S. Fotheringham, and P. Rogerson (eds.), *Spatial Analysis and GIS*. London: Taylor and Francis Ltd., pp. 83-104.

Openshaw, S. and Clarke, G. (1996), 'Developing spatial analysis functions relevant to GIS environments'. In M. Fisher, H.J. Scholten and D.J. Unwin (eds.), *Spatial Analytical Perspectives in GIS*. London: Taylor and Francis.

Orford, S. (1999), *Valuing the Built Environment: GIS and House Price Analysis*. Aldershot: Ashgate Publishing Ltd.

Orford, S. (2000), 'Modelling spatial structures in local housing market dynamics: A multilevel perspective'. *Urban Studies*, **37** (9), pp. 1643-1671.

O'Sullivan, S. and Morrall, J. (1996), 'Walking distance to and from light rail transit stations'. *Transportation Research Record*, **1538**, pp. 19-26.

Páez, A., Uchida, T. and Miyamoto, K. (2001), 'Spatial association and heterogeneity issues in land price models'. *Urban Studies*, **38** (9), pp. 1493-1508.

Páez, A., Uchida, T. and Miyamoto, K. (2002a), 'A general framework for estimation and inference of geographically weighted regression models: 1. Location-specific kernel bandwidths and a test for spatial non-stationarity'. *Environment and Planning A*, **34**, pp. 733-754.

Páez, A., Uchida, T. and Miyamoto, K. (2002b), 'A general framework for estimation and inference of geographically weighted regression models: 2. Spatial association and model specification tests'. *Environment and Planning A*, **34**, pp. 733-754.

Palmquist, R.B. (1982), 'Measuring environmental effects on property values without hedonic regression'. *Journal of Urban Economics*, **11**, pp. 333-347.

Palmquist, R.B. (1984), 'Estimating the demand for the characteristics of housing'. *Review of Economics and Statistics*, **66**, pp. 394-404.

Palmquist, R.B. (1991), *Hedonic Methods in Measuring the Demand for Environmental Quality*. In J.B. Braden and C.D. Kolstad (eds.), Amsterdam: North Holland.

Parker, H. (1988), 'Unique qualities of a geographic information systems: A commentary'. *Photogrametric Engineering and Remote Sensing*, **54** (11), pp. 1547-1549.

Paterson, R.W. and Boyle, K.J. (2002), 'Out of sight, out of mind? Using GIS to incorporate visibility in hedonic property value models'. *Land Economics*, **78** (3), pp. 417-425.

Parker, H. (2002), *Crossrail: Property Value Enhancement*. London: Canary Wharf Group.

Pharoah, T. (2002), *Jubilee Line Extension Development Impact Study*. London: University of Wesminster.

Pinch, S. (1985), *Cities and Services: The Geography of Collective Consumption*. Routledge and Kegan Paul.

Pisarski, A.E. (1996), *Community in America II: The second national report on commuting patterns and trends.* Lansdowne, VA: Eno Foundation for Transportation.

Podobnik, B. (2002), *The social and environmental achivements of new urbanism: Evidence from Orenco station.* Department of Sociology, Lewis and Clarke college, [online], Available: www.lclark.edu/~podobnik/orenco02.pdf

Potter, R.B. and Lloyd-Evans, S. (1998), *The City in the Developing World.* Harlow: Longman.

Poudenx, P. (2008), 'The effect of transportation policies on energy consumption and greenhouse gas emission from urban passenger transportation'. *Transportation Research Part A*, **42**, pp. 901-909.

Poudyal, N.C., Hodges, D.G. and Merrett, C.D. (2009), 'A hedonic analysis of the demand for and benefits of urban recreation parks'. *Journal of Land Use Policy*, **26**, pp. 975-983.

Powe, N.A., Garrod, D. Willis, K.G. (1995), 'Valuation of urban amenities using an hedonic price model'. *Journal of Property Research*, **12**, pp. 137-147.

Powe, N.A., Garrod, G.D., Brunsdon, C.F. and Willis, K.G. (1997), 'Using a geographic information system to estimate an hedonic price model of the benefits of woodland access'. *Forestry*, **70** (2), pp. 139-149.

Pryce, G. (2002), 'Heteroscedasticity: Testing and correcting in SPSS', [online], Available: http://www.spsstools.net/spss.htm.

Pucher, J. (2004), Public Transportation, in S. Hanson and G. Giuliano (eds.), *The Geography of Urban Transportation.* New York: The Guilford Press. pp. 199-236.

Pundt, H. and Brinkkötter-Runde, K. (2000), ' Visualisation of spatial data for field based GIS'. *Computers and Geosciences*, **26**, pp. 51-56.

Quigley, J.M. (1982), 'Non-linear budget constraints and consumer demand: An application to public programs for residential housing'. *Journal of Urban Economics*, **12** (2), pp. 177-201.

Randall, A. (1991), Total and nonuse values, in Braden, J.B. and Kolstad, C.D. (eds.) *Measuring the Demand for Environmental Quality*, London: North-Holland, pp. 303-321.

Renne, J.L. (2005), *Transit-oriented Development: Measuring Benefits, Analysis Trends and Evaluating Policy.* Ph.D. thesis (unpublished), The States University of New Jersey, New Jersey.

Richardson, H.W., Vipond, J. and Furbey, R.A. (1974), 'Determinants of urban house prices'. *Urban Studies*, **11**, pp. 189-199.

Ridker, R.G. and Henning, J.A. (1967), 'The determination of residential property values with special reference to air pollution'. *Review of Economics and Statistics*, **49**, pp. 246-257.

Rogerson, P.A. and Fotheringham, A.S. (1994), GIS and Spatial Analysis: Introduction and Overview. In: A.S. Fotheringham, and P. Rogerson, (eds.), *Spatial Analysis and GIS.* Taylor and Francis Ltd. pp. 1-10.

Rogerson, P.A. (2006), *Statistical Methods for Geography: A Student's Guide.* London: SAGE Publications Ltd.

Rosen, S. (1974), 'Hedonic prices and implicit markets: Product differentiation in pure competitions'. *Journal of Political Economy*, **72**, pp. 34-55.

Ross, S.L. and Yinger, J. (1999), Sorting and Voting: A Review of the Literature on Urban Public Finance. In: P. Cheshire and E. Mills (eds.), *Handbook of Urban and Regional Economics.* Amsterdam: North-Holland. 3, pp. 2001-2060.

Ryan, S. (1997), 'The value of access to highways and light rail transit: Evidence for industrial and office firms'. *Urban Studies*, **42** (4), pp. 751-764.

Ryan, S. (1999), 'Property values and transportation facilities: Finding the transportation-land use connection'. *Journal of Planning Literature*, **13** (4), pp. 412-427.

Samat, N. (2002), *A Geographic Information System and Cellular Automata Spatial Model of Urban Development for Penang State, Malaysia.* Ph. D. thesis (unpublished), University of Leeds, Leeds.

Sanchez, T.W. (1993), Measuring the Impact of Highways and Roads on Residential Property Values with GIS: An Empirical Analysis of Atlanta, in R.E. Klosterman and S.P. French (eds.), *Third International Conference on Cumputers in Urban Planning and Management*, 2.

Sandberg, K. (2004), Hedonic prices, economic growth and spatial dependence, [online], Available: http://www.econ.umu.se/ues/ues631.pdf [17 May 2006]

Schnare, A. and Struyk, R.J. (1976), 'Segmentation in urban housing markets'. *Journal of Urban Economics*, **3**, pp. 146-166.

Shah Alam City Hall (2000), *Selangor Structure Plan.* Selangor: Shah Alam.

Sharifi, M.A., Boerboom, L., Shamsudin, K.B. and Veeramuthu, L. (2006), 'Spatial multiple criteria decision analysis in integrated planning for public transport and land use development study in the Klang Valley, Malaysia'. *Conference Proceedings*, ISPRS Technical Commision II, Vienna, pp. 85-91.

Sheppard, S. (1999), Hedonic Analysis of Housing Market. In: E.S. Mills and P. Cheshire (eds.), *Handbook of Regional and Urban Economics.* Oxford: Elsevier Science.

Shukla, V. and Waddell, P. (1991), 'Firm location and land use in discrete urban space: A study of the spatial structure of Dallas-Fort Worth'. *Regional Science and Urban Economics*, **21**, pp. 225-253.

Sirat, M. (2000), 'Globalising Kuala Lumpur and the strategic role of the produce services sector'. *Urban Studies*, **37** (12), pp. 2217-2240.

Small, K. and Song. S. (1992), ''Wasteful' Commuting: A Resolution'. *Journal of Political Economy*, 100, pp. 888-898.

Smerk, G.M. (1992), 'Public Transportation and the City', in G.E. Gray and L.A. Hoel (eds.), *Public Transportation:* Planning, Operations and Management. Englewood Cliffs, NJ: Prentice Hall.

Smith, T.R., Menon, S., Starr, J. and Estes, J. (1987), 'Requirements and principles for the implementation and construction of large-scale geographic information systems'. *International Journal of Geographic Information Systems*, **1** (1), pp. 13-31.

So, H.M., Tse, R.Y.C. and Ganesan, S. (1997), 'Estimating the influence of transport on house prices: Evidence from Hong Kong'. *Journal of Property Valuation and Investment*, **15** (1), pp. 40-47.

Song, Y. and Knapp, G.J. (2004), 'Measuring urban form'. *Journal of the American Planning Association*, **70**, pp.210-225.

Stopher, P.R. (2004), 'Reducing traffic congestion: A reality check'. *Transport Policy*, **11** (2), pp. 117-131.

Taplin, M.R. (1990), *Light Transit Proposals in British Cities: A Review*, in Symposium on the Potential of Light Rail Transit in British Cities. London: Thomas Telford Ltd.

Thayer, J.D. (2002), *Stepwise regression as an exploratory data analysis procedure.* Paper presented at the Annual Meeting of the American Educational Research Association, New Orleans.

The Bay Area Rapid Transit (2006). 'Station list', [online], Available: http://www.bart.gov/stations/index.aspx

The Federal Territory Development and the Klang Valley Planning Devision (2004), *Progress report 5: 2001-2005, The application of geographic information systems (GIS) for the Klang Valley Region*, Prime Minister's Department of Malaysia.

The Malayan Railway (2005), 'The Malayan Railway Traffic Statistics 1995-2005', [online], Available: http://www.ktmb.com.my/%5Cimages%5Cdefault%5Cstatistic%5Ccommuter.pdf [20 Feb 2006].

Toronto Transit Commision (2006), *Toronto's Yonge subway system*, [online], Available: http://www3.ttc.ca/Subway/index.jsp [11 Dec 2006].

Transportation Research Board (2002), 'The congestion mitigation and air quality improvement program: Assessing ten years of experience'. Washington, DC: National Academy Press.

Tse, R.Y.C. (2002), 'Estimating neighbourhood effects in house prices: Towards a new hedonic model approach'. *Urban Studies*, **39** (7), pp. 1165-1180.

Tu, Y. (2000), 'The local housing submarket structure and its properties'. *Urban Studies*, **34** (2), pp. 745-767.

Tu, C.C. (2005), 'How does a new sports stadium affect housing values? The case of FedEx field'. *Land Economics*, **81** (3), pp. 379-395.

Turner, R.K., Pearce, D. and Bateman, I. (1994), *Environmental Economics: An Elementary Introduction*. London: Harvester Wheatsheaf.

Tyrvainen, L. (1997), 'The amenity value of the urban forest: An application of the hedonic pricing method'. *Landscape and Urban Planning*, **37** (3), pp. 211-222.

Ungerer, M.J. and Goodchild, M.F. (2002), 'Integrating spatial data analysis and GIS: A new implementation using the component object model (COM)'. *International Journal of Geographical Information Science*, **16** (1), pp. 41-53.

Unterman, R.K. (1984), *Accommodating the Pedestrian: Adapting Towns and Neighborhoods for Walking and Biking*. Florence, Kentucky: Van Nostrand Reinhold.

U.S. Environmental Protection Agency (2001), 'Our built and natural environments: A technical review of the interactions between land use, transportation and environmental quality. Washington, DC: Author.

Veldhuisen, K.J. and Timmermans, H.P. (1984), 'Specification of individual residential utility-functions-A comparative analysis of three measurement procedures'. *Environment and Planning A*, **16** (12), pp. 1573-1582.

VNI Rainbow Appraisal Service, Inc. (1992), *Analysis of the Impact of Light Rail Transit on Real Estate Values*. San Diego, CA: VNI Rainbow Appraisal Service.

Voith, R. (1991), 'Transportation, sorting and house values'. *American Real Estate and Urban Economics Association Journal*, **19** (2), pp. 117-37.

Vuchic, V. (1992), Urban passenger transportation models. In G.E. Gray and L. Hoel (eds.), *Public Transportation*. Englewood Cliffs, NJ: Prentice Hall, pp. 79-113.

Waddell, P., Berry, B.J.L. and Hock, I. (1993), 'Housing price gradients: The intersection of space and built form'. *Geographical Analysis*, **25** (1), pp. 5-19.

Watkins, C. (1998a), *The Definition and Identification of Housing Submarkets in Glasgow*. Ph.D. Thesis (unpublished), University of Paisley, Scotland.

Webber, M. (1976), 'The BART experience: What have we learned?' *The Public Interest*, **12** (3), pp. 79-108.

Weimer, D.L. and Wolkoff, M.J. (2001), 'School performance and housing values: Using non-contiguous district and incorporation boundaries to identify school effects'. *National Tax Journal*, **54** (3), pp. 231-253.

Weinberger, R. (2000), *Commercial Property Values and Proximity to Light Rail: Calculating Benefits with a Hedonic Price Model.* Paper Presented at the 79th Annual Meeting of the Transportation Research Board, Washington, D.C.

Wheeler, D., Shaw, G. and Barr, S. (2004), *Statistical Techniques in Geographical Analysis*, 3rd edition. London: David Fulton Publishers Ltd.

Wheeler, D. and Tiefelsdorf, M. (2005), 'Multicollinearity and correlation among local regression coefficients in geographically weighted regression'. *Journal of Geographical Systems*, **7** (2), pp. 1-28.

Whittingham, M.J., Stephens, P.A., Bradburg, R.B. and Freckleton, R.P. (2006), 'Why do we still use stepwise modelling in ecology and behaviour?' *Journal of Animal Ecology*, **75**, pp. 1182-1189.

Wilkinson, R.K. (1971), 'The determinants of relative house prices'. *Urban Studies*, **8**, pp. 50-59.

Wilkinson, R.K. (1973b), 'Measuring the determinants of relative house prices'. *Environment and Planning A*, **5**, pp. 357-367.

Willis, K.G., Powe, N.A. and Garrod, G.D. (2005), 'Estimating the value of improved street lighting: A factor analytical discrete choice approach'. *Urban Studies*, **42** (12), pp. 2289-2303.

Willis, K.G. and Garrod, G.D. (1992), *The Value of Waterside Properties: Estimating the Impact of Waterways and Canals on Property Values Through Hedonic Price Models and Contingent Valuation Methods.* Newcastle on Tyne: Newcastle University.

Winston, C. and Langer, A. (2006), 'The effect of government highway spending on road users' congestion costs'. Brooking Institute, [online], Available: www.brookings.edu/views/papers/winston/200605-aeijc.pdf

Witte, A., Sumka, M. and Erekson, H. (1979), 'An estimation of a structural hedonic price model of the housing market: An application of Rosen's theory of implicit markets'. *Econometrica*, **47**, pp. 1151-1173.

Woodcock, J., Banister, D., Prentice, A.M. and Roberts, I. (2007), 'Energy and transport'. *Lancet*, **370**, pp. 1078-1088.

Workman, S.L. and Broad, D. (1997), *Measuring the Neighbourhood Benefits of Rail Transit Accessibility*. Report no. 97-1371. Washington, D.C: Transportation Research Board.

World Health Organisation (2002a), The injury chart book, Department of Injuries and Violence Prevention, [online], Available: http://whqlibdoc.who.int/publications/924156220X.pdf

Wu, F. (2002), Georeferencing social spatial data and intra-urban property price modelling in a data poor context: The case study for Shanghai'. In D. Kidner, G. Higgs and S. White (eds.), *Socio-economic Applications of Geographic Information Science*. London: Taylor and Francis.

Yinger, J. (1975), *The Black-White Price Differential in Housing: Some Further Evidence*. Madison: Institute for Research on Poverty.

Zabel, J.E. and Kiel, K.A. (2000), 'Estimating the demand for air quality in four US cities'. *Land Economics*, 76 (2), pp. 174-194.

Zhang, Z. and Griffith, D.A. (2000), 'Integrating GIS components and spatial statistical analysis in DBMSs'. *International Journal of Geographical Information Science*, 14 (6), pp. 543-566.

Zhu, X. and Liu, S. (2004), 'Analysis of the impact of the MRT system on accessibility in Singapore using an integrated GIS tool'. *Journal of Transport Geography*, 12, pp. 89-101.

# Appendices

**Table A1.1:** The Summarises some of the Heavy and Light Rail Transit Studies in the United Kingdom and North America

| Location (Author and Year Published) | Rail Transit System | Size of Study Area | Study Period/ System Opening | Dependent Variable | Access Variable | Access Variable Significant? |
|---|---|---|---|---|---|---|
| Camden County, New Jersey (Boyce et al. 1972) | Heavy rail transit: Lindenwold rail | Test area: Lindenwold corridor<br><br>Control area: Woodbury corridor | 1965-71/1969 | Residential sales price | Travel cost savings (difference between auto and rail travel costs to the CBD) | Travel cost savings significant in estimating residential sales price ($149 increase in sales price for each dollar travel cost savings). However, travel savings not significantly correlated to residential sales price in the control area. |
| Washington, D.C. (Lerman et al. 1978) | Heavy rail transit: Metro rail | Within two miles of Metro rail station | 1969-76/not indicated | 1. Single-family residential sales price<br>2. Multi-family sales price<br>3. Retail property sales price | a. Reciprocal form of straight line distance to nearest station<br>b. Straight line distance to nearest transit station<br>c. Transit distance to CBD | 1a. 1.077 2b. – 6.464 3b. – 0.678<br>1c. – 5.767 2c. 4.556 |
| Toronto (Dewess 1976) | Heavy rail transit: Bloor-Danforth subway line | Within one mile of Bloor subway corridor | 1. 1961<br>2. 1971/opening 1968 | Single-family residential sales price | a. Walking distance to Bloor Street<br>b. Distance along Bloor to CBD<br>c. Time cost to Bloor Street<br>d. Time cost to Bloor and then CBD<br>e. Monetary cost of travel to Bloor<br>f. Monetary cost of travel to Bloor and then CBD<br>g. One-third mile walking distance (dummy variable) | 1a. – 0.17 2a. ns<br>1b. ns 2b. – 5.94<br>1c. – 16.4 2c. – 23.7<br>1d. ns 2d. – 29.5<br>1e. ns 2e. na<br>1f. ns 2f. na<br>1g. – 0.52 2g. ns<br>1h. ns 2h. – 43.8<br>1i. ns 2i. – 55.8 |

| Location (Author and Year Published) | Rail Transit System | Size of Study Area | Study Period/ System Opening | Dependent Variable | Access Variable | Access Variable Significant? |
|---|---|---|---|---|---|---|
| | | | | | h. One-third mile walking distance (dummy variable)<br>i. One-third mile time cost (dummy variable) | |
| San Francisco (Dyett et al. 1979 – cited by Ryan, 1997) | Heavy rail transit: BART | 1. Six residential areas within 5,000 feet of a BART station<br>2. Three commercial areas within 5,000 feet of a BART station | 1973-76/1972-74 | 1. Residential property prices<br>2. Office rents | Distance to BART station in feet | The study found four of six station areas had greater residential price uplift compared to other residential areas. Office rents only uplift slightly after station openings compared with other office areas. |
| Washington (Damm et al., 1980) | Heavy rail transit: Metro | Not indicated | 1967-76/not indicated | 1. Single-family residential sales prices<br>2. Multi-family residential sales prices<br>3. Commercial sales prices | a. Distance of a parcel to the nearest Metro station | The study found distance of a parcel to the nearest Metro station was a statistically significant and increasing distance from the station was associated with lower property values. |
| Toronto, Canada (Bajic 1983) | Heavy rail transit: Spadina subway line | 1. Test area: within four kilometres of subway line<br>2. Control area: Metropolitan | 1. Before: 1971<br>2. After: 1978/opening 1978 | Single-family residential sales prices | a. Transit commute time from property to subway line<br>b. Auto commute time from property to freeway interchange | 1ai. – 0.1279 2ai. – 0.1256<br>1aii. – 0.0947 2aii. – 0.0285<br>1bi. – 0.2284 2bi. – 0.1602<br>1bii. 0.0173 2bii. – 0.0190 |

| Location (Author and Year Published) | Rail Transit System | Size of Study Area | Study Period/ System Opening | Dependent Variable | Access Variable | Access Variable Significant? |
|---|---|---|---|---|---|---|
| | | Toronto | | | | |
| Pennsylvania-Buck, Chester, Delaware, and Montgomery Counties and New Jersey – Camden County (Voith 1991) | Heavy rail transit | Not indicated | 1980/not indicated | Aggregate median home value of census tracts | 1. Availability of commuter rail service in census tract<br>2. Travel time from census tract to CBD by auto<br>3. Number of peak hour trains serving each census tract<br>4. Difference in commute time between auto and commuter rail<br>5. Average length of commute in minutes from each tract regardless of destination | 1. 7,358.6<br>2. 157.1<br>3. ns<br>4. ns<br>5. ns |
| Atlanta (Nelson 1992) | Heavy rail transit: East line of MARTA | Within 1.25 miles of rail right-or-way | 1986/1971 | 1. Single-family residential sales price from properties on north side of Atlanta<br>2. Single-family residential sales prices from properties on south side of Atlanta | a. Straight line distance to nearest station<br>b. Straight line distance to nearest station squared | 1a. 965.72 2a. – 1045.6<br>1b. – 23.16 2b. 15.559 |
| Miami (Gatzlaff and Smith 1993) | Heavy rail transit: Metro rail | Within one square mile of a station | 1971-90/1984 | Single-family residential sales prices | Distance to nearest rail station | Distance to station significant for 3 of 8 stations on 21 mile heavy rail line. Two stations were an amenity for residential properties; one station was a disamenity |

| Location (Author and Year Published) | Rail Transit System | Size of Study Area | Study Period/ System Opening | Dependent Variable | Access Variable | Access Variable Significant? |
|---|---|---|---|---|---|---|
| Boston (Armstrong, 1994) | Heavy rail transit: Fitchburg-Gardner commuter rail line | Within 10 miles of commuter rail right-of-way | 1990/not indicated | Single-family residential sales prices | 1. Estimated auto travel time to nearest highway interchange<br>2. Actual auto travel time from preferred highway interchange to CBD | 1. ns<br>2. − 0.04550<br>3. ns<br>4. − 0.10929<br>5. ns |
| Washington D.C (Benjamin and Sirmans 1994) | Heavy rail transit: Metro rail | Within 10n miles of a station | July 1992/not indicated | Apartment rents | Distance to Metro rail station | − 2.44 |
| Alameda County, Contra Costa County and San Mateo County (Landis et al. 1995) | Heavy rail transit: BART and CalTrain | 1. Mean distance of properties to stations is 6.4 kilometres, and 2 kilometres to freeway interchange<br>2. Mean distance of properties to station is 11.5 kilometres and 3.3 kilometres to freeway interchange<br>3. Mean distance of properties to | 1990/1972-75 and 1980 | Single-family residential sales prices | a. Roadway distance to nearest rail station<br>b. Roadway distance to nearest highway interchange<br>c. Adjacent to rail right-of-way<br>d. Adjacent to highway right-of-way | 1a. − 2.29 2a. − 1.96 3a. ns<br>1b. 2.80 2b. 3.41 3b. ns<br>1c. ns 2c. ns 3c. ns<br>1d. ns 2d. ns 3d. ns |

| Location (Author and Year Published) | Rail Transit System | Size of Study Area | Study Period/ System Opening | Dependent Variable | Access Variable | Access Variable Significant? |
|---|---|---|---|---|---|---|
| | | Station is 5.3 kilometres and 2.5 kilometres to freeway interchange | | | | |
| Alameda County and Contra Costa County (Landis et al. 1995-same study as above but different dependent variable) | Heavy rail transit: BART | Within one-half mile of a station | 1988-94/1972-75 | Commercial sales prices (office, retail, industrial, auto, parking, vacant) | a. Within one-quarter mile of station<br>b. Within one-half mile of station | 1a. Not significant for commercial uses<br>1b. 0.40 (vacant land)<br>2a. Not significant for commercial uses<br>2b. Not significant for commercial uses |
| Portland, Oregon (Chen at al. 1997) | Light rail transit: MAX | Within 700 meters of station | 1992-94/not indicated | Single-family residential sales prices | a. Distance to the LRT line in feet<br>b. Distance to the nearest LRT station in feet | a. ns<br>b. 2.647 |
| San Francisco and Portland Oregon (Workman and Broad 1997) | Heavy rail transit: BART and East Burnside Line | Within a one mile radius of station | 1. 1984-96/1972 and 1995 | a. Single-family residential sales prices<br>b. Single-family residential sales prices for properties farther than 2,500 feet from station | i. Street network distance to nearest transit station<br>ii. Street network distance to nearest highway interchange | 1ai. – 15.78<br>1aii. 7.94<br>2bi. 1.41<br>2bii. – 0.7527 |

| Location (Author and Year Published) | Rail Transit System | Size of Study Area | Study Period/ System Opening | Dependent Variable | Access Variable | Access Variable Significant? |
|---|---|---|---|---|---|---|
| South Bay region, East County region and Central City region of San Diego (Ryan 1997) | Light rail Transit | 1. Within 6 miles of freeway or station<br>2. Within 9 miles of freeway or station<br>3. Within 2 miles of freeway or station | 1986 – 95<br>1. 1981<br>2. 1986<br>3. 1991 | a. Office asking rents<br>b. Industrial asking rents | i. Straight line distance to nearest rail station<br>ii. Straight line distance to nearest highway interchange | 1ai. ns 2ai. 0.054 3ai. ns<br>1aii. – 0.104 2aii. – 0.042 3aii. – 0.066<br>1bi. ns 2bi. ns 3bi. 0.033<br>1bii. – 0.043 2bii. ns 3bii. 0.034 |
| South Yorkshire (Henneberry 1998) | Light rail transit: Sheffield Supertram | Not indicated | 1. April 1988 (before the decision was taken to build)<br>2. April 1993 (wide public knowledge but before any substantial construction work had started)<br>3. April 1996 (after construction was completed) | Residential sales prices | a. Nearest straight line distance from property to tram line.<br>b. Nearest straight line distance from property to tram station | 1ai. – 0.0434 2ai. 0.0319 3ai. ns<br>1bi. – 0.0426 2bi. 0.0319 3bi. ns |
| Greater Manchester (Forrest et al., 1996) | Light rail transit: Metrolink | Within 1-2 kilometres of the station | 1. 1990<br>2. 1992-93/1992 | 1. Detached house sales prices<br>2. Semi-detached house sales prices<br>3. Detached bungalow sales prices | 1. Within 1 kilometre of the nearest station<br>2. Within 1-2 kilometres of the nearest station | 1. ns<br>2. ns<br>3.ns<br>4.ns |

| Location (Author and Year Published) | Rail Transit System | Size of Study Area | Study Period/ System Opening | Dependent Variable | Access Variable | Access Variable Significant? |
|---|---|---|---|---|---|---|
| | | | | 4. Semi-detached bungalow sales prices | | |
| Portland (Dueker and Bianco 1999) | Light rail transit | Within a quarter miles of rail station | 1995/1986 | Multi family residential sales prices | 1. Distance to nearest rail stations<br>2. Travel times by LRT from Portland CBD to and Gresham<br>3. Travel times by bus from Portland CBD to and Gresham | a. Median house value raised at increasing rates the closer to the station. The largest change, $2,300 was for homes up to 200 feet away from the station.<br>b. 46 minutes in the PM peak and 44 minutes in the PM peak<br>c. 58-69 minutes in the PM peak and 56-58 minutes in the AM peak |
| Portland (Knapp et al. 1999) | Light rail transit | Within one miles of rail station 1000 metre radius of each station | 1. Before and after announcement/ 1998 | 1. Land values | a. Land parcel lies within half mile to proposed rail station<br>b. Land parcel lies within one mile to proposed rail station | 1ai. – 0.546 2ai. 3.947<br>1bi. 0.148 2bi. 2.466 |
| City Fringe, East of City Fringe, Isle of Dogs and East London, (Chesterton 2000) | Heavy rail transit: London Jubilee line extension (JLE) | 1000 metre radius of each station | 1. 1989-93 (baseline period)<br>2. 1994-97 (anticipatory period)<br>3. 1998-99 (pre-opening period) | 1. Terraced house sales prices<br>2. Flats and Maisonettes sales prices<br>3. Commercial property market | a. Walking time to a rail station | 1ai. ns 1aii. 0.0488 1aiii. 0.0502<br>2ai. na 2aii. 0.0265 2aiii. 0.0108<br>3. The opening of JLE has had a positive effects on commercial property market |

| Location (Author and Year Published) | Rail Transit System | Size of Study Area | Study Period/ System Opening | Dependent Variable | Access Variable | Access Variable Significant? |
|---|---|---|---|---|---|---|
| East of City (Chesterton 2000- same study but different study area) | Heavy rail transit: London Jubilee line extension (JLE) | 1000 metre radius of each station | 1. 1989-93 (baseline period)<br>2. 1994-97 (anticipatory period)<br>3. 1998-99 (pre-opening period) | 1. Terraced house sales prices<br>2. Flats and Maisonettes sales prices<br>3. Commercial property market | a. Walking time to a rail station | 1ai. ns 1aii. 0.0161 1aiii. 0.0187<br>2ai. 0.0132 2aii. ns 2aiii. 0.0045<br>3. JLE has had a limited direct effect on commercial property market |
| Isle of Dogs (Chesterton 2000- same study but different study area) | Heavy rail transit: London Jubilee line extension (JLE) | 1000 metre radius of each station | 1. 1989-93 (baseline period)<br>2. 1994-97 (anticipatory period)<br>3. 1998-99 (pre-opening period) | 1. Terraced house sales prices<br>2. Flats and Maisonettes sales prices<br>3. Commercial property market | a. Walking time to a rail station | 1ai. na 1aii. ns 1aiii. 0.0585<br>2ai. ns 2aii. 0.0330 2aiii. Na<br>3. An established office location, which has been reinforced by the opening of JLE |
| East London (Chesterton 2000 – same study but different study area) | Heavy rail transit: London Jubilee line extension (JLE) | Within 1000 feet of the rail station<br>Within one mile of the rail station | 1. 1989-93 (baseline period)<br>2. 1994-97 (anticipatory period)<br>3. 1998 -99 (pre-opening period) | 1. Terraced house sales prices<br>2. Flats and Maisonettes sales prices<br>3. Commercial property market | a. Walking time to a rail station | 1ai. ns 1aii. 0.0056 1aiii. 0.0034<br>2ai. ns 2aii. na 2.aiii. ns<br>3. JLE is an early shock in an area that will be affected by other future shock. |
| Washington D.C. (FTA 2000) | Heavy rail transit: Metro rail | Within one quarter of mile of a rail station | Not indicated | Commercial property sales prices | Distance to nearest Metro station | Price per square foot decreases by about $2.30 for every 1000 feet further from Metro station |
| Santa Clara County, California (Weinberger, 2000) | Light rail transit | Within half mile of a rail station | 1984-1998/1991 | Commercial rents and sales prices | 1. Within a quarter of mile<br>2. Quarter to half mile<br>3. Half to three-quarter mile | a. 0.0569<br>b. 0.0266<br>c. ns |

| Location (Author and Year Published) | Rail Transit System | Size of Study Area | Study Period/ System Opening | Dependent Variable | Access Variable | Access Variable Significant? |
|---|---|---|---|---|---|---|
| Santa Clara County, California (Cervero and Duncan 2001) | Heavy rail transit and light rail transit | Within half mile of a rail station | 1998-1999/1991 | 1. Commercial property<br>2. Office property<br>3. Light industrial property | 1. Within one quarter of a mile of a commuter station<br>2. Within one quarter of a mile of a LRT station | a. 25.430<br>b. 4.062 |
| Los Angeles County (Cervero and Duncan 2002) | Heavy rail transit and light rail transit | | 1. 1999-2001 (for commercial)<br>2. 2000 (for residential)/ | 1. Multi-family residential sales prices | a. Subway Red line: within half mile of rail station<br>b. Metrolink Antelope Valley line: within half mile of rail station<br>c. Metrolink Riverside line: within half mile of rail station<br>d. Metrolink San Bernardino line: within half mile of rail station<br>e. Metrolink Ventura line: within half mile of rail station<br>f. LRT Blue line: within half mile of rail station<br>g. LRT Blue line: within half mile of rail station<br>h. Regional job accessibility by transit: within 30 minutes peak period travel by transit | i. 21,707.4<br>ii. −12,554.8<br>iii. 13, 168.8<br>iv. −12,309.4<br>v. 1,888.7<br>vi. 4,349.9<br>vii. 12,228.9<br>viii. 104.1 |
| Los Angeles County (Cervero and | Heavy rail transit and light rail | Within half mile of a rail station | 1. 1999-2001 (for commercial)<br>2. 2000 (for | 1. Condominiums sales prices | a. Subway Red line: within half mile of rail station | i. −38,192.1<br>ii. 28,683.8<br>iii. 3,019.2 |

| Location (Author and Year Published) | Rail Transit System | Size of Study Area | Study Period/ System Opening | Dependent Variable | Access Variable | Access Variable Significant? |
|---|---|---|---|---|---|---|
| Duncan 2002-same study but different dependent and access variable) | transit | | residential/ | | b. Metrolink Antelope Valley: within half mile of rail station<br>c. Metrolink Orange County line: within half mile of rail station<br>d. Metrolink riverside line: within half mile of rail station<br>e. Metrolink San Bernardino line: within half mile of rail station<br>f. Metrolink Ventura line: within half mile of rail station<br>g. LRT Blue line: within half mile of rail station<br>h. Regional job accessibility by transit: 30 minutes peak period travel by transit | iv. 19,555.5<br>v. 32,381.9<br>vi. −28,903.7<br>vii. −14,174.0<br>viii. 47.3 |
| Los Angeles County (Cervero and Duncan 2002-same study but different dependent and access variable) | Heavy rail transit and light rail transit | Within half mile of a rail station | 1. 1999-2001 (for commercial)<br>2. 2000 (for residential)/ | Single-family residential sales prices | a. Subway Red line: within half mile of rail station<br>b. Metrolink Antelope Valley line: Within half mile of rail station<br>c. Metrolink Orange County line: within half mile of rail station<br>d. Metrolink Riverside line: within half mile of rail station<br>e. Metrolink San | i. −18,469.4<br>ii. 25,675.3<br>iii. 2,273.3<br>iv. 27,770.7<br>v. 6,164.2<br>vi. −1,591.7<br>vii. 13,351.5<br>viii. −7,073.6 |

| Location (Author and Year Published) | Rail Transit System | Size of Study Area | Study Period/ System Opening | Dependent Variable | Access Variable | Access Variable Significant? |
|---|---|---|---|---|---|---|
| | | | | | Bernardino line: within half mile of rail station<br>f. Metrolink Ventura line: within half mile of rail station<br>g. LRT Blue line: within half mile of rail station<br>h. LRT Green line: within half mile of rail station | |
| Los Angeles County (Cervero and Duncan-same study but different dependent and access variable) | Heavy rail transit and light rail transit | 1. Within half mile of a rail station<br>2. Within quarter mile of a rail station | 1. 1999-2001 (for commercial)<br>2. 2000 (for residential) | Commercial properties sales prices | a. Subway Red line: within half mile of rail station<br>b. Metrolink Antelope Valley line: Within half mile of rail station<br>c. Metrolink Orange County line: within half mile of rail station<br>d. Metrolink Riverside line: within half mile of rail station<br>e. Metrolink Ventura line: within half mile of rail station<br>f. LRT Blue line: within half mile of rail station<br>g. LRT Green line: within half mile of rail station<br>h. Regional labour force accessibility by transit: 30 minutes peak period transit travel time | i. −272,451.7<br>ii. 136,928.6<br>iii. 594,334.0<br>iv. 217,779.0<br>v. − 45,640.8<br>vi. 14,876.6<br>vii. 2,573.6<br>viii. 435.2 |

| Location (Author and Year Published) | Rail Transit System | Size of Study Area | Study Period/ System Opening | Dependent Variable | Access Variable | Access Variable Significant? |
|---|---|---|---|---|---|---|
| San Diego County (Cervero and Duncan 2002) | Heavy rail transit and light rail transit | 1. Within half mile of rail station.<br>2. Within quarter mile of rail station | 1. 1999-2001 (for commercial)<br>2. 2000 (for residential)/ | 1.Multi-Family residential sales prices<br>2. Condominiums sales prices<br>3. Single-family residential sales prices<br>4. Commercial properties sales prices | a. LRT South line: within half mile of LRT station<br>b. LRT East line: within half mile of LRT station<br>c. LRT Mission Valley line: within half mile of LRT station<br>d. LRT Downtown: within quarter mile of LRT station<br>e. LRT North line: within half mile LRT station.<br>f. LRT Straight line distance in miles<br>g. Commuter rail: within half mile of Coaster station<br>h. Commuter rail: within quarter mile of downtown coaster station<br>i. Commuter rail straight line in miles | 1a. 60,051.6<br>1b. 104,887.4<br>1c. 23,103.7<br>1d. 31,242.3<br>1e. na<br>1f. na<br>1g. −43,378.8<br>1h. na<br>1i. na<br><br>2a. 6,442.5<br>2b. 11,917.6<br>2c. 5,539.6<br>2d. 4,144.8<br>2e. na<br>2f. na<br>2g. 85,232.1<br>2h. na<br>2i. na<br><br>3a. 6,774.8<br>3b. −17,643.0<br>3c. na<br>3d. na<br>3e. −48,707.6<br>3f. −5,659.3<br>3g. 78,597.9<br>3h. na<br>3i. −12,308.3<br><br>4a. −104,266.8<br>4b. −12,795.6<br>4c. 813,124.2<br>4d. 50,196.4<br>4e. na<br>4f. na<br>4g. −111,917.0 |

| Location (Author and Year Published) | Rail Transit System | Size of Study Area | Study Period/ System Opening | Dependent Variable | Access Variable | Access Variable Significant? |
|---|---|---|---|---|---|---|
| | | | | | | 4h. − 1,143,027.5<br>4i. na |
| Tyne and Wear (Du and Mulley, 2006) | Heavy rail transit system | 1. Within two kilometre of rail stations | 1. 2002/2004 | 1. Residential sales prices | 1. Public transport travel time to secondary school at peak hour.<br>2. Car travel time with capacity speed to employment.<br>3. Crow line to the nearest metro station. | 1. -963.73<br>2. 2,167.94<br>3. -4.55 |
| Buffalo, New York (Hess and Almeida, 2007) | Light rail transit | 1. Half mile radius of rail stations | 1.2002 | 1. Residential sales prices | 1. Straight-line-distance from a LRT station.<br>2. Network-distance from a LRT station. | 1. -2.31<br>2. -0.99 |

**Table A7.2**: The relationship between dummy variables and other variables

| | | SELLING | STR_DIST | STR_STN1 | STR_STN2 | STR_STN3 | STR_STN4 | WALK_DIST | WALK_STN1 | WALK_STN2 | WALK_STN3 | WALK_STN4 | WALK_STN5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SELLING | Pearson Correlation | 1 | -0.067 | 0.025 | 0.072 | 0.000 | -0.109 | -0.097 | -0.062 | 0.094 | 0.167 | -0.105 | -0.081 |
| | Sig. (2-tailed) | | 0.008 | 0.324 | 0.004 | 0.985 | 0.000 | 0.000 | 0.014 | 0.000 | 0.000 | 0.000 | 0.001 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| STR_DIST | Pearson Correlation | -0.067 | 1 | -0.647 | -0.338 | 0.248 | 0.753 | 0.828 | -0.307 | -0.491 | -0.113 | -0.042 | 0.720 |
| | Sig. (2-tailed) | 0.008 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.095 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| STR_STN1 | Pearson Correlation | 0.025 | -0.647 | 1 | -0.314 | -0.340 | -0.230 | -0.420 | 0.444 | 0.266 | -0.157 | -0.062 | -0.265 |
| | Sig. (2-tailed) | 0.324 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.014 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| STR_STN2 | Pearson Correlation | 0.072 | -0.338 | -0.314 | 1 | -0.454 | -0.308 | -0.414 | -0.139 | 0.366 | 0.390 | -0.225 | -0.347 |
| | Sig. (2-tailed) | 0.004 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| STR_STN3 | Pearson Correlation | 0.000 | 0.248 | -0.340 | -0.454 | 1 | -0.333 | 0.209 | -0.151 | -0.362 | -0.090 | 0.518 | -0.044 |
| | Sig. (2-tailed) | 0.985 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.079 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| STR_STN4 | Pearson Correlation | -0.109 | 0.753 | -0.230 | -0.308 | -0.333 | 1 | 0.659 | -0.102 | -0.260 | -0.191 | -0.300 | 0.730 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| WALK_DIST | Pearson Correlation | -0.097 | 0.828 | -0.420 | -0.414 | 0.209 | 0.659 | 1 | -0.394 | -0.634 | -0.170 | 0.102 | 0.791 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| WALK_STN1 | Pearson Correlation | -0.062 | -0.307 | 0.444 | -0.139 | -0.151 | -0.102 | -0.394 | 1 | -0.118 | -0.086 | -0.138 | -0.139 |
| | Sig. (2-tailed) | 0.014 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.001 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| WALK_STN2 | Pearson Correlation | 0.094 | -0.491 | 0.266 | 0.366 | -0.362 | -0.260 | -0.634 | -0.118 | 1 | -0.220 | -0.351 | -0.355 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| WALK_STN3 | Pearson Correlation | 0.167 | -0.113 | -0.157 | 0.390 | -0.090 | -0.191 | -0.170 | -0.086 | -0.220 | 1 | -0.257 | -0.260 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| WALK_STN4 | Pearson Correlation | -0.105 | -0.042 | -0.062 | -0.225 | 0.518 | -0.300 | 0.102 | -0.138 | -0.351 | -0.257 | 1 | -0.414 |
| | Sig. (2-tailed) | 0.000 | 0.095 | 0.014 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| WALK_STN5 | Pearson Correlation | -0.081 | 0.720 | -0.265 | -0.347 | -0.044 | 0.730 | 0.791 | -0.139 | -0.355 | -0.260 | -0.414 | 1 |
| | Sig. (2-tailed) | 0.001 | 0.000 | 0.000 | 0.000 | 0.079 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| FLRAREA | Pearson Correlation | 0.762 | 0.019 | -0.111 | 0.140 | 0.002 | -0.054 | -0.006 | -0.071 | -0.047 | 0.219 | -0.061 | -0.029 |
| | Sig. (2-tailed) | 0.000 | 0.439 | 0.000 | 0.000 | 0.931 | 0.031 | 0.810 | 0.005 | 0.060 | 0.000 | 0.015 | 0.248 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| BEDS | Pearson Correlation | 0.518 | 0.037 | -0.004 | -0.059 | 0.103 | -0.052 | 0.092 | -0.057 | -0.166 | 0.163 | 0.020 | 0.035 |
| | Sig. (2-tailed) | 0.000 | 0.145 | 0.878 | 0.018 | 0.000 | 0.040 | 0.000 | 0.022 | 0.000 | 0.000 | 0.423 | 0.159 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| BATH | Pearson Correlation | 0.527 | 0.006 | 0.008 | -0.033 | 0.091 | -0.080 | 0.056 | -0.054 | -0.126 | 0.167 | 0.004 | 0.010 |
| | Sig. (2-tailed) | 0.000 | 0.799 | 0.759 | 0.196 | 0.000 | 0.001 | 0.025 | 0.031 | 0.000 | 0.000 | 0.864 | 0.680 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| TYPTRRD | Pearson Correlation | -0.282 | -0.026 | 0.063 | 0.016 | -0.054 | -0.016 | 0.156 | -0.068 | -0.189 | 0.154 | -0.097 | 0.185 |
| | Sig. (2-tailed) | 0.000 | 0.304 | 0.012 | 0.536 | 0.031 | 0.517 | 0.000 | 0.007 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |

| | | FLRAREA | BEDS | BATH | TYPTRRD | TYP_CLUSTER | TYPSEMID | TYPDETCH | TYPFLAT | TYPAPT | TYPCONDO | SWMPOOL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SELLING | Pearson Correlation | 0.762 | 0.518 | 0.527 | -0.282 | -0.124 | 0.075 | 0.692 | -0.055 | -0.233 | 0.045 | -0.084 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 | 0.000 | 0.028 | 0.000 | 0.071 | 0.001 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| STR_DIST | Pearson Correlation | 0.019 | 0.037 | 0.006 | -0.026 | 0.243 | 0.080 | 0.062 | -0.071 | 0.043 | -0.171 | -0.104 |
| | Sig. (2-tailed) | 0.439 | 0.145 | 0.799 | 0.304 | 0.000 | 0.001 | 0.014 | 0.005 | 0.085 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| STR_STN1 | Pearson Correlation | -0.111 | -0.004 | 0.008 | 0.063 | -0.075 | -0.032 | -0.158 | 0.116 | -0.127 | 0.201 | 0.039 |
| | Sig. (2-tailed) | 0.000 | 0.878 | 0.759 | 0.012 | 0.003 | 0.203 | 0.000 | 0.000 | 0.000 | 0.000 | 0.124 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| STR_STN2 | Pearson Correlation | 0.140 | -0.059 | -0.033 | 0.016 | -0.100 | -0.032 | 0.145 | -0.036 | -0.174 | 0.086 | -0.104 |
| | Sig. (2-tailed) | 0.000 | 0.018 | 0.196 | 0.536 | 0.000 | 0.198 | 0.000 | 0.147 | 0.000 | 0.001 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| STR_STN3 | Pearson Correlation | 0.002 | 0.103 | 0.091 | -0.054 | -0.109 | -0.040 | 0.007 | -0.040 | 0.364 | -0.240 | 0.189 |
| | Sig. (2-tailed) | 0.931 | 0.000 | 0.000 | 0.031 | 0.000 | 0.109 | 0.782 | 0.116 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| STR_STN4 | Pearson Correlation | -0.054 | -0.052 | -0.080 | -0.016 | 0.326 | 0.119 | -0.019 | -0.027 | -0.108 | -0.014 | -0.145 |
| | Sig. (2-tailed) | 0.031 | 0.040 | 0.001 | 0.517 | 0.000 | 0.000 | 0.440 | 0.288 | 0.000 | 0.591 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| WALK_DIST | Pearson Correlation | -0.006 | 0.092 | 0.056 | 0.156 | 0.228 | 0.106 | 0.014 | -0.078 | -0.031 | -0.289 | -0.228 |
| | Sig. (2-tailed) | 0.810 | 0.000 | 0.025 | 0.000 | 0.000 | 0.000 | 0.568 | 0.002 | 0.220 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| WALK_STN1 | Pearson Correlation | -0.071 | -0.057 | -0.054 | -0.068 | -0.033 | -0.026 | -0.081 | -0.012 | 0.085 | 0.092 | 0.016 |
| | Sig. (2-tailed) | 0.005 | 0.022 | 0.031 | 0.007 | 0.185 | 0.299 | 0.001 | 0.630 | 0.001 | 0.000 | 0.514 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| WALK_STN2 | Pearson Correlation | -0.047 | -0.166 | -0.126 | -0.189 | -0.085 | -0.067 | -0.087 | 0.103 | -0.126 | 0.477 | 0.259 |
| | Sig. (2-tailed) | 0.060 | 0.000 | 0.000 | 0.000 | 0.001 | 0.008 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| WALK_STN3 | Pearson Correlation | 0.219 | 0.163 | 0.167 | 0.154 | -0.062 | 0.012 | 0.228 | -0.023 | -0.170 | -0.194 | -0.276 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.014 | 0.622 | 0.000 | 0.369 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| WALK_STN4 | Pearson Correlation | -0.061 | 0.020 | 0.004 | -0.097 | -0.099 | -0.043 | -0.037 | -0.036 | 0.418 | -0.207 | 0.255 |
| | Sig. (2-tailed) | 0.015 | 0.423 | 0.864 | 0.000 | 0.000 | 0.089 | 0.145 | 0.152 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| WALK_STN5 | Pearson Correlation | -0.029 | 0.035 | 0.010 | 0.185 | 0.239 | 0.107 | -0.020 | -0.036 | -0.209 | -0.130 | -0.291 |
| | Sig. (2-tailed) | 0.248 | 0.159 | 0.680 | 0.000 | 0.000 | 0.000 | 0.437 | 0.147 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| FLRAREA | Pearson Correlation | 1 | 0.471 | 0.477 | -0.280 | -0.083 | 0.095 | 0.836 | -0.039 | -0.180 | -0.158 | -0.251 |
| | Sig. (2-tailed) | | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.123 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| BEDS | Pearson Correlation | 0.471 | 1 | 0.946 | 0.056 | -0.077 | 0.080 | 0.421 | -0.126 | -0.090 | -0.312 | -0.289 |
| | Sig. (2-tailed) | 0.000 | | 0.000 | 0.025 | 0.002 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| BATH | Pearson Correlation | 0.477 | 0.946 | 1 | 0.041 | -0.089 | 0.086 | 0.430 | -0.072 | -0.102 | -0.292 | -0.281 |
| | Sig. (2-tailed) | 0.000 | 0.000 | | 0.103 | 0.000 | 0.001 | 0.000 | 0.004 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| TYPTRRD | Pearson Correlation | -0.280 | 0.056 | 0.041 | 1 | -0.142 | -0.111 | -0.344 | -0.052 | -0.442 | -0.444 | -0.631 |
| | Sig. (2-tailed) | 0.000 | 0.025 | 0.103 | | 0.000 | 0.000 | 0.000 | 0.040 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |

# Appendix B

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TYP_CLUSTER | Pearson Correlation | -0.128 | 0.243 | -0.075 | -0.100 | -0.109 | 0.326 | 0.228 | -0.031 | -0.085 | -0.062 | -0.099 | 0.239 | -0.083 | -0.077 | -0.089 | -0.142 | 1 | -0.019 | -0.058 | -0.009 | -0.079 | -0.075 | -0.107 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.185 | 0.001 | 0.014 | 0.000 | 0.000 | 0.001 | 0.002 | 0.000 | 0.000 | | 0.455 | 0.021 | 0.729 | 0.003 | 0.003 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| TYPSEMID | Pearson Correlation | 0.075 | 0.080 | -0.032 | -0.032 | -0.040 | 0.119 | 0.106 | -0.026 | -0.067 | 0.012 | -0.043 | 0.107 | 0.099 | 0.080 | 0.086 | -0.111 | -0.019 | 1 | -0.046 | -0.007 | -0.059 | -0.059 | -0.084 |
| | Sig. (2-tailed) | 0.003 | 0.001 | 0.203 | 0.198 | 0.109 | 0.000 | 0.000 | 0.299 | 0.008 | 0.622 | 0.089 | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 | 0.455 | | 0.070 | 0.784 | 0.020 | 0.019 | 0.001 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| TYPDETCH | Pearson Correlation | 0.692 | 0.062 | -0.158 | 0.145 | 0.007 | -0.019 | 0.014 | -0.081 | -0.087 | 0.228 | -0.037 | -0.020 | 0.836 | 0.421 | 0.430 | -0.344 | -0.058 | -0.046 | 1 | -0.021 | -0.181 | -0.182 | -0.254 |
| | Sig. (2-tailed) | 0.000 | 0.014 | 0.000 | 0.000 | 0.782 | 0.440 | 0.568 | 0.001 | 0.001 | 0.000 | 0.145 | 0.437 | 0.000 | 0.000 | 0.000 | 0.000 | 0.021 | 0.070 | | 0.401 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| TYPFLAT | Pearson Correlation | -0.055 | -0.071 | 0.116 | -0.036 | -0.040 | -0.027 | -0.078 | -0.012 | 0.103 | -0.023 | -0.036 | -0.036 | -0.039 | -0.126 | -0.072 | -0.052 | -0.009 | -0.007 | -0.021 | 1 | -0.027 | -0.027 | -0.039 |
| | Sig. (2-tailed) | 0.028 | 0.005 | 0.000 | 0.147 | 0.116 | 0.288 | 0.002 | 0.630 | 0.000 | 0.369 | 0.152 | 0.147 | 0.123 | 0.000 | 0.004 | 0.040 | 0.729 | 0.784 | 0.401 | | 0.281 | 0.279 | 0.123 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| TYPAPT | Pearson Correlation | -0.233 | 0.043 | -0.127 | -0.174 | 0.364 | -0.108 | -0.031 | 0.085 | -0.126 | -0.170 | 0.418 | -0.209 | -0.181 | -0.090 | -0.102 | -0.442 | -0.079 | -0.059 | -0.181 | -0.027 | 1 | -0.233 | 0.389 |
| | Sig. (2-tailed) | 0.000 | 0.085 | 0.000 | 0.000 | 0.000 | 0.000 | 0.220 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 | 0.020 | 0.000 | 0.281 | | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| TYPCONDO | Pearson Correlation | 0.045 | -0.171 | 0.201 | 0.086 | -0.240 | -0.014 | -0.289 | 0.092 | 0.477 | -0.194 | -0.207 | -0.130 | -0.158 | -0.312 | -0.292 | -0.444 | -0.075 | -0.059 | -0.182 | -0.027 | -0.233 | 1 | 0.703 |
| | Sig. (2-tailed) | 0.071 | 0.000 | 0.000 | 0.001 | 0.000 | 0.591 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 | 0.019 | 0.000 | 0.279 | 0.000 | | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| SWMPOOL | Pearson Correlation | -0.084 | -0.104 | 0.039 | -0.104 | 0.189 | -0.145 | -0.228 | 0.016 | 0.259 | -0.276 | 0.255 | -0.291 | -0.251 | -0.289 | -0.281 | -0.631 | -0.107 | -0.084 | -0.258 | -0.039 | 0.389 | 0.703 | 1 |
| | Sig. (2-tailed) | 0.001 | 0.000 | 0.124 | 0.000 | 0.000 | 0.000 | 0.000 | 0.514 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.123 | 0.000 | 0.000 | |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| SAUNA | Pearson Correlation | -0.203 | -0.146 | -0.113 | -0.007 | 0.326 | -0.272 | -0.270 | 0.055 | 0.146 | -0.230 | 0.387 | -0.371 | -0.228 | -0.334 | -0.331 | -0.525 | -0.089 | -0.070 | -0.215 | -0.032 | 0.489 | 0.419 | 0.832 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.772 | 0.000 | 0.000 | 0.000 | 0.029 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.006 | 0.000 | 0.200 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| GYM | Pearson Correlation | -0.063 | -0.272 | 0.097 | -0.067 | 0.237 | -0.306 | -0.365 | 0.091 | 0.296 | -0.259 | 0.301 | -0.418 | -0.234 | -0.247 | -0.239 | -0.592 | -0.100 | -0.078 | -0.242 | -0.036 | 0.461 | 0.564 | 0.911 |
| | Sig. (2-tailed) | 0.012 | 0.000 | 0.000 | 0.008 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.149 | 0.000 | 0.000 | 0.000 |
| | N | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 |
| SPORTSF | Pearson Correlation | -0.087 | -0.121 | 0.060 | -0.111 | 0.181 | -0.150 | -0.248 | 0.073 | 0.249 | -0.279 | 0.248 | -0.297 | -0.254 | -0.288 | -0.280 | -0.639 | -0.108 | -0.085 | -0.261 | -0.039 | 0.414 | 0.697 | 0.987 |
| | Sig. (2-tailed) | 0.001 | 0.000 | 0.017 | 0.000 | 0.000 | 0.000 | 0.000 | 0.004 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.119 | 0.000 | 0.000 | 0.000 |
| | N | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 |
| LAUNDRY | Pearson Correlation | -0.050 | -0.141 | 0.181 | -0.075 | 0.014 | -0.111 | -0.237 | 0.508 | -0.045 | -0.093 | 0.034 | -0.151 | -0.073 | -0.106 | -0.110 | -0.214 | -0.036 | -0.028 | -0.087 | -0.013 | 0.012 | 0.357 | 0.246 |
| | Sig. (2-tailed) | 0.049 | 0.000 | 0.000 | 0.003 | 0.584 | 0.000 | 0.000 | 0.000 | 0.072 | 0.000 | 0.172 | 0.000 | 0.004 | 0.000 | 0.000 | 0.000 | 0.152 | 0.261 | 0.001 | 0.601 | 0.620 | 0.000 | 0.000 |
| | N | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 |
| STR_CBD | Pearson Correlation | 0.013 | 0.010 | -0.106 | 0.168 | -0.078 | 0.005 | -0.028 | 0.081 | -0.026 | 0.030 | -0.040 | 0.005 | 0.236 | 0.063 | 0.062 | -0.060 | -0.064 | 0.068 | 0.218 | -0.020 | 0.004 | -0.103 | -0.138 |
| | Sig. (2-tailed) | 0.611 | 0.688 | 0.000 | 0.000 | 0.002 | 0.844 | 0.260 | 0.001 | 0.295 | 0.229 | 0.111 | 0.857 | 0.000 | 0.012 | 0.014 | 0.016 | 0.011 | 0.007 | 0.000 | 0.432 | 0.885 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| STR_MJRROAD | Pearson Correlation | -0.270 | 0.184 | -0.332 | -0.055 | 0.345 | -0.017 | 0.086 | -0.130 | -0.123 | -0.159 | 0.378 | -0.084 | -0.297 | -0.209 | -0.210 | -0.258 | 0.102 | 0.004 | -0.250 | -0.012 | 0.525 | -0.024 | 0.465 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.028 | 0.000 | 0.512 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.867 | 0.000 | 0.633 | 0.000 | 0.333 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| STR_HIGHWAY | Pearson Correlation | -0.060 | 0.234 | -0.069 | -0.146 | 0.003 | 0.232 | 0.356 | -0.189 | -0.229 | 0.106 | -0.121 | 0.356 | -0.204 | 0.096 | 0.083 | 0.555 | 0.222 | 0.015 | -0.173 | -0.056 | -0.261 | -0.339 | -0.438 |
| | Sig. (2-tailed) | 0.030 | 0.000 | 0.013 | 0.000 | 0.906 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.003 | 0.000 | 0.000 | 0.596 | 0.000 | 0.045 | 0.000 | 0.000 | 0.000 |
| | N | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 |
| PRIMARY_SCH | Pearson Correlation | -0.116 | -0.067 | -0.204 | -0.025 | 0.387 | -0.233 | -0.125 | -0.027 | 0.025 | -0.145 | 0.327 | -0.226 | -0.141 | -0.046 | -0.036 | -0.216 | -0.009 | -0.037 | -0.149 | 0.020 | 0.565 | -0.152 | 0.407 |
| | Sig. (2-tailed) | 0.000 | 0.008 | 0.000 | 0.323 | 0.000 | 0.000 | 0.000 | 0.279 | 0.318 | 0.000 | 0.000 | 0.000 | 0.000 | 0.066 | 0.158 | 0.000 | 0.712 | 0.142 | 0.000 | 0.419 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| SECONDARY_SCH | Pearson Correlation | -0.091 | 0.453 | -0.267 | -0.199 | 0.151 | 0.323 | 0.363 | -0.117 | -0.345 | 0.051 | 0.136 | 0.198 | 0.072 | 0.126 | 0.104 | -0.109 | -0.082 | 0.090 | 0.102 | -0.104 | 0.263 | -0.192 | 0.030 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.042 | 0.000 | 0.000 | 0.004 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.229 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| UNIVERSITY | Pearson Correlation | 0.060 | 0.065 | 0.054 | -0.234 | 0.154 | 0.034 | 0.208 | -0.159 | -0.007 | -0.244 | 0.096 | 0.167 | -0.114 | 0.108 | 0.113 | -0.033 | -0.050 | 0.098 | -0.137 | -0.016 | 0.136 | 0.013 | 0.195 |
| | Sig. (2-tailed) | 0.017 | 0.009 | 0.033 | 0.000 | 0.000 | 0.180 | 0.000 | 0.000 | 0.796 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.190 | 0.047 | 0.000 | 0.000 | 0.535 | 0.000 | 0.603 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| HOSPITALS | Pearson Correlation | -0.226 | 0.315 | -0.073 | -0.192 | -0.005 | 0.307 | 0.441 | -0.200 | -0.277 | 0.015 | -0.064 | 0.399 | -0.345 | -0.022 | -0.044 | 0.619 | 0.083 | -0.029 | -0.303 | -0.051 | -0.241 | -0.308 | -0.403 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.004 | 0.000 | 0.849 | 0.000 | 0.000 | 0.000 | 0.000 | 0.564 | 0.011 | 0.000 | 0.000 | 0.382 | 0.083 | 0.000 | 0.001 | 0.248 | 0.000 | 0.043 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| INSTITUTE | Pearson Correlation | 0.017 | 0.227 | -0.194 | -0.079 | 0.169 | 0.086 | 0.204 | -0.207 | 0.031 | -0.180 | -0.017 | 0.218 | -0.202 | 0.100 | 0.102 | 0.086 | -0.042 | 0.043 | -0.238 | -0.025 | 0.114 | -0.017 | 0.094 |

# Appendix B

| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sig. (2-tailed) | 0.512 | 0.000 | 0.000 | 0.002 | 0.000 | 0.001 | 0.000 | 0.000 | 0.218 | 0.000 | 0.507 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.094 | 0.089 | 0.000 | 0.330 | 0.000 | 0.506 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| COMMERCIAL | Pearson Correlation | -0.239 | 0.036 | -0.321 | -0.015 | 0.448 | -0.201 | -0.063 | -0.046 | -0.067 | -0.139 | 0.402 | -0.213 | -0.215 | -0.247 | -0.232 | -0.341 | -0.001 | -0.022 | -0.188 | 0.066 | 0.401 | -0.012 | 0.532 |
| | Sig. (2-tailed) | 0.000 | 0.153 | 0.000 | 0.557 | 0.000 | 0.000 | 0.012 | 0.070 | 0.008 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.975 | 0.377 | 0.000 | 0.007 | 0.000 | 0.629 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| WORSHIP | Pearson Correlation | -0.212 | 0.121 | 0.087 | -0.096 | -0.195 | 0.261 | 0.273 | -0.057 | -0.169 | 0.027 | -0.132 | 0.291 | -0.228 | -0.078 | -0.102 | 0.560 | 0.142 | -0.057 | -0.184 | -0.033 | -0.339 | -0.259 | -0.408 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.022 | 0.000 | 0.283 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 | 0.024 | 0.000 | 0.184 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| GREEN | Pearson Correlation | 0.036 | -0.162 | -0.109 | 0.071 | 0.275 | -0.306 | -0.146 | 0.094 | -0.028 | -0.128 | 0.324 | -0.241 | 0.189 | -0.051 | -0.033 | -0.382 | -0.181 | 0.037 | 0.179 | 0.070 | 0.371 | 0.018 | 0.339 |
| | Sig. (2-tailed) | 0.154 | 0.000 | 0.000 | 0.005 | 0.000 | 0.000 | 0.000 | 0.000 | 0.261 | 0.000 | 0.000 | 0.000 | 0.000 | 0.036 | 0.187 | 0.000 | 0.000 | 0.145 | 0.000 | 0.009 | 0.000 | 0.478 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| LAKES | Pearson Correlation | 0.000 | 0.127 | 0.114 | -0.288 | 0.042 | 0.172 | 0.210 | -0.118 | -0.017 | -0.091 | -0.037 | 0.175 | -0.243 | -0.008 | -0.015 | 0.023 | 0.024 | -0.050 | -0.240 | -0.016 | 0.104 | 0.074 | 0.165 |
| | Sig. (2-tailed) | 0.988 | 0.000 | 0.000 | 0.000 | 0.094 | 0.000 | 0.000 | 0.000 | 0.499 | 0.000 | 0.140 | 0.000 | 0.000 | 0.750 | 0.545 | 0.358 | 0.331 | 0.046 | 0.000 | 0.527 | 0.000 | 0.002 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| INDUSTRY | Pearson Correlation | -0.148 | 0.018 | -0.177 | -0.078 | 0.315 | -0.111 | -0.087 | -0.061 | 0.044 | -0.198 | 0.331 | -0.193 | -0.222 | -0.236 | -0.231 | -0.264 | -0.169 | -0.044 | -0.204 | 0.066 | 0.466 | 0.114 | 0.530 |
| | Sig. (2-tailed) | 0.000 | 0.466 | 0.000 | 0.002 | 0.000 | 0.000 | 0.001 | 0.015 | 0.081 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.069 | 0.000 | 0.067 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| RECREATION | Pearson Correlation | -0.137 | 0.086 | 0.032 | -0.227 | 0.123 | 0.086 | 0.247 | -0.150 | -0.188 | -0.014 | 0.053 | 0.199 | -0.313 | -0.025 | -0.035 | 0.471 | 0.121 | 0.008 | -0.264 | -0.019 | -0.168 | -0.254 | -0.215 |
| | Sig. (2-tailed) | 0.000 | 0.001 | 0.199 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.568 | 0.036 | 0.000 | 0.000 | 0.318 | 0.161 | 0.000 | 0.000 | 0.761 | 0.000 | 0.449 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| CEMETERY | Pearson Correlation | -0.123 | 0.152 | -0.250 | -0.056 | 0.257 | 0.007 | 0.027 | -0.054 | -0.109 | -0.075 | 0.316 | -0.132 | -0.038 | -0.248 | -0.242 | -0.364 | -0.222 | -0.008 | 0.008 | 0.057 | 0.398 | 0.139 | 0.437 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.027 | 0.000 | 0.770 | 0.281 | 0.032 | 0.000 | 0.003 | 0.000 | 0.000 | 0.133 | 0.000 | 0.000 | 0.000 | 0.000 | 0.752 | 0.749 | 0.024 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| FOREST | Pearson Correlation | 0.273 | -0.260 | 0.091 | 0.139 | -0.002 | -0.254 | -0.323 | 0.121 | 0.227 | -0.033 | 0.085 | -0.324 | 0.403 | 0.113 | 0.128 | -0.551 | -0.179 | 0.057 | 0.350 | 0.018 | 0.202 | 0.254 | 0.343 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.949 | 0.000 | 0.000 | 0.000 | 0.000 | 0.197 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.036 | 0.000 | 0.484 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| YOUNG | Pearson Correlation | -0.070 | -0.083 | 0.103 | 0.012 | -0.109 | 0.014 | -0.245 | 0.035 | 0.411 | -0.250 | -0.072 | -0.134 | -0.266 | -0.133 | -0.130 | -0.289 | -0.077 | -0.090 | -0.269 | 0.033 | 0.281 | 0.365 | 0.469 |
| | Sig. (2-tailed) | 0.005 | 0.001 | 0.000 | 0.639 | 0.000 | 0.580 | 0.000 | 0.169 | 0.000 | 0.000 | 0.004 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | 0.195 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| ELDERLY | Pearson Correlation | 0.313 | -0.165 | 0.058 | 0.140 | -0.030 | -0.186 | -0.130 | 0.090 | -0.011 | 0.147 | 0.024 | -0.166 | 0.518 | 0.209 | 0.219 | -0.268 | -0.150 | 0.079 | 0.459 | -0.016 | -0.058 | 0.049 | -0.033 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.022 | 0.000 | 0.233 | 0.000 | 0.000 | 0.000 | 0.674 | 0.000 | 0.336 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.533 | 0.021 | 0.051 | 0.196 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| EMPLOY | Pearson Correlation | -0.142 | 0.078 | -0.036 | 0.098 | -0.179 | 0.139 | -0.092 | 0.033 | 0.233 | -0.135 | -0.173 | 0.044 | -0.188 | -0.081 | -0.094 | -0.016 | -0.020 | -0.059 | -0.182 | -0.007 | 0.068 | 0.132 | 0.073 |
| | Sig. (2-tailed) | 0.000 | 0.002 | 0.151 | 0.000 | 0.000 | 0.000 | 0.000 | 0.188 | 0.000 | 0.000 | 0.000 | 0.077 | 0.000 | 0.001 | 0.000 | 0.526 | 0.430 | 0.019 | 0.000 | 0.774 | 0.007 | 0.000 | 0.004 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| MALAY | Pearson Correlation | -0.233 | 0.239 | -0.071 | -0.194 | 0.038 | 0.254 | 0.296 | -0.123 | -0.173 | -0.046 | -0.034 | 0.285 | -0.396 | -0.112 | -0.122 | 0.436 | 0.176 | -0.040 | -0.343 | -0.005 | -0.122 | -0.200 | -0.197 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.005 | 0.000 | 0.129 | 0.000 | 0.000 | 0.000 | 0.000 | 0.066 | 0.177 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.109 | 0.000 | 0.832 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| CHI | Pearson Correlation | 0.100 | -0.187 | -0.029 | 0.228 | -0.007 | -0.231 | -0.299 | 0.137 | 0.166 | 0.002 | 0.065 | -0.281 | 0.293 | 0.018 | 0.024 | -0.434 | -0.165 | 0.020 | 0.257 | 0.019 | 0.226 | 0.165 | 0.233 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.245 | 0.000 | 0.788 | 0.000 | 0.000 | 0.000 | 0.000 | 0.947 | 0.010 | 0.000 | 0.000 | 0.482 | 0.331 | 0.000 | 0.000 | 0.432 | 0.000 | 0.443 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| IND | Pearson Correlation | 0.366 | -0.178 | 0.146 | 0.087 | -0.065 | -0.171 | -0.087 | 0.050 | -0.018 | 0.186 | -0.032 | -0.114 | 0.506 | 0.268 | 0.275 | -0.155 | -0.102 | 0.088 | 0.446 | -0.035 | -0.203 | 0.047 | -0.131 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.001 | 0.010 | 0.000 | 0.001 | 0.047 | 0.463 | 0.000 | 0.200 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.160 | 0.000 | 0.090 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

a. Cannot be computed because at least one of the variables is constant.

Appendix B

| SAUNA | GYM | SPORTSF | LAUNDRY | STR_CBD | STR_MJRROAD | STR_HIGHWAY | PRIMARY_SCH | SECONDARY_SCH | UNIVERSITY | HOSPITALS | INSTITUTE | COMMERCIAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -0.203 | -0.063 | -0.087 | -0.050 | 0.013 | -0.270 | -0.060 | -0.116 | -0.091 | 0.060 | -0.226 | 0.017 | -0.239 |
| 0.000 | 0.012 | 0.001 | 0.049 | 0.611 | 0.000 | 0.030 | 0.000 | 0.000 | 0.017 | 0.000 | 0.512 | 0.000 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.146 | -0.272 | -0.121 | -0.141 | 0.010 | 0.184 | 0.234 | -0.067 | 0.453 | 0.065 | 0.315 | 0.227 | 0.036 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.688 | 0.000 | 0.000 | 0.008 | 0.000 | 0.009 | 0.000 | 0.000 | 0.153 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.113 | 0.097 | 0.060 | 0.181 | -0.106 | -0.332 | -0.069 | -0.204 | -0.267 | 0.054 | -0.073 | -0.194 | -0.321 |
| 0.000 | 0.000 | 0.017 | 0.000 | 0.000 | 0.000 | 0.013 | 0.000 | 0.000 | 0.033 | 0.004 | 0.000 | 0.000 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.007 | -0.067 | -0.111 | -0.075 | 0.168 | -0.055 | -0.146 | -0.025 | -0.199 | -0.234 | -0.192 | -0.079 | -0.015 |
| 0.772 | 0.008 | 0.000 | 0.003 | 0.000 | 0.028 | 0.000 | 0.323 | 0.000 | 0.000 | 0.000 | 0.002 | 0.557 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.326 | 0.237 | 0.181 | 0.014 | -0.078 | 0.345 | 0.003 | 0.387 | 0.151 | 0.154 | -0.005 | 0.169 | 0.448 |
| 0.000 | 0.000 | 0.000 | 0.584 | 0.002 | 0.000 | 0.906 | 0.000 | 0.000 | 0.000 | 0.849 | 0.000 | 0.000 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.272 | -0.306 | -0.150 | -0.111 | 0.005 | -0.017 | 0.232 | -0.233 | 0.323 | 0.034 | 0.307 | 0.086 | -0.201 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.844 | 0.512 | 0.000 | 0.000 | 0.000 | 0.180 | 0.000 | 0.001 | 0.000 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.270 | -0.365 | -0.248 | -0.237 | -0.028 | 0.086 | 0.356 | -0.125 | 0.363 | 0.208 | 0.441 | 0.204 | -0.063 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.260 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.012 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.055 | 0.091 | 0.073 | 0.508 | 0.081 | -0.130 | -0.189 | -0.027 | -0.117 | -0.159 | -0.200 | -0.207 | -0.046 |
| 0.029 | 0.000 | 0.004 | 0.000 | 0.001 | 0.000 | 0.000 | 0.279 | 0.000 | 0.000 | 0.000 | 0.000 | 0.070 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.146 | 0.296 | 0.249 | -0.045 | -0.026 | -0.123 | -0.229 | 0.025 | -0.345 | -0.007 | -0.277 | 0.031 | -0.067 |
| 0.000 | 0.000 | 0.000 | 0.072 | 0.295 | 0.000 | 0.000 | 0.318 | 0.000 | 0.796 | 0.000 | 0.218 | 0.008 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.230 | -0.259 | -0.279 | -0.093 | 0.030 | -0.159 | 0.106 | -0.145 | 0.051 | -0.244 | 0.015 | -0.180 | -0.139 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.229 | 0.000 | 0.000 | 0.000 | 0.042 | 0.000 | 0.564 | 0.000 | 0.000 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.387 | 0.301 | 0.248 | 0.034 | -0.040 | 0.378 | -0.121 | 0.327 | 0.136 | 0.096 | -0.064 | -0.017 | 0.402 |
| 0.000 | 0.000 | 0.000 | 0.172 | 0.111 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.011 | 0.507 | 0.000 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.371 | -0.418 | -0.297 | -0.151 | 0.005 | -0.084 | 0.356 | -0.226 | 0.198 | 0.167 | 0.399 | 0.218 | -0.213 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.857 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.228 | -0.234 | -0.254 | -0.073 | 0.236 | -0.297 | -0.204 | -0.141 | 0.072 | -0.114 | -0.345 | -0.202 | -0.215 |
| 0.000 | 0.000 | 0.000 | 0.004 | 0.000 | 0.000 | 0.000 | 0.000 | 0.004 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.334 | -0.247 | -0.288 | -0.106 | 0.063 | -0.209 | 0.096 | -0.046 | 0.126 | 0.108 | -0.022 | 0.100 | -0.247 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.012 | 0.000 | 0.001 | 0.066 | 0.000 | 0.000 | 0.382 | 0.000 | 0.000 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.331 | -0.239 | -0.280 | -0.110 | 0.062 | -0.210 | 0.083 | -0.036 | 0.104 | 0.113 | -0.044 | 0.102 | -0.232 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.014 | 0.000 | 0.003 | 0.158 | 0.000 | 0.000 | 0.083 | 0.000 | 0.000 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.525 | -0.592 | -0.639 | -0.214 | -0.060 | -0.258 | 0.555 | -0.216 | -0.109 | -0.033 | 0.619 | 0.086 | -0.341 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.016 | 0.000 | 0.000 | 0.000 | 0.000 | 0.190 | 0.000 | 0.001 | 0.000 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |

| WORSHIP | GREEN | LAKES | INDUSTRY | RECREATION | CEMETERY | FOREST | YOUNG | ELDERLY | EMPLOY | MALAY | CHI | IND |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -0.212 | 0.036 | 0.000 | -0.140 | -0.137 | -0.123 | 0.273 | -0.070 | 0.313 | -0.142 | -0.233 | 0.101 | 0.364 |
| 0.000 | 0.154 | 0.988 | 0.000 | 0.000 | 0.000 | 0.000 | 0.019 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.121 | -0.162 | 0.127 | 0.018 | 0.086 | 0.152 | -0.260 | -0.083 | -0.169 | 0.078 | 0.239 | -0.187 | -0.174 |
| 0.000 | 0.000 | 0.000 | 0.466 | 0.001 | 0.000 | 0.000 | 0.001 | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.087 | -0.109 | 0.114 | -0.177 | 0.032 | -0.250 | 0.091 | 0.103 | 0.058 | -0.034 | -0.071 | -0.029 | 0.144 |
| 0.001 | 0.000 | 0.000 | 0.000 | 0.199 | 0.000 | 0.000 | 0.000 | 0.022 | 0.151 | 0.009 | 0.245 | 0.000 |
| 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.096 | 0.070 | -0.288 | -0.078 | -0.227 | -0.056 | 0.139 | 0.012 | 0.140 | 0.098 | -0.194 | 0.228 | 0.087 |
| 0.000 | 0.005 | 0.000 | 0.002 | 0.000 | 0.027 | 0.000 | 0.639 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 |
| 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.195 | 0.275 | 0.042 | 0.315 | 0.123 | 0.257 | -0.002 | -0.109 | -0.030 | -0.179 | 0.038 | -0.007 | -0.069 |
| 0.000 | 0.000 | 0.094 | 0.000 | 0.000 | 0.000 | 0.949 | 0.000 | 0.233 | 0.000 | 0.129 | 0.788 | 0.010 |
| 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.261 | -0.306 | 0.172 | -0.111 | 0.086 | 0.007 | -0.254 | 0.014 | -0.186 | 0.139 | 0.254 | -0.231 | -0.171 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.770 | 0.000 | 0.580 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.273 | -0.146 | 0.210 | -0.087 | 0.247 | 0.027 | -0.323 | -0.245 | -0.130 | -0.092 | 0.296 | -0.299 | -0.087 |
| 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.281 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 |
| 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.057 | 0.094 | -0.118 | -0.061 | -0.150 | -0.054 | 0.121 | 0.035 | 0.090 | 0.033 | -0.123 | 0.137 | 0.050 |
| 0.022 | 0.000 | 0.000 | 0.015 | 0.000 | 0.032 | 0.000 | 0.169 | 0.000 | 0.188 | 0.000 | 0.000 | 0.047 |
| 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.169 | -0.028 | -0.017 | 0.044 | -0.188 | -0.109 | 0.227 | 0.411 | -0.011 | 0.233 | -0.173 | 0.166 | -0.018 |
| 0.000 | 0.261 | 0.499 | 0.081 | 0.000 | 0.000 | 0.000 | 0.000 | 0.674 | 0.000 | 0.000 | 0.000 | 0.463 |
| 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.027 | -0.128 | -0.091 | -0.198 | -0.014 | -0.075 | -0.033 | -0.250 | 0.147 | -0.135 | -0.046 | 0.002 | 0.186 |
| 0.283 | 0.000 | 0.000 | 0.000 | 0.568 | 0.003 | 0.197 | 0.000 | 0.000 | 0.000 | 0.066 | 0.947 | 0.000 |
| 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.132 | 0.324 | -0.037 | 0.331 | 0.053 | 0.316 | 0.085 | -0.072 | 0.024 | -0.173 | -0.034 | 0.065 | -0.032 |
| 0.000 | 0.000 | 0.140 | 0.000 | 0.036 | 0.000 | 0.001 | 0.004 | 0.336 | 0.000 | 0.177 | 0.010 | 0.200 |
| 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.293 | -0.241 | 0.175 | -0.193 | 0.199 | -0.132 | -0.324 | -0.134 | -0.166 | 0.044 | 0.285 | -0.281 | -0.114 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.077 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.228 | 0.189 | -0.243 | -0.222 | -0.313 | -0.038 | 0.403 | -0.266 | 0.518 | -0.188 | -0.396 | 0.293 | 0.506 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.133 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.078 | -0.053 | -0.008 | -0.236 | -0.025 | -0.248 | 0.113 | -0.133 | 0.209 | -0.081 | -0.112 | 0.018 | 0.268 |
| 0.002 | 0.036 | 0.750 | 0.000 | 0.318 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.482 | 0.000 |
| 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.102 | -0.033 | -0.015 | -0.231 | -0.035 | -0.242 | 0.128 | -0.130 | 0.219 | -0.094 | -0.122 | 0.024 | 0.275 |
| 0.000 | 0.187 | 0.545 | 0.000 | 0.161 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.331 | 0.000 |
| 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.560 | -0.382 | 0.023 | -0.264 | 0.471 | -0.364 | -0.551 | -0.289 | -0.268 | -0.016 | 0.436 | -0.434 | -0.155 |
| 0.000 | 0.000 | 0.358 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.526 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |

# Appendix B

| | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -0.089 | -0.100 | -0.108 | -0.036 | -0.064 | 0.102 | 0.222 | -0.009 | -0.082 | -0.050 | 0.083 | -0.042 | -0.001 | 0.142 | -0.181 | 0.024 | -0.169 | 0.121 | -0.222 | -0.179 | -0.077 | -0.150 | -0.020 | 0.176 | -0.169 | -0.103 |
| 0.000 | 0.000 | 0.000 | 0.152 | 0.011 | 0.000 | 0.000 | 0.712 | 0.001 | 0.047 | 0.001 | 0.094 | 0.975 | 0.000 | 0.000 | 0.331 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.434 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.070 | -0.078 | -0.085 | -0.028 | 0.069 | 0.004 | 0.015 | -0.037 | 0.090 | 0.098 | -0.029 | 0.041 | -0.022 | -0.057 | 0.037 | -0.050 | -0.046 | 0.000 | -0.008 | 0.051 | -0.090 | 0.079 | -0.059 | -0.044 | 0.020 | [illegible] |
| 0.006 | 0.002 | 0.001 | 0.261 | 0.007 | 0.867 | 0.596 | 0.142 | 0.000 | 0.001 | 0.248 | 0.089 | 0.377 | 0.024 | 0.145 | 0.046 | 0.069 | 0.760 | 0.752 | 0.036 | 0.000 | 0.002 | 0.019 | 0.109 | 0.432 | 0.000 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.215 | -0.242 | -0.261 | -0.087 | 0.218 | -0.250 | -0.173 | -0.149 | 0.102 | -0.137 | -0.301 | -0.234 | -0.184 | -0.184 | 0.175 | -0.240 | -0.204 | -0.264 | 0.000 | 0.350 | -0.269 | 0.459 | -0.182 | -0.341 | 0.257 | [illegible] |
| 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.749 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.032 | -0.036 | -0.039 | -0.013 | -0.020 | -0.012 | -0.056 | 0.020 | -0.104 | -0.016 | -0.051 | -0.025 | 0.068 | -0.031 | 0.070 | -0.016 | 0.046 | -0.019 | 0.057 | 0.018 | 0.033 | -0.016 | -0.007 | -0.005 | 0.019 | -0.031 |
| 0.200 | 0.149 | 0.119 | 0.603 | 0.432 | 0.633 | 0.045 | 0.419 | 0.000 | 0.535 | 0.043 | 0.330 | 0.007 | 0.184 | 0.019 | 0.527 | 0.067 | 0.445 | 0.024 | 0.484 | 0.195 | 0.531 | 0.774 | 0.812 | 0.441 | [illegible] |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.489 | 0.461 | 0.414 | 0.012 | 0.004 | 0.525 | -0.261 | 0.565 | 0.263 | 0.136 | -0.241 | 0.114 | 0.607 | -0.335 | 0.371 | 0.104 | 0.446 | -0.168 | 0.390 | 0.202 | 0.281 | -0.058 | 0.068 | -0.122 | 0.224 | -0.201 |
| 0.000 | 0.000 | 0.000 | 0.620 | 0.885 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.021 | 0.007 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.419 | 0.564 | 0.693 | 0.357 | -0.107 | -0.024 | -0.339 | -0.152 | -0.192 | 0.013 | -0.306 | -0.017 | -0.012 | -0.259 | 0.018 | 0.076 | 0.114 | -0.256 | 0.139 | 0.254 | 0.365 | 0.049 | 0.132 | -0.200 | 0.169 | [illegible] |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.333 | 0.000 | 0.000 | 0.000 | 0.603 | 0.000 | 0.506 | 0.628 | 0.000 | 0.470 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.051 | 0.000 | 0.000 | 0.000 | [illegible] |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.832 | 0.911 | 0.987 | 0.246 | -0.138 | 0.465 | -0.438 | 0.407 | 0.030 | 0.195 | -0.401 | 0.094 | 0.532 | -0.481 | 0.335 | 0.165 | 0.530 | -0.215 | 0.437 | 0.341 | 0.469 | -0.031 | 0.071 | -0.197 | 0.231 | -0.131 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.229 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.196 | 0.004 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 1 | 0.886 | 0.820 | 0.294 | -0.059 | 0.564 | -0.401 | 0.577 | -0.014 | 0.022 | -0.423 | -0.083 | 0.734 | -0.413 | 0.477 | -0.026 | 0.628 | -0.164 | 0.566 | 0.299 | 0.177 | 0.028 | -0.131 | -0.155 | 0.229 | -0.127 |
| | 0.000 | 0.000 | 0.000 | 0.018 | 0.000 | 0.000 | 0.000 | 0.569 | 0.382 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.299 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.267 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.886 | 1 | 0.926 | 0.266 | -0.204 | 0.451 | -0.392 | 0.524 | -0.076 | 0.190 | -0.464 | 0.013 | 0.591 | -0.467 | 0.415 | 0.141 | 0.534 | -0.113 | 0.384 | 0.352 | 0.335 | 0.007 | -0.140 | -0.160 | 0.156 | -0.074 |
| 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | 0.607 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.782 | 0.000 | 0.000 | 0.000 | 0.003 |
| 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,293 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 |
| 0.820 | 0.926 | 1 | 0.242 | -0.147 | 0.453 | -0.449 | 0.409 | 0.044 | 0.187 | -0.414 | 0.074 | 0.535 | -0.487 | 0.354 | 0.166 | 0.509 | -0.219 | 0.424 | 0.346 | 0.476 | -0.038 | 0.071 | -0.196 | 0.236 | -0.143 |
| 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.082 | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.129 | 0.004 | 0.000 | 0.000 | 0.000 |
| 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,293 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 |
| 0.294 | 0.266 | 0.242 | 1 | 0.040 | -0.176 | -0.227 | -0.158 | -0.177 | -0.259 | -0.270 | -0.267 | -0.058 | -0.110 | 0.060 | -0.162 | 0.000 | -0.200 | 0.142 | 0.177 | -0.136 | 0.245 | -0.129 | -0.189 | 0.148 | 0.224 |
| 0.000 | 0.000 | 0.000 | | 0.111 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.021 | 0.000 | 0.017 | 0.000 | 0.987 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,293 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 | 1,578 |
| -0.059 | -0.204 | -0.147 | 0.040 | 1 | -0.172 | -0.155 | -0.018 | 0.194 | -0.078 | -0.348 | -0.142 | -0.108 | -0.202 | 0.289 | -0.415 | -0.219 | -0.543 | -0.118 | 0.442 | -0.037 | 0.459 | 0.179 | -0.490 | 0.521 | 0.324 |
| 0.018 | 0.000 | 0.000 | 0.111 | | 0.000 | 0.000 | 0.466 | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.139 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.564 | 0.451 | 0.453 | -0.176 | -0.172 | 1 | -0.093 | 0.551 | 0.129 | 0.237 | 0.028 | 0.367 | 0.766 | -0.323 | 0.229 | 0.003 | 0.567 | 0.090 | 0.445 | -0.138 | 0.207 | -0.349 | 0.021 | 0.189 | -0.044 | -0.447 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.001 | 0.000 | 0.000 | 0.000 | 0.268 | 0.000 | 0.000 | 0.000 | 0.000 | 0.891 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.408 | 0.000 | 0.080 | 0.000 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.401 | -0.392 | -0.449 | -0.227 | -0.155 | -0.093 | 1 | -0.150 | -0.141 | 0.386 | 0.845 | 0.283 | -0.232 | 0.706 | -0.642 | 0.589 | -0.086 | 0.862 | -0.293 | -0.860 | -0.195 | -0.622 | -0.080 | 0.817 | -0.810 | -0.437 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.004 | 0.000 | 0.000 | 0.000 |
| 1,295 | 1,293 | 1,293 | 1,293 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 |
| 0.573 | 0.524 | 0.409 | -0.158 | -0.018 | 0.551 | -0.150 | 1 | 0.005 | 0.241 | -0.214 | 0.262 | 0.766 | -0.360 | 0.464 | 0.073 | 0.513 | 0.021 | 0.207 | 0.179 | 0.229 | -0.098 | -0.044 | -0.021 | 0.107 | -0.236 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.466 | 0.000 | 0.000 | | 0.854 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.004 | 0.000 | 0.408 | 0.000 | 0.000 | 0.000 | 0.000 | 0.081 | 0.395 | 0.000 | 0.000 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.014 | -0.076 | 0.044 | -0.177 | 0.194 | 0.129 | -0.141 | 0.005 | 1 | 0.104 | -0.089 | 0.002 | 0.071 | -0.154 | 0.206 | 0.037 | 0.012 | -0.198 | 0.163 | 0.189 | -0.025 | 0.172 | 0.048 | -0.190 | 0.215 | 0.106 |
| 0.569 | 0.002 | 0.082 | 0.000 | 0.000 | 0.000 | 0.000 | 0.854 | | 0.000 | 0.000 | 0.922 | 0.005 | 0.000 | 0.000 | 0.139 | 0.628 | 0.000 | 0.000 | 0.000 | 0.318 | 0.000 | 0.054 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.022 | 0.190 | 0.187 | -0.259 | -0.078 | 0.237 | 0.386 | 0.241 | 0.104 | 1 | 0.106 | 0.662 | 0.112 | -0.206 | 0.100 | 0.547 | 0.083 | 0.332 | -0.248 | -0.056 | 0.257 | -0.250 | 0.023 | 0.178 | -0.198 | -0.196 |
| 0.382 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.026 | 0.000 | 0.000 | 0.360 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.423 | -0.464 | -0.414 | -0.270 | -0.348 | 0.028 | 0.845 | -0.214 | -0.089 | 0.106 | 1 | 0.296 | -0.193 | 0.770 | -0.682 | 0.441 | 0.057 | 0.762 | -0.084 | -0.933 | -0.048 | -0.745 | 0.159 | 0.822 | -0.740 | -0.607 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.268 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.024 | 0.000 | 0.001 | 0.000 | 0.054 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.083 | 0.013 | 0.074 | -0.267 | -0.142 | 0.367 | 0.283 | 0.262 | 0.002 | 0.662 | 0.296 | 1 | 0.143 | -0.188 | -0.159 | 0.320 | 0.139 | 0.188 | -0.230 | -0.248 | 0.411 | -0.412 | 0.368 | 0.216 | -0.138 | -0.379 |

Appendix B

| | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.001 | 0.607 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.922 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.00 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,58 |
| 0.734 | 0.591 | 0.535 | -0.058 | -0.108 | 0.766 | -0.232 | 0.766 | 0.071 | 0.112 | -0.193 | 0.143 | | -0.376 | 0.527 | 0.026 | 0.708 | 0.012 | 0.596 | 0.089 | 0.138 | -0.159 | -0.114 | 0.022 | 0.110 | -0.31 |
| 0.000 | 0.000 | 0.000 | 0.021 | 0.000 | 0.000 | 0.000 | 0.000 | 0.005 | 0.000 | 0.001 | 0.001 | | 0.000 | 0.001 | 0.309 | 0.001 | 0.621 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.376 | 0.000 | 0.00 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,58 |
| -0.413 | -0.467 | -0.487 | -0.110 | -0.202 | -0.323 | 0.706 | -0.360 | -0.154 | -0.206 | 0.770 | -0.188 | -0.376 | | -0.576 | 0.295 | 0.008 | 0.637 | -0.067 | -0.712 | -0.172 | -0.490 | 0.040 | 0.648 | -0.619 | -0.37 |
| 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 | | 0.001 | 0.001 | 0.752 | 0.000 | 0.008 | 0.001 | 0.001 | 0.000 | 0.109 | 0.000 | 0.000 | 0.00 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,58 |
| 0.477 | 0.415 | 0.354 | 0.060 | 0.289 | 0.229 | -0.642 | 0.464 | 0.206 | 0.100 | -0.682 | -0.159 | 0.527 | -0.576 | | -0.312 | 0.215 | -0.447 | 0.248 | 0.689 | -0.034 | 0.506 | -0.243 | -0.552 | 0.548 | 0.33 |
| 0.000 | 0.000 | 0.000 | 0.017 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 | 0.001 | | 0.001 | 0.001 | 0.000 | 0.001 | 0.000 | 0.181 | 0.000 | 0.000 | 0.000 | 0.000 | 0.00 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,58 |
| -0.026 | 0.141 | 0.166 | -0.162 | -0.415 | 0.003 | 0.589 | 0.073 | 0.037 | 0.547 | 0.441 | 0.320 | 0.026 | 0.295 | -0.312 | | 0.247 | 0.594 | 0.025 | -0.395 | 0.224 | -0.481 | 0.024 | 0.464 | -0.472 | -0.38 |
| 0.299 | 0.000 | 0.000 | 0.000 | 0.000 | 0.891 | 0.000 | 0.004 | 0.139 | 0.000 | 0.000 | 0.000 | 0.309 | 0.001 | 0.000 | | 0.001 | 0.000 | 0.324 | 0.001 | 0.000 | 0.000 | 0.335 | 0.000 | 0.000 | 0.00 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,58 |
| 0.628 | 0.534 | 0.509 | 0.000 | -0.219 | 0.567 | -0.086 | 0.511 | 0.012 | 0.087 | 0.057 | 0.139 | 0.708 | 0.008 | 0.215 | 0.247 | | 0.205 | 0.764 | -0.074 | 0.354 | -0.385 | 0.103 | 0.222 | -0.080 | -0.50 |
| 0.000 | 0.000 | 0.001 | 0.987 | 0.000 | 0.000 | 0.002 | 0.000 | 0.628 | 0.001 | 0.024 | 0.001 | 0.001 | 0.752 | 0.001 | 0.000 | | 0.001 | 0.001 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.00 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,58 |
| -0.164 | -0.113 | -0.219 | -0.200 | -0.543 | 0.090 | 0.862 | 0.021 | -0.198 | 0.332 | 0.762 | 0.188 | 0.012 | 0.637 | -0.447 | 0.594 | 0.205 | | -0.055 | -0.806 | -0.146 | -0.701 | -0.209 | 0.862 | -0.863 | -0.53 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.408 | 0.000 | 0.000 | 0.000 | 0.000 | 0.621 | 0.000 | 0.000 | 0.000 | 0.001 | | 0.030 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.00 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,58 |
| 0.566 | 0.384 | 0.424 | 0.142 | -0.118 | 0.445 | -0.293 | 0.207 | 0.163 | -0.248 | -0.084 | -0.230 | 0.596 | -0.067 | 0.248 | 0.025 | 0.764 | -0.055 | | 0.051 | 0.076 | -0.092 | -0.040 | 0.022 | 0.090 | -0.23 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.008 | 0.000 | 0.324 | 0.001 | 0.030 | | 0.044 | 0.002 | 0.000 | 0.113 | 0.389 | 0.000 | 0.00 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,58 |
| 0.295 | 0.352 | 0.346 | 0.177 | 0.442 | -0.138 | -0.860 | 0.179 | 0.189 | -0.056 | -0.933 | -0.248 | 0.089 | -0.712 | 0.689 | -0.395 | -0.074 | -0.806 | 0.051 | | 0.108 | 0.799 | -0.059 | -0.887 | 0.795 | 0.65 |
| 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.026 | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 | 0.000 | 0.003 | 0.000 | 0.044 | | 0.001 | 0.000 | 0.018 | 0.000 | 0.000 | 0.00 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,58 |
| 0.177 | 0.335 | 0.476 | -0.136 | -0.037 | 0.207 | -0.195 | 0.229 | -0.025 | 0.257 | -0.048 | 0.411 | 0.138 | -0.172 | -0.034 | 0.224 | 0.354 | -0.146 | 0.076 | 0.108 | | -0.458 | 0.791 | 0.046 | 0.106 | -0.56 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.139 | 0.000 | 0.000 | 0.000 | 0.318 | 0.000 | 0.054 | 0.000 | 0.001 | 0.001 | 0.181 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | | 0.001 | 0.000 | 0.066 | 0.000 | 0.00 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,58 |
| 0.028 | 0.007 | -0.038 | 0.245 | 0.459 | -0.349 | -0.622 | -0.098 | 0.172 | -0.250 | -0.745 | -0.412 | -0.155 | -0.490 | 0.506 | -0.481 | -0.385 | -0.701 | -0.092 | 0.799 | -0.458 | | -0.425 | -0.844 | 0.664 | 0.95 |
| 0.267 | 0.782 | 0.128 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.00 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,58 |
| -0.133 | -0.140 | 0.073 | -0.129 | 0.179 | 0.021 | -0.080 | -0.044 | 0.048 | 0.023 | 0.159 | 0.368 | -0.114 | 0.040 | -0.243 | 0.024 | 0.103 | -0.209 | -0.040 | -0.059 | 0.791 | -0.425 | | -0.004 | 0.238 | -0.51 |
| 0.000 | 0.000 | 0.004 | 0.000 | 0.000 | 0.408 | 0.004 | 0.081 | 0.054 | 0.360 | 0.000 | 0.000 | 0.000 | 0.109 | 0.000 | 0.335 | 0.000 | 0.000 | 0.113 | 0.018 | 0.000 | 0.000 | | 0.869 | 0.000 | 0.00 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,58 |
| -0.155 | -0.160 | -0.196 | -0.189 | -0.490 | 0.189 | 0.817 | -0.021 | -0.190 | 0.178 | 0.822 | 0.216 | 0.022 | 0.648 | -0.552 | 0.464 | 0.222 | 0.862 | 0.022 | -0.887 | 0.046 | -0.844 | -0.004 | | -0.944 | -0.75 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.395 | 0.000 | 0.000 | 0.000 | 0.000 | 0.376 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.389 | 0.000 | 0.066 | 0.000 | 0.869 | | 0.000 | 0.00 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,58 |
| 0.229 | 0.156 | 0.236 | 0.148 | 0.521 | -0.044 | -0.810 | 0.107 | 0.215 | -0.198 | -0.740 | -0.138 | 0.110 | -0.619 | 0.548 | -0.472 | -0.080 | -0.863 | 0.090 | 0.795 | 0.106 | 0.664 | 0.238 | -0.944 | | 0.51 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.080 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.00 |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,58 |
| -0.127 | -0.076 | -0.142 | 0.224 | 0.328 | -0.447 | -0.433 | -0.236 | 0.106 | -0.198 | -0.607 | -0.379 | -0.314 | -0.375 | 0.330 | -0.387 | -0.508 | -0.535 | -0.233 | 0.659 | -0.560 | 0.951 | -0.519 | -0.750 | 0.516 | |
| 0.000 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | |
| 1,580 | 1,578 | 1,578 | 1,578 | 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,58 |

Appendix C

```
'MultiOrigin2MultiDest
'
'Purpose:
' To calculate the least cost path from multiple origins to multiple destinations
' one at a time.
' The script determines the path from each origin to each destination separately.
' A view with a line theme and two point themes (origins and destinations) are required
'
'Author:
' ESRI sample script
'
'Modified:
' Dan Patterson
' Dan_Patterson@carleton.ca
'
theView = av.GetActiveDoc
if (not (theView.Is(View))) then
  msgBox.Error("Active document is not a view.",Script.The.GetName)
  Return NIL
end
'
theViewUnits=theView.GetUnits.AsString
theViewUnits=theViewUnits.Substitute("UNITS_LINEAR_","").Proper
thePrj=theView.GetProjection
'
'Select the network line theme
' check for proper network theme
' make the NetDef and check it for errors
'
theLineThemes={}
for each t in theView.GetThemes
  if(NetDef.CanMakeFromTheme(t)) then
    theLineThemes.add(t)
  end
end
'
aNetTheme=msgbox.List(theLineThemes,"Select the Network theme",
              "Solve point to point along network")
if (aNetTheme = nil) then
  Return NIL
end
aNetDef = NetDef.Make(aNetTheme.GetFTab)
if (aNetDef.HasError) then
  msgBox.Error("NetDef has error.","")
  Return NIL
```

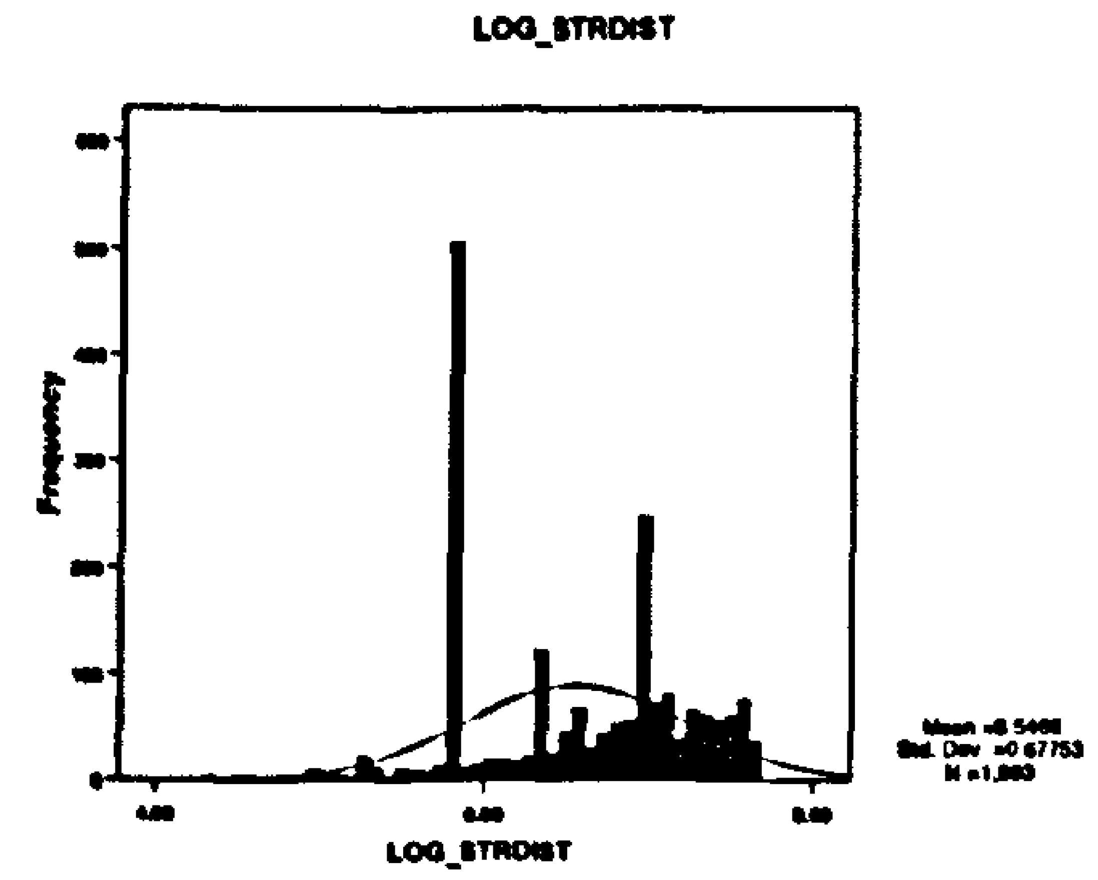
```
end
'
'make the Network object
'
aNetwork = Network.Make(aNetDef)
'
theSearchTol=aNetwork.GetDefaultSearchTol
theSearchTol=aNetwork.GetSearchTol
theNewTol=msgbox.input("Search tolerance is: "+theSearchTol.AsString + NL +
                "Change by a factor of...(1=default, 2=double search distance)",
                "Feature location tolerance","1")
if(theNewTol<>NIL) then
  if(theNewTol.IsNumber) then
    theNewTol=theSearchTol*(theNewTol.AsNumber)
  else
    theNewTol=theSearchTol
  end
else
  Return NIL
end
'
'msgbox.info(theNewTol.AsString,"Search Tolerance")
'
aNetwork.SetSearchTol(theNewTol)
'
'Get the origin and destination point themes
'
thePointThemes={}
for each t in theView.GetThemes
  if (t.GetFTab.GetSrcName.GetSubName = "Point") then
    thePointThemes.add(t)
  end
end
'
hasError=False
theOriginTheme=msgbox.List(thePointThemes,"Select the origin theme",
                "Solve point to point along network")
if (theOriginTheme <> nil) then
  theDestTheme=msgbox.List(thePointThemes,"Select the destination theme",
                "Solve point to point along network")
  if(theDestTheme=nil) then
    hasError=TRUE
  end
else
  hasError=True
```

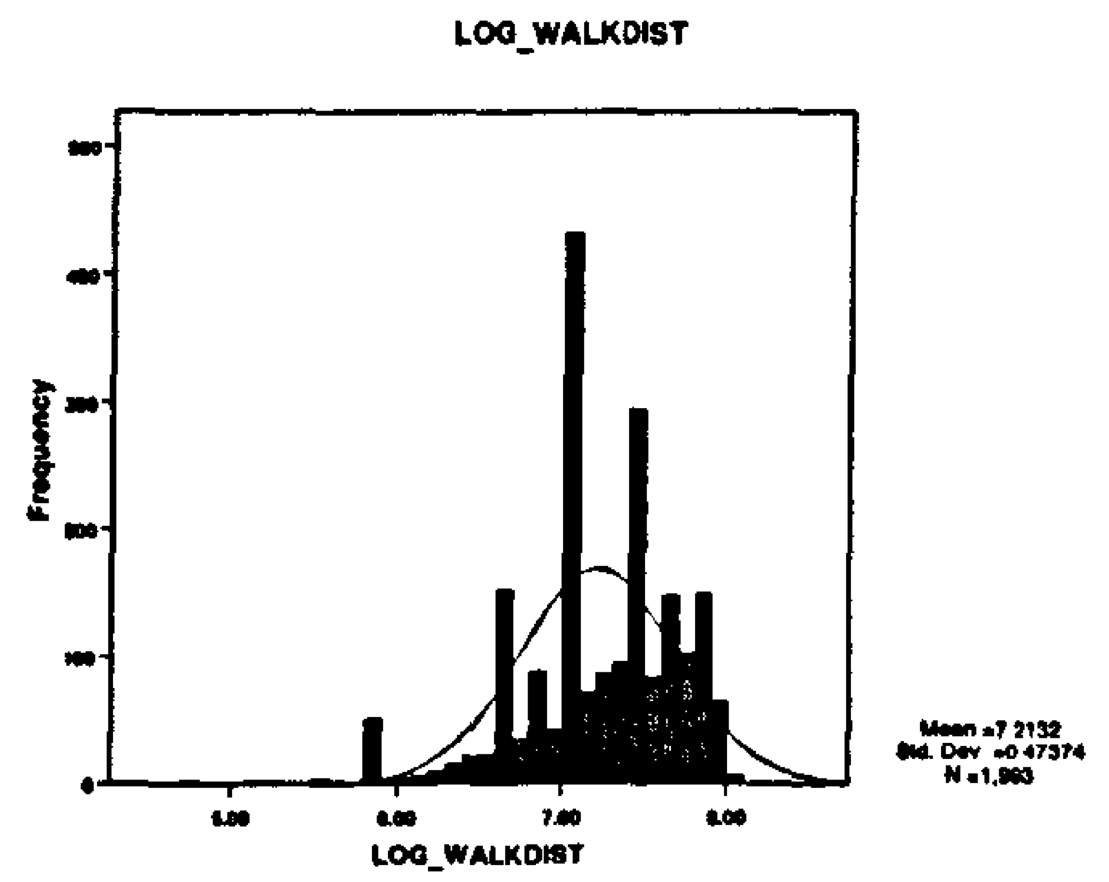
```
end
'
if(hasError) then
  msgBox.Error("Theme not found or selected.","")
  Return NIL
end
'
theOriginFTab = theOriginTheme.GetFTab
theOriginShapeFld = theOriginFTab.FindField("Shape")
theOriginFlds=theOriginFTab.GetFields.Clone
theOriginFlds.Remove(0)
theOriginLabelFld=msgbox.List(theOriginFlds,"Select a label field",
                    "Origin theme")
if(theOriginLabelFld=NIL) then
  Return NIL
end
'
theOWidth=theOriginLabelFld.GetWidth

theDestFTab =theDestTheme.GetFTab
theDestShapeFld = theDestFTab.FindField("Shape")
theDestFlds=theDestFtab.GetFields.Clone
theDestFlds.Remove(0)
theDestLabelFld=msgbox.List(theDestFlds,"Select a label field",
                    "Destination theme")
if(theDestLabelFld=NIL) then
  Return NIL
end
'
theDWidth=theDestLabelFld.GetWidth

theOutFName=FileDialog.Put((av.GetProject.GetWorkDir.asString+"\Paths.shp").AsFileNa
me,
                  "*.shp","Specify a output filename and saving folder")
if(theOutFName=NIL) then
  Return NIL
end
theOutFTab=FTab.MakeNew(theOutFName,Polyline)
theOutIDFld=Field.Make("ID",#FIELD_DECIMAL,6,0)
theOutFromFld=Field.Make("From",#Field_Char,theOWidth,0)
theOutToFld=Field.Make("To", #Field_Char,theDWidth,0)
theOutDistFld=Field.Make("Distance",#FIELD_DECIMAL,15,2)
theOutFTab.AddFields({theOutIDFld,theOutFromFld,theOutToFld,theOutDistFld})
theOutShpFld=theOutFtab.FindField("Shape")
'
'Make a point list from the Origin and Destination themes,
```

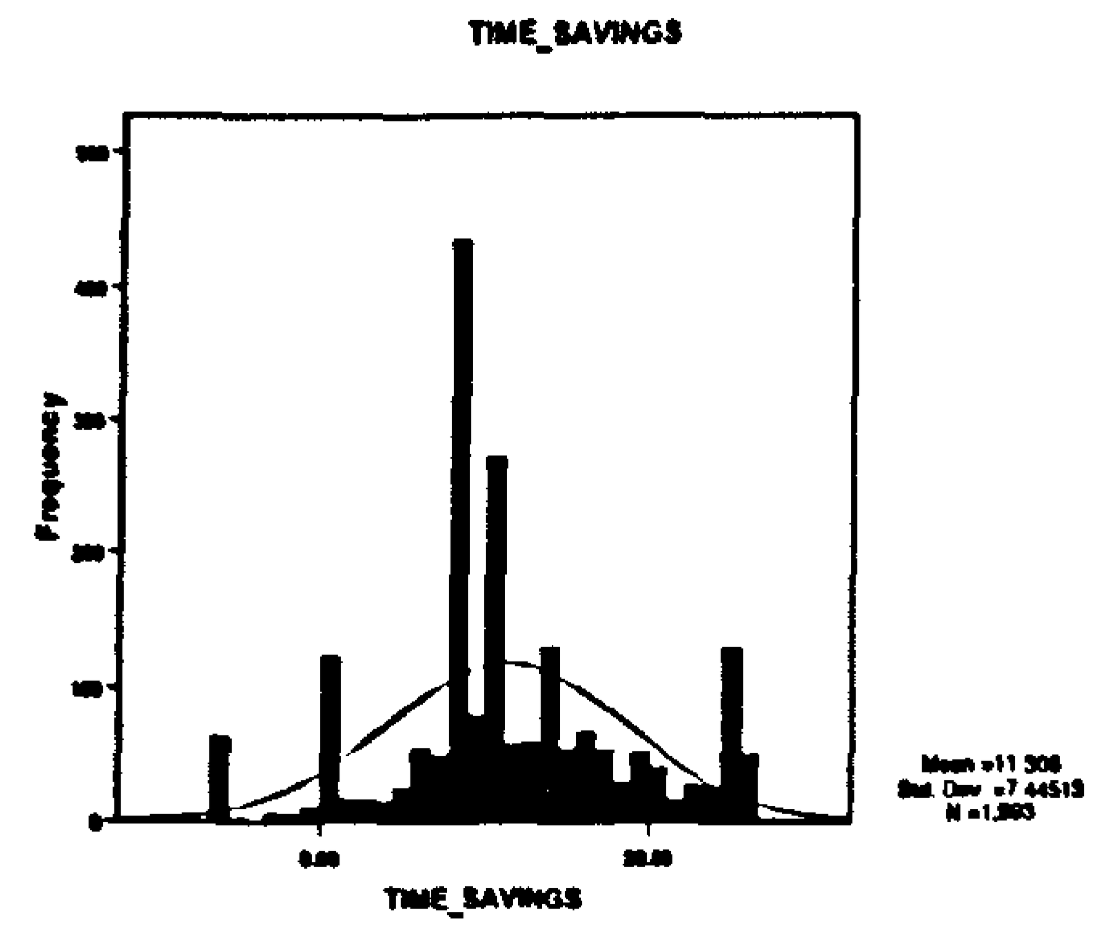
```
' validate the points, and create a shape for the resultant
'
theOriginBM=theOriginFTab.GetSelection
theOriginBMout=theOriginBM.Clone
if(theOriginBM.Count=0) then
 theOriginBM.SetAll
end
theDestBM=theDestFTab.GetSelection
theDestBMout=theDestBM.Clone
if(theDestBM.Count=0) then
 theDestBM.SetAll
end
'
if(theOutFTab.StartEditingWithRecovery) then
 theOutFTab.BeginTransaction
 pointList = {}
 for each rec in theOriginBM
  p = theOriginFTab.ReturnValue(theOriginShapeFld, rec)
  theOriginName=theOriginFTab.ReturnValueString(theOriginLabelFld, rec)
  if (aNetwork.IsPointOnNetwork(p)) then
   pointList.Add(p)
  else
   msgbox.info(theOriginName +NL+"Not close enough to network.  It will be skipped",
          "Origin not located.")
   continue
  end
  for each rec in theDestBM
   p2 = theDestFTab.ReturnValue(theDestShapeFld, rec)
   theDestName=theDestFTab.ReturnValueString(theDestLabelFld, rec)
   if (aNetwork.IsPointOnNetwork(p2)) then
    pointList.Add(p2)
   else
    msgbox.info(theDestName+NL+"Not close enough to network.  It will be skipped.",
          "Destination not located.")
    continue
   end

   findBestOrder  = True
   returnToOrigin = False 'True
   ' calculate the path
   pathCost = aNetwork.FindPath(pointList, findBestOrder, returnToOrigin)
   ' make sure the FindPath succeeded
   if ((not (aNetwork.HasPathResult)) or (pathCost = 0)) then
    msgBox.Error("Path not found.","")
    break
   end
```

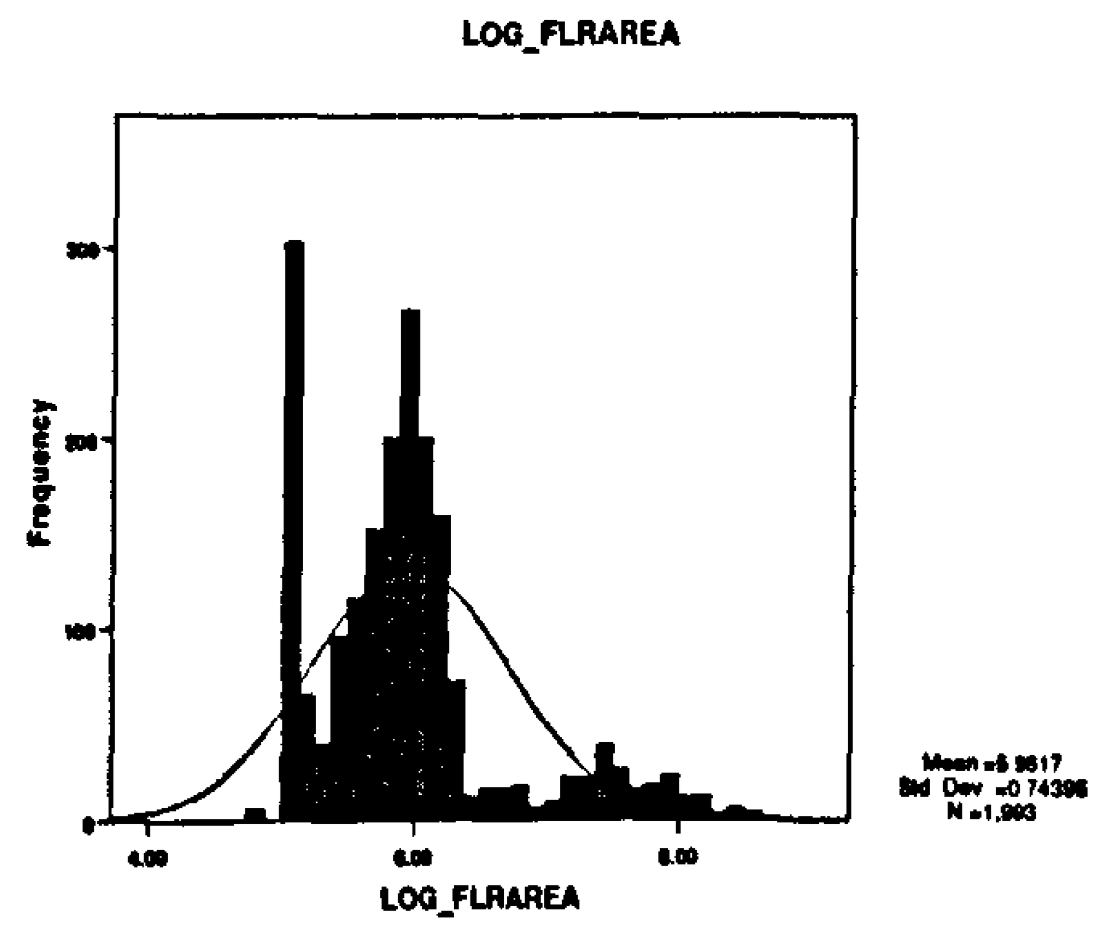
```
      aPathShape = aNetwork.ReturnPathShape
      if(thePrj<>NIL) then
        aPrjShape=aPathShape.ReturnProjected(thePrj)
        theLength=aPrjShape.ReturnLength
      else
        theLength=aPathShape.ReturnLength
      end
      theRec=theOutFtab.AddRecord
      theOutFtab.SetValue(theOutShpFld,theRec,aPathShape)
      theOutFTab.SetValue(theOutIDFld,theRec,theRec)
      theOutFTab.SetValue(theOutFromFld,theRec,theOriginName)
      theOutFTab.SetValue(theOutToFld,theRec,theDestName)
      theOutFTab.SetValue(theOutDistFld,theRec,theLength)
      '
      pointList.Remove(1)
      '
    end
    pointList={}
    theOutFTab.EndTransaction
  end
end
'
theOutFTab.StopEditingWithRecovery(True)
'
theOriginFTab.SetSelection(theOriginBMout)
theDestFTab.SetSelection(theDestBMout)
'
theNetTheme=Theme.Make(SrcName.Make(theOutFName.Asstring))
theView.AddTheme(theNetTheme)
theNetTheme.SetVisible(True)
av.PurgeObjects
```

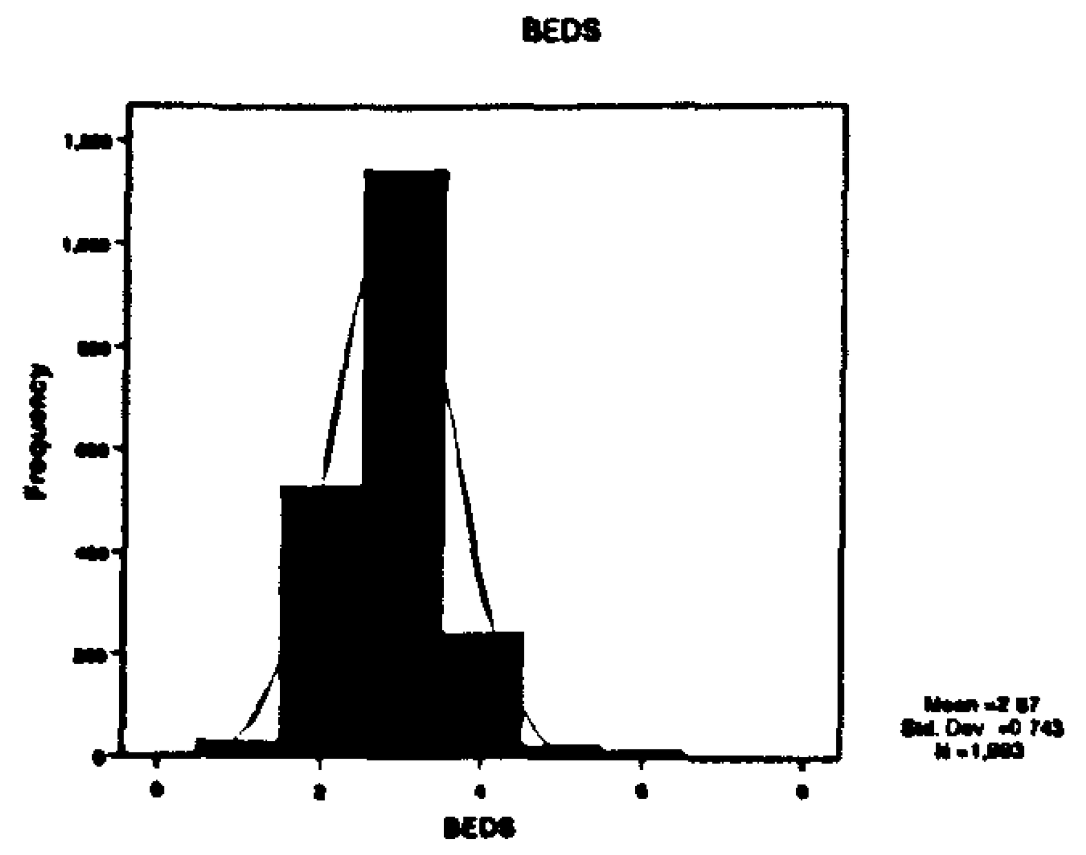
# Appendix D
## Distribution of Selected Variables

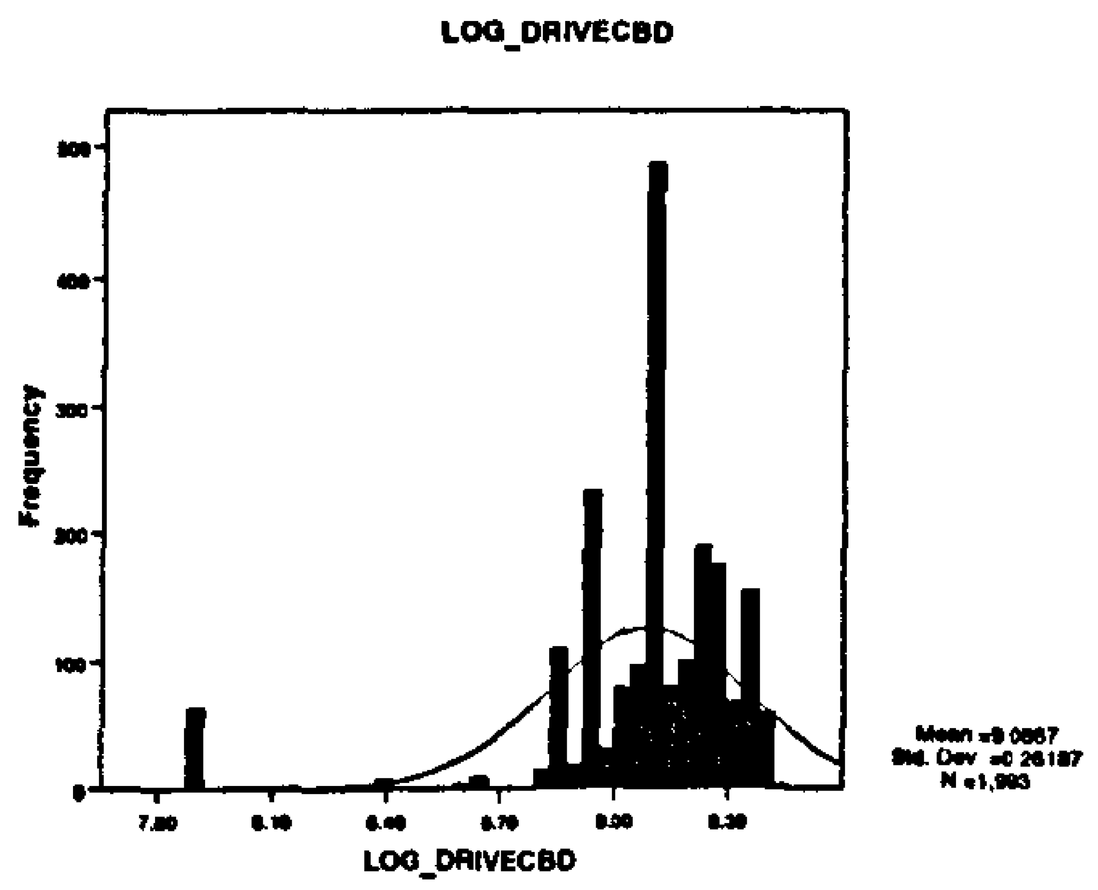


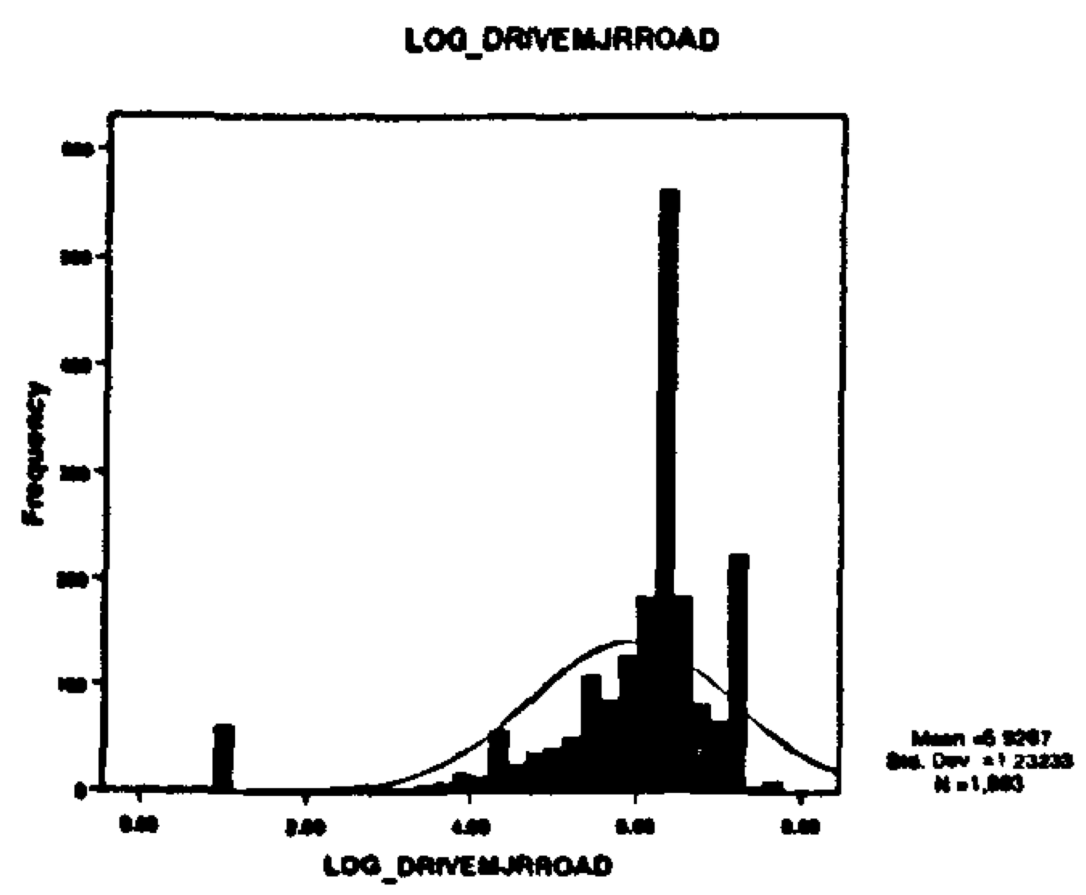



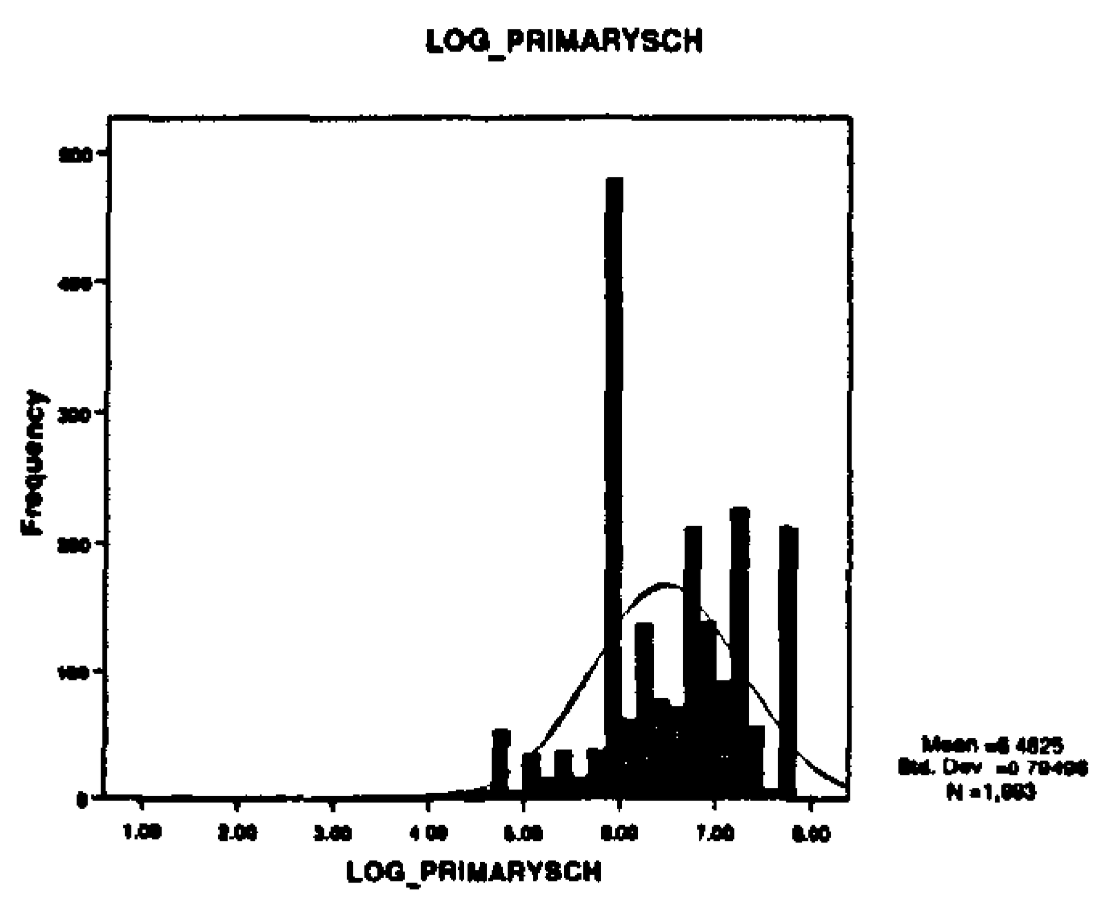



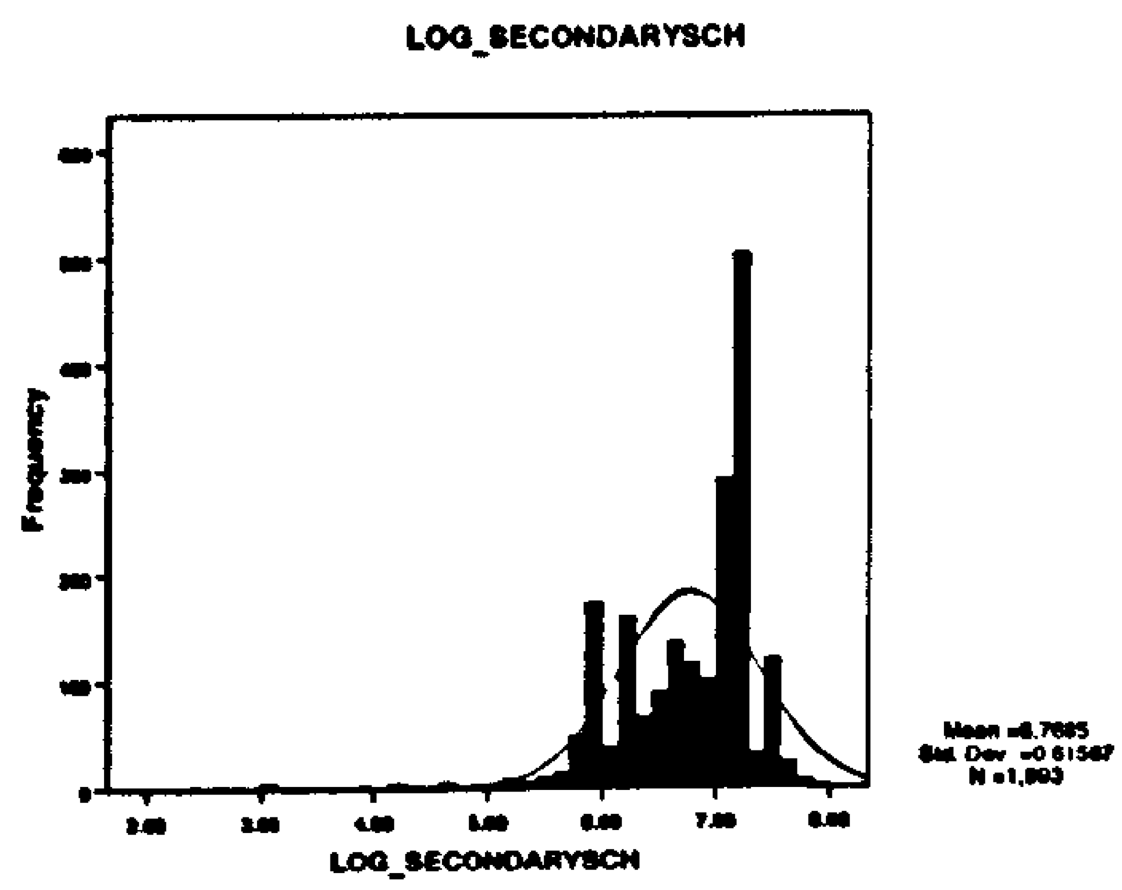



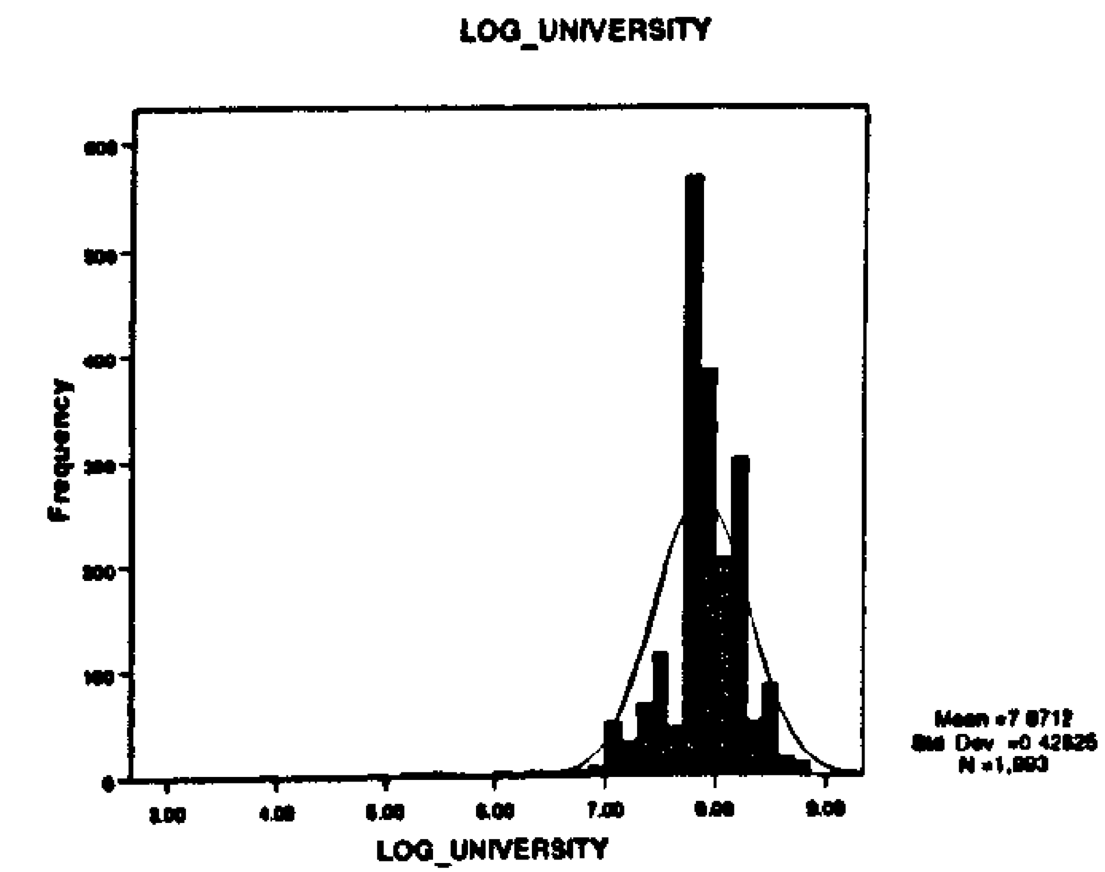



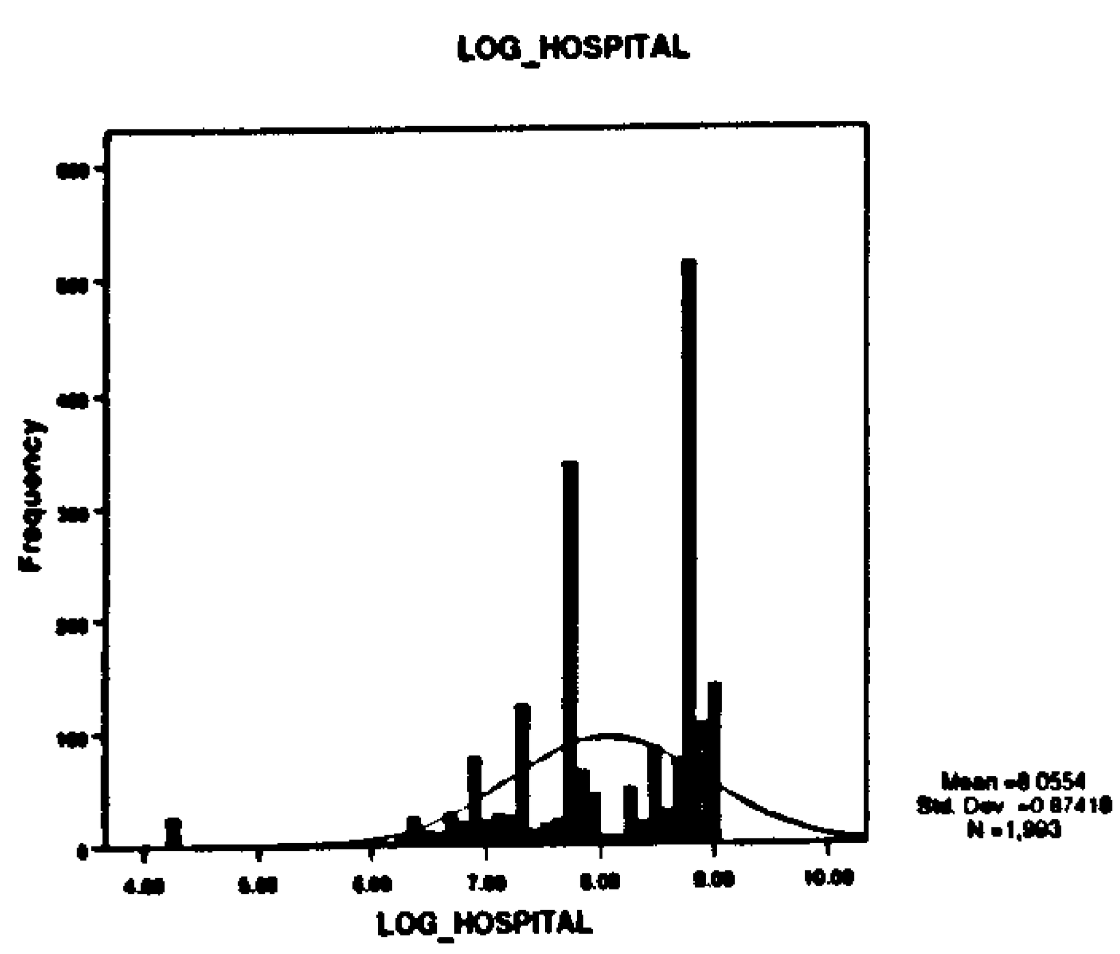



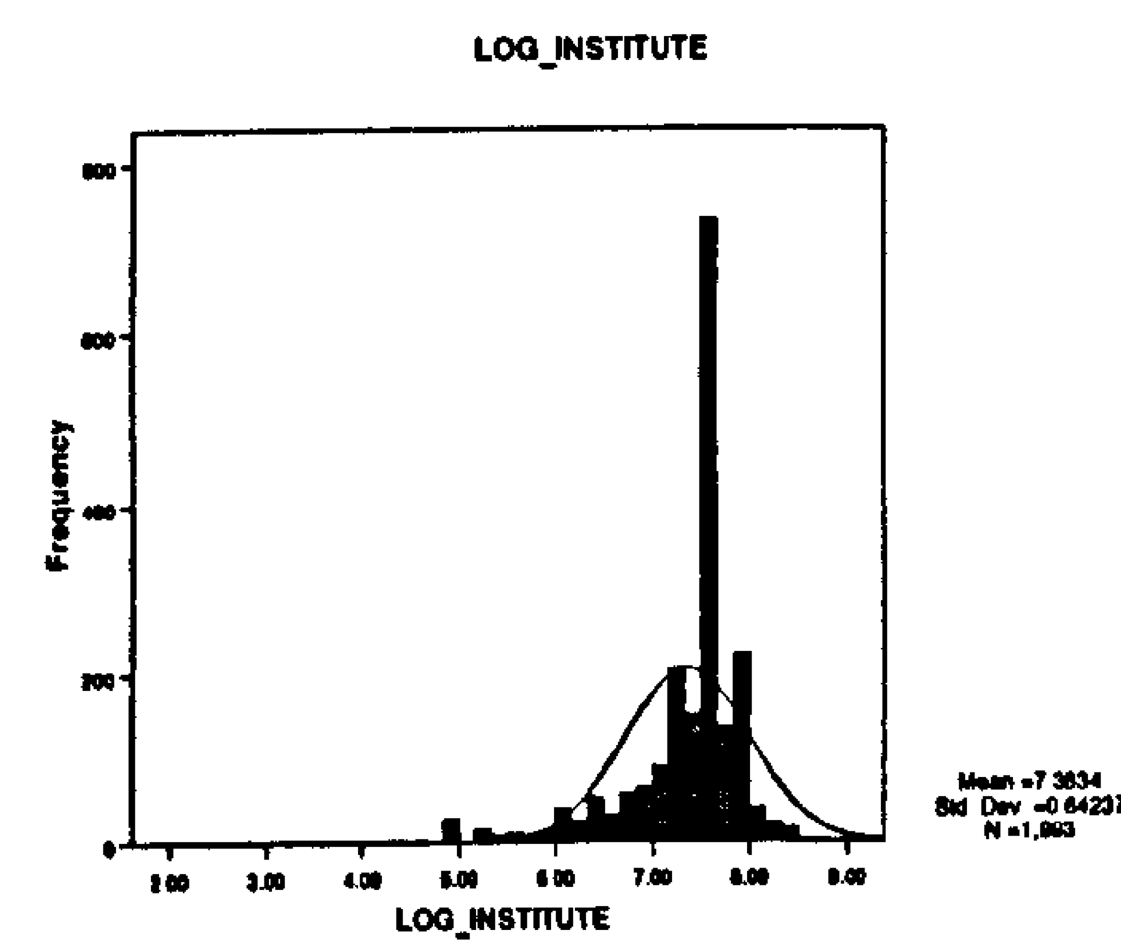



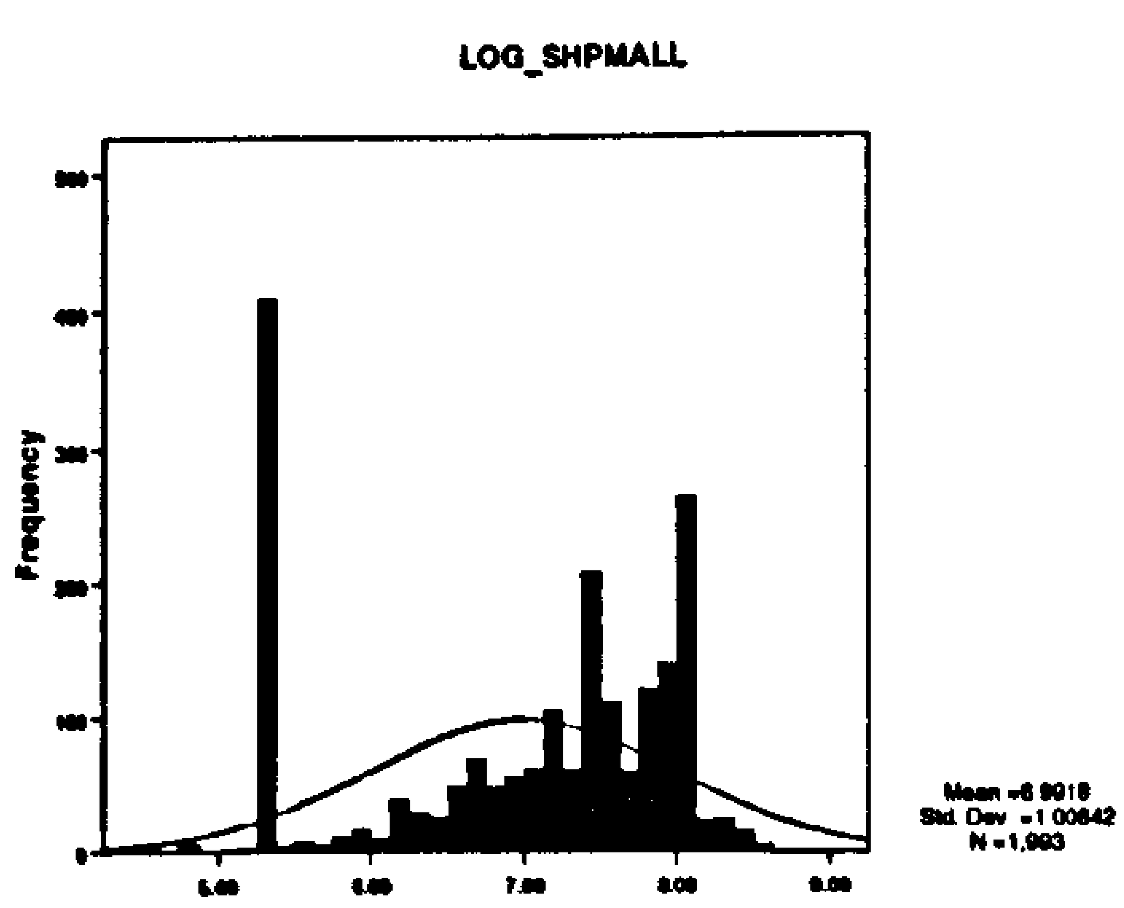
## Appendix D

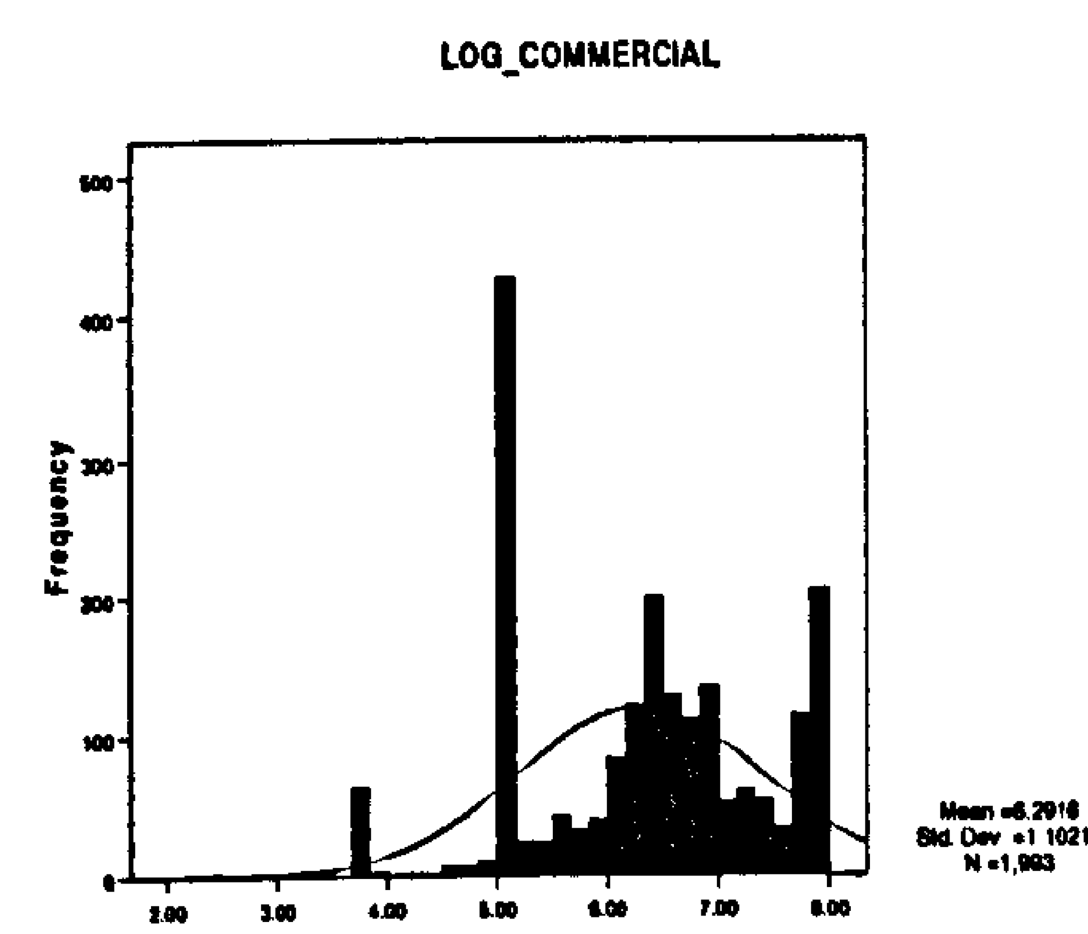

LOG_SECONDARYSCH
Frequency
LOG_SECONDARYSCH
Mean =6.7685
Std. Dev =0.61567
N =1,993

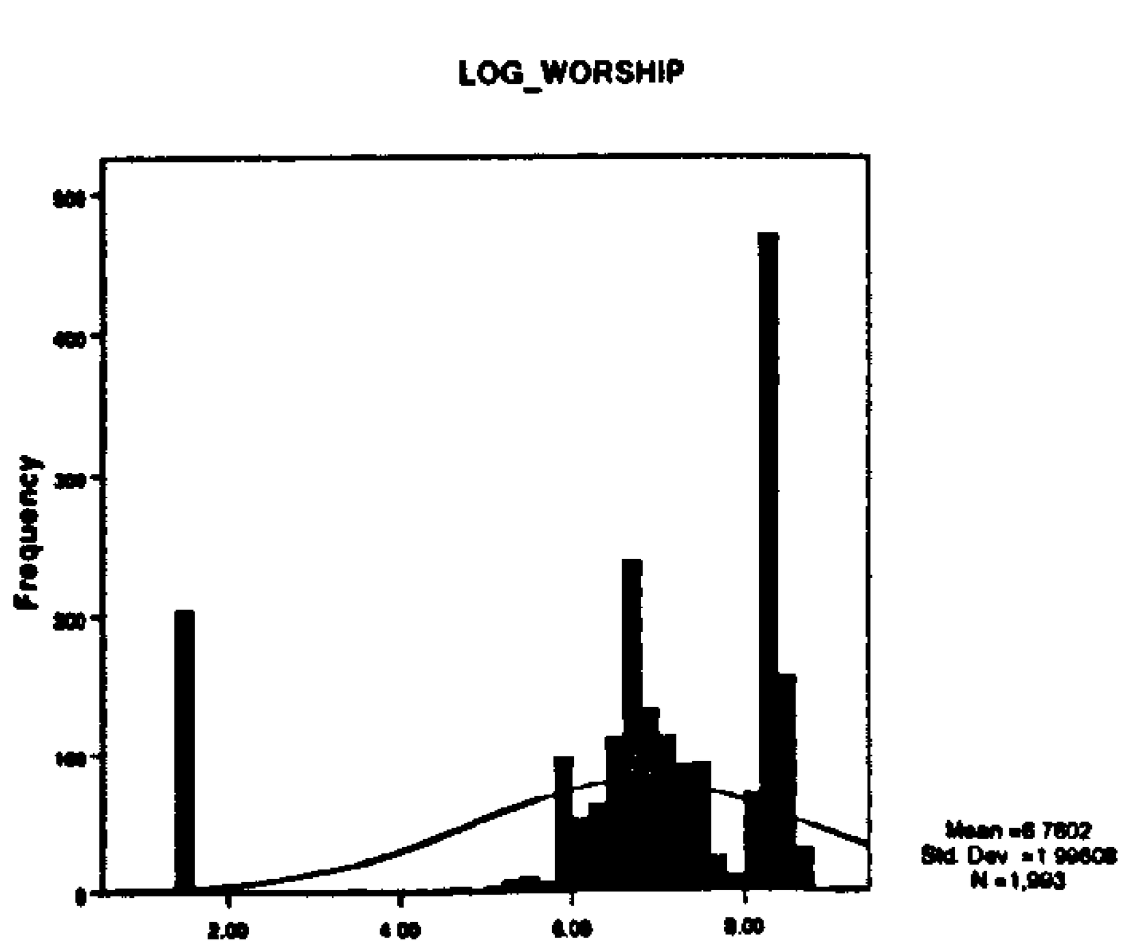

LOG_UNIVERSITY
Frequency
LOG_UNIVERSITY
Mean =7.8712
Std. Dev =0.42825
N =1,993

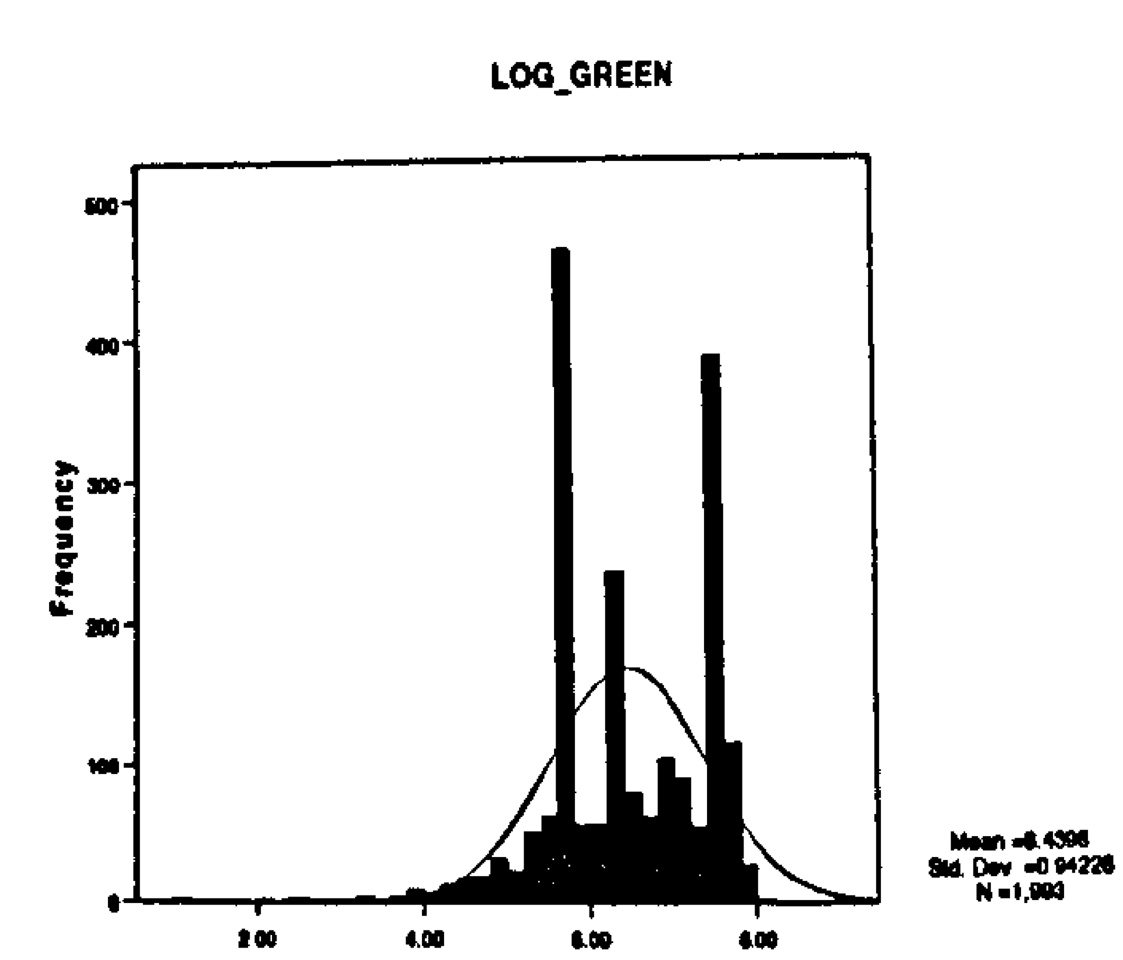

LOG_HOSPITAL
Frequency
LOG_HOSPITAL
Mean =8.0554
Std. Dev =0.87418
N =1,993


LOG_INSTITUTE
Frequency
LOG_INSTITUTE
Mean =7.3834
Std. Dev =0.64237
N =1,993

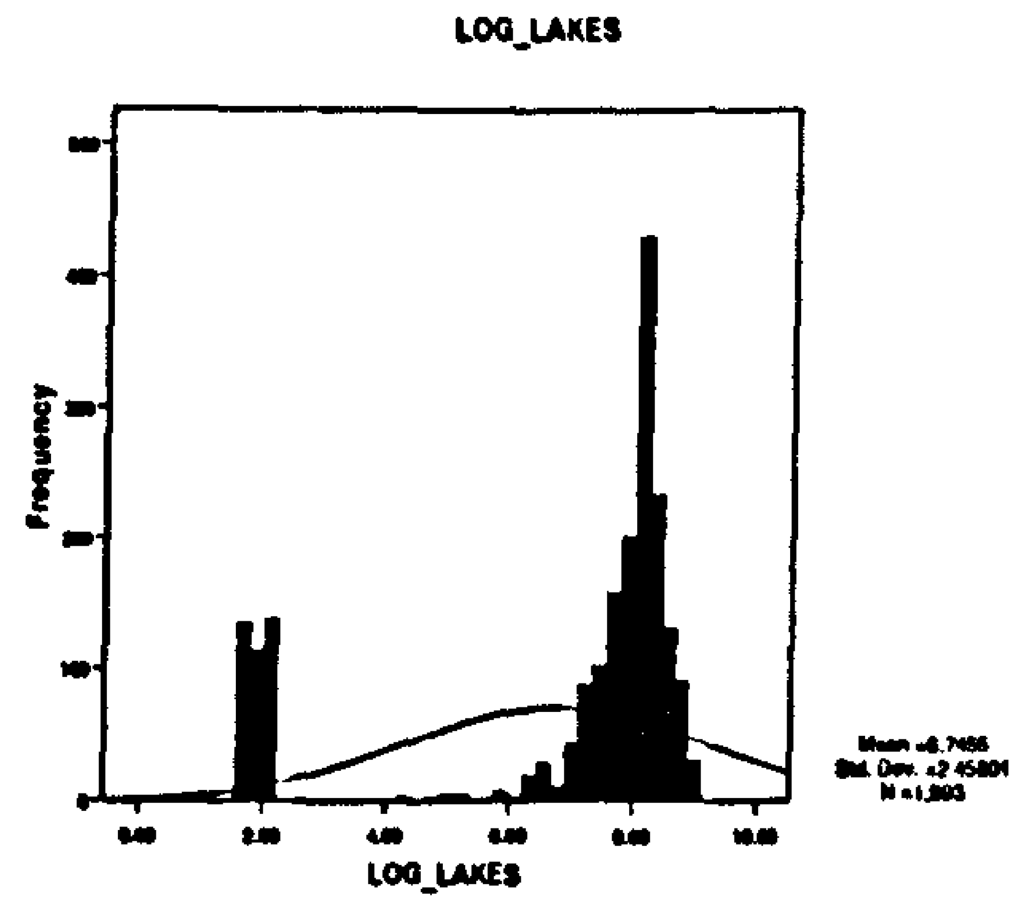

LOG_SHPMALL
Frequency
LOG_SHPMALL
Mean =6.9918
Std. Dev =1.00642
N =1,993


LOG_COMMERCIAL
Frequency
LOG_COMMERCIAL
Mean =6.2918
Std. Dev =1.10214
N =1,993

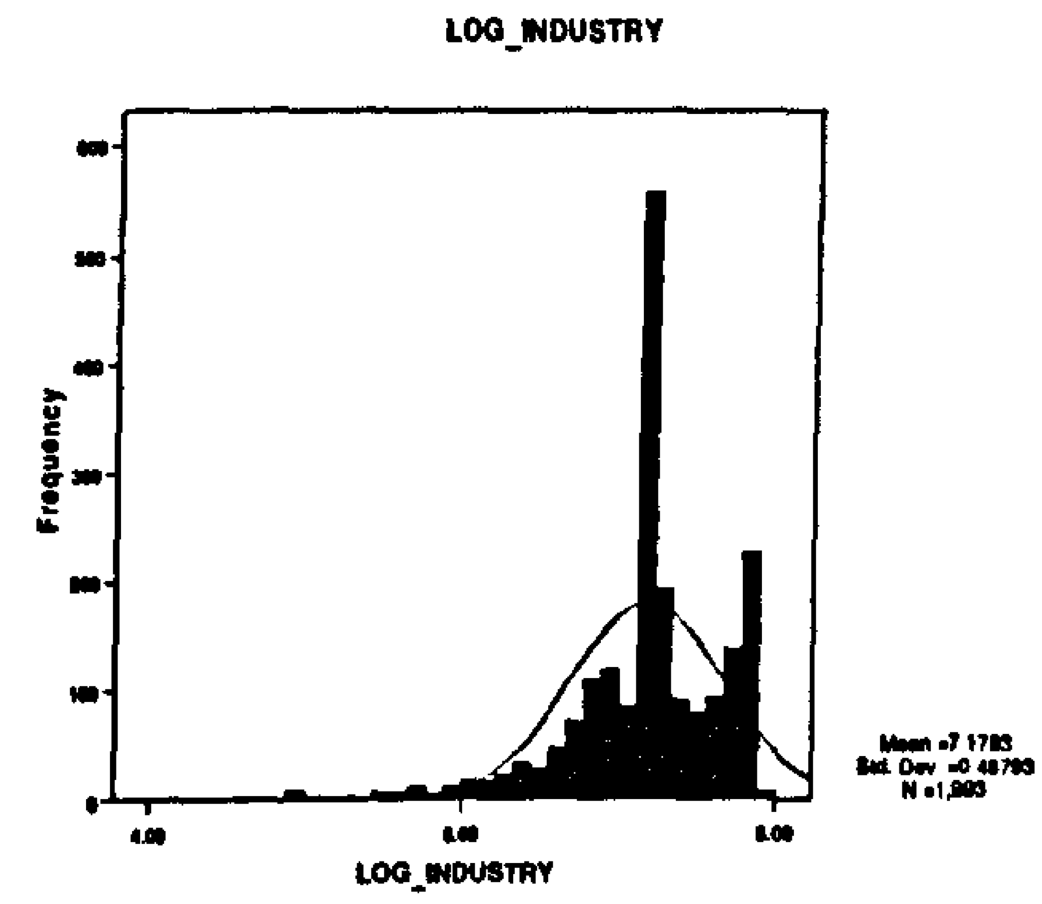

LOG_WORSHIP
Frequency
LOG_WORSHIP
Mean =6.7602
Std. Dev =1.99608
N =1,993


LOG_GREEN
Frequency
LOG_GREEN
Mean =6.4398
Std. Dev =0.94228
N =1,993

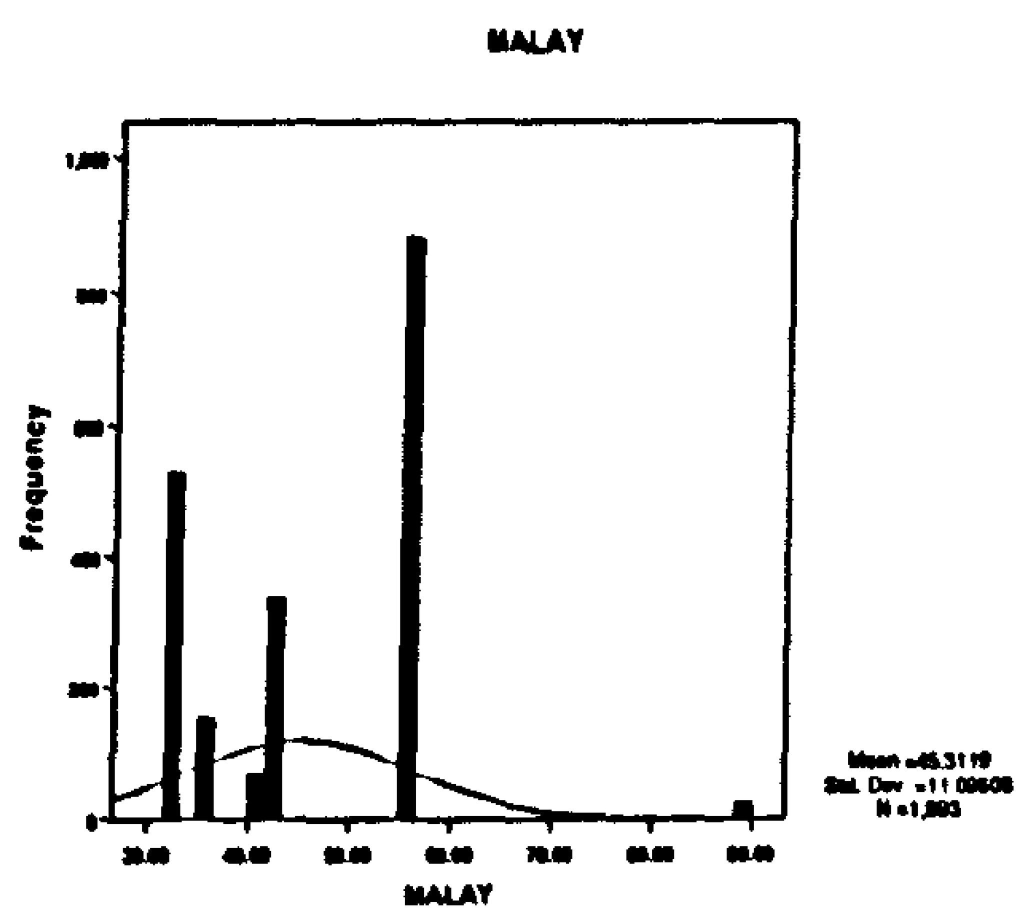
Appendix D



LOG_LAKES
Frequency
LOG_LAKES

LOG_INDUSTRY
Frequency
LOG_INDUSTRY

MALAY
Frequency
MALAY

Appendix E

# Scatter Plots of Detecting Potential Outliers

The potential outliers of dependent and independent variables were detected by using scatter plots that can be performed within SPSS environment. The results of scatter plots analysis are shown below:

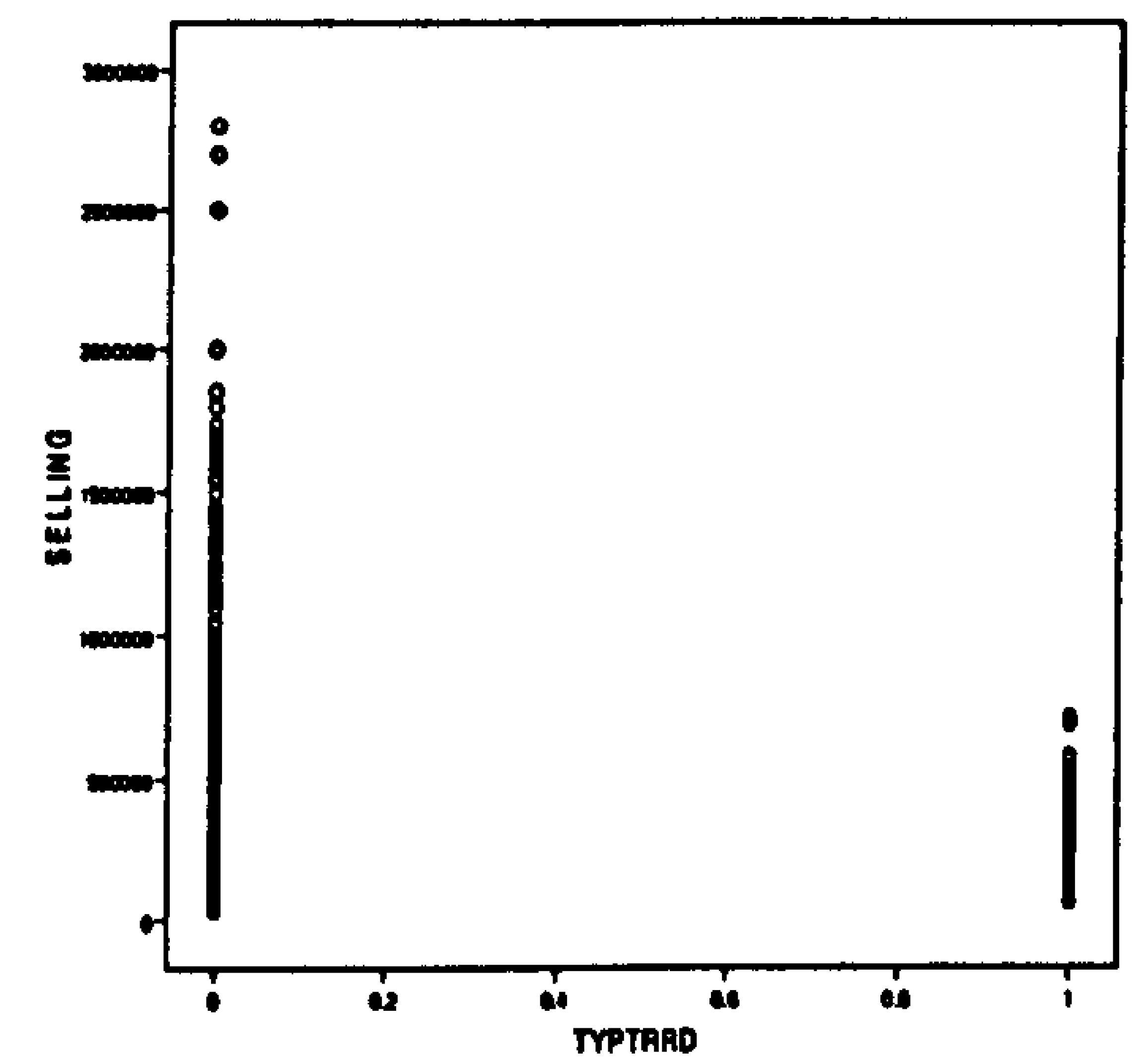



**Figure E.1**: Scatter plot of SELLING and TYPTRRD variables

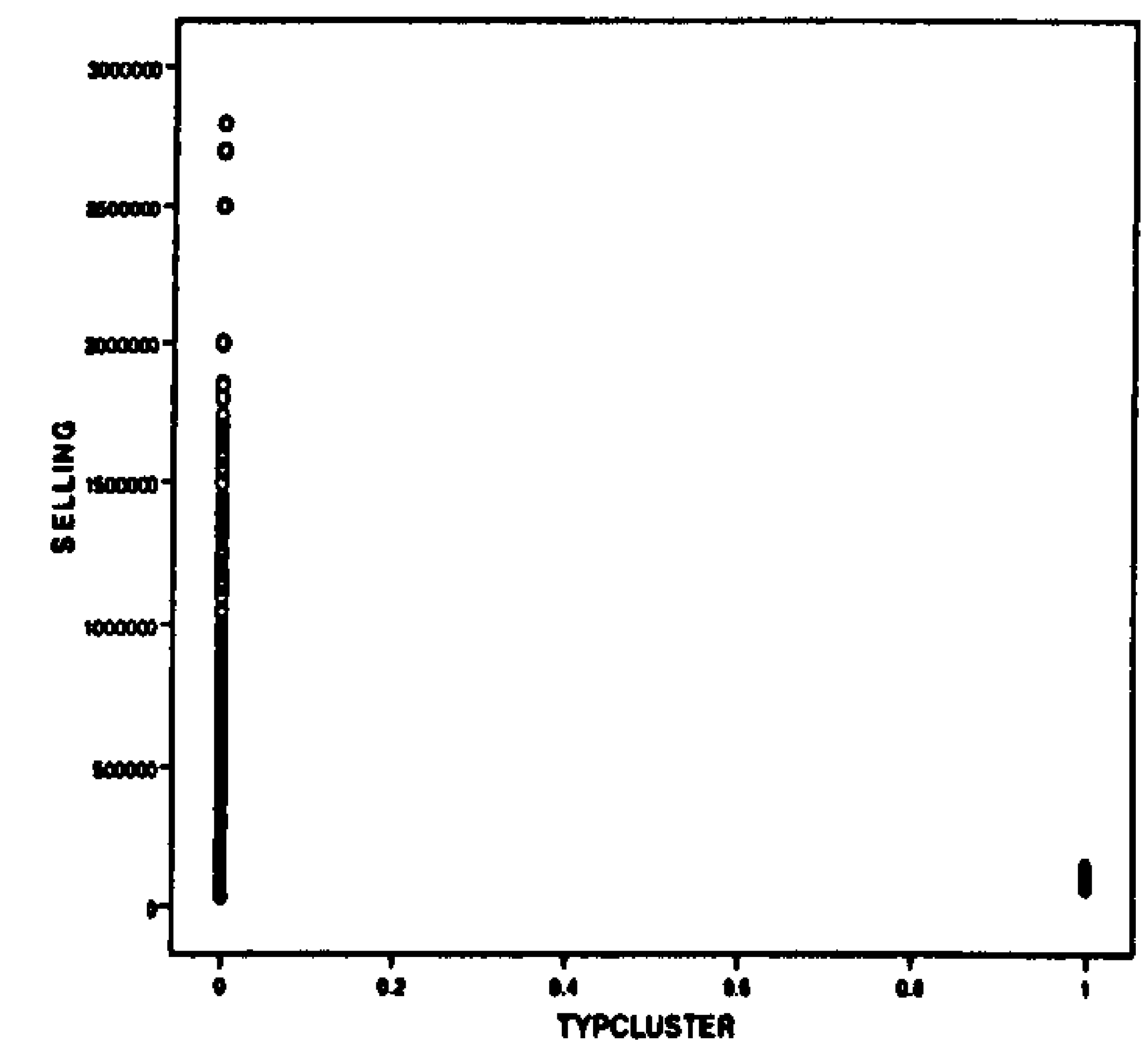



**Figure E.2**: Scatter plot of SELLING and TYPCLUSTER variables

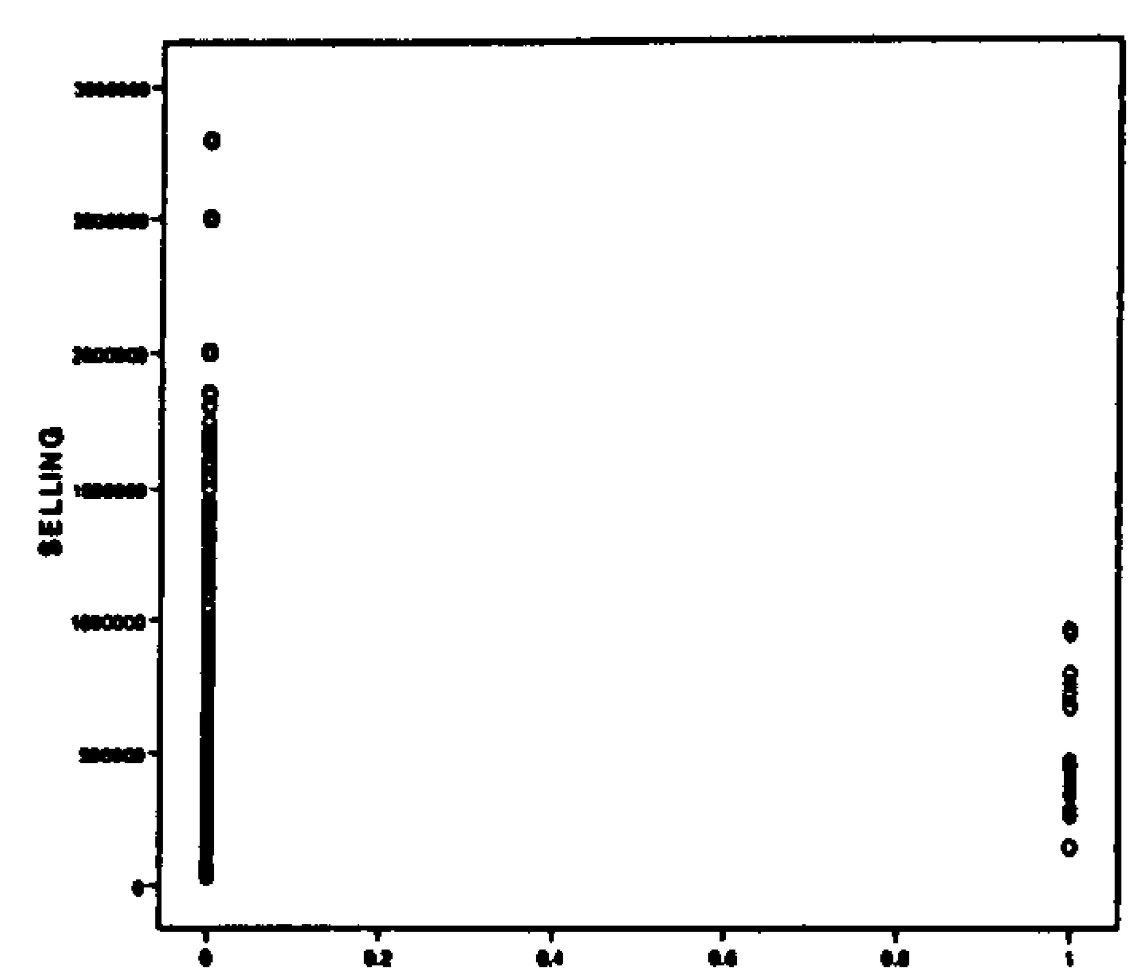



**Figure E.3**: Scatter plot of SELLING and TYPSEMID variables

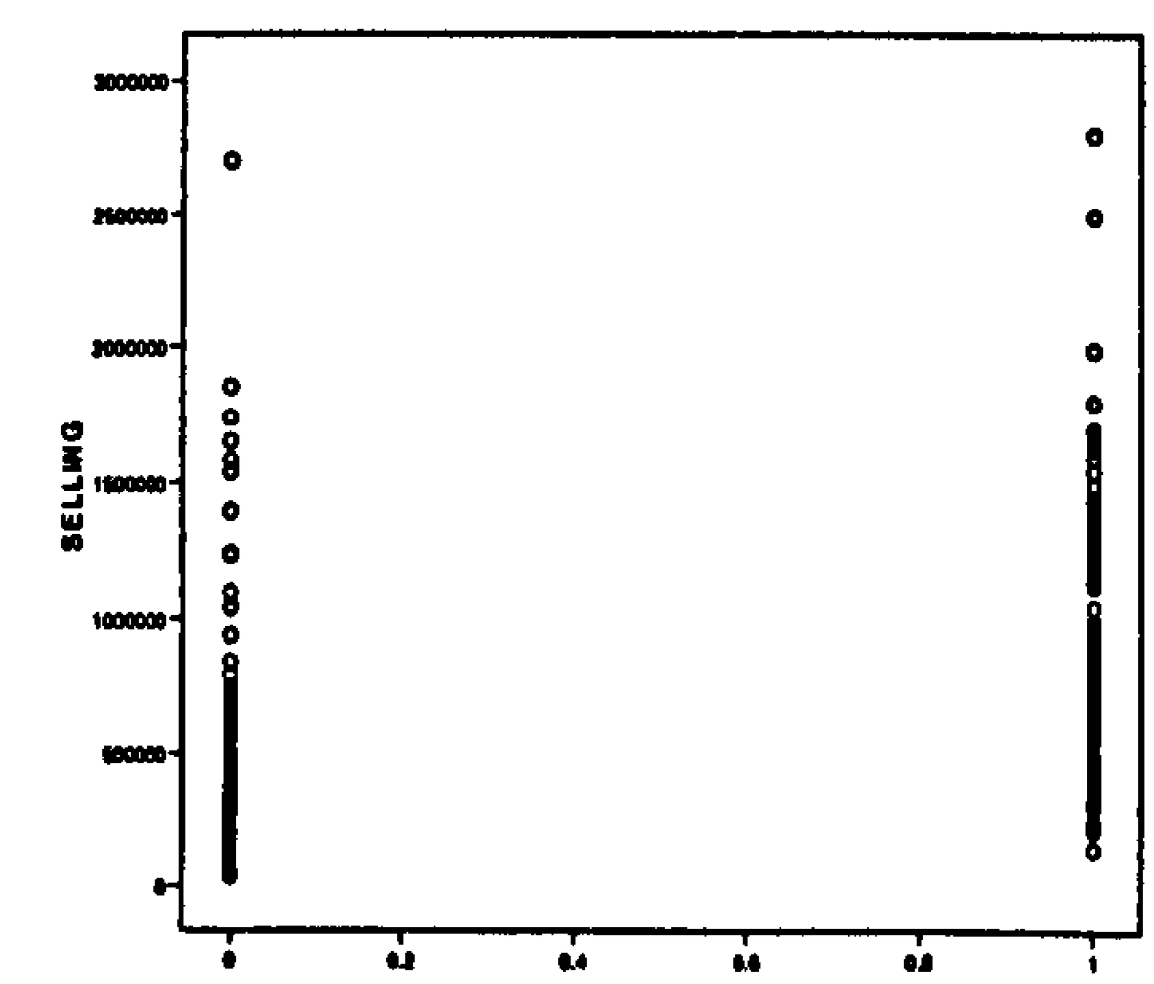



**Figure E.4**: Scatter plot of SELLING and TYPDETCH variables

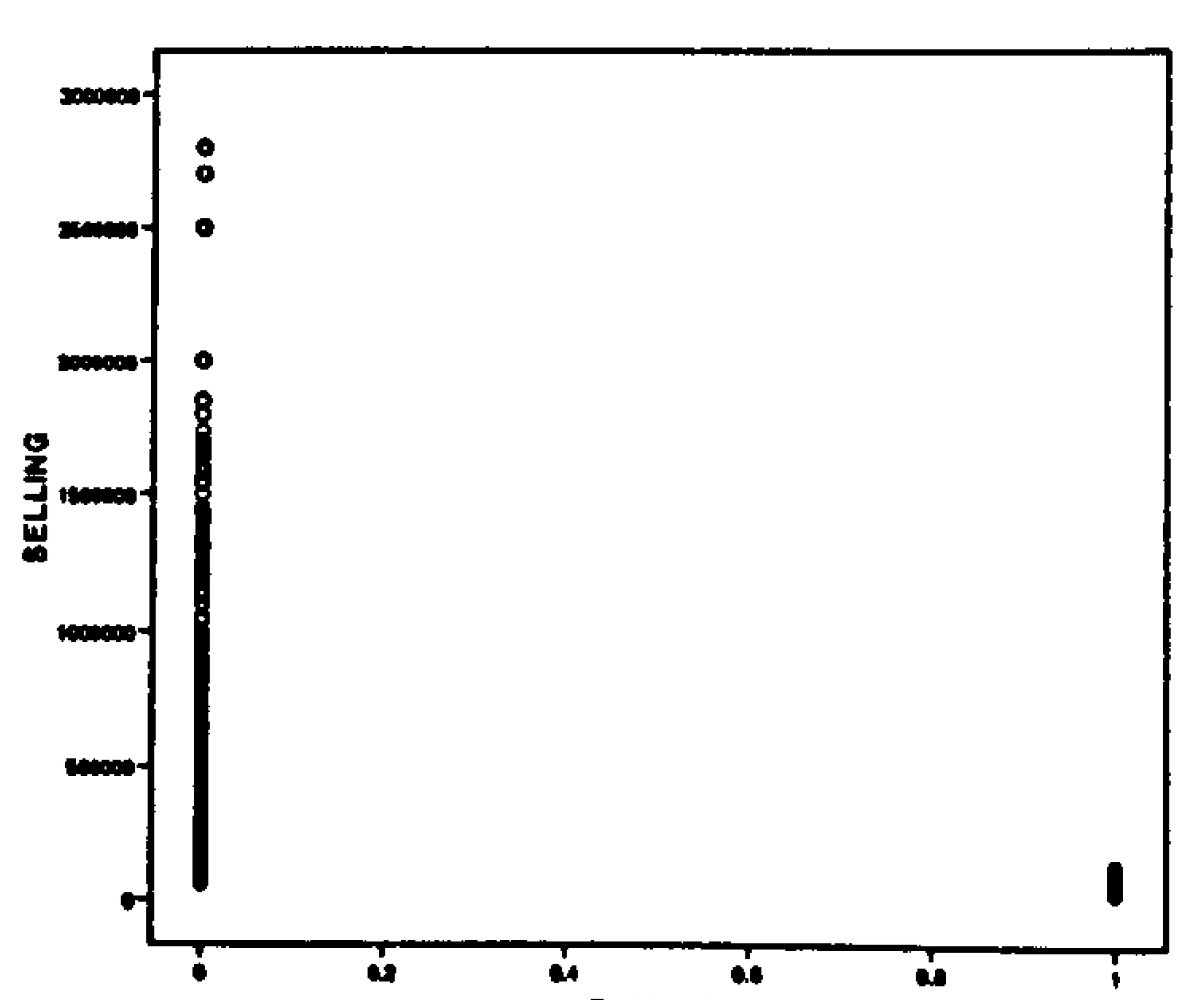



**Figure E.5**: Scatter plot of SELLING and TYPFLAT variables

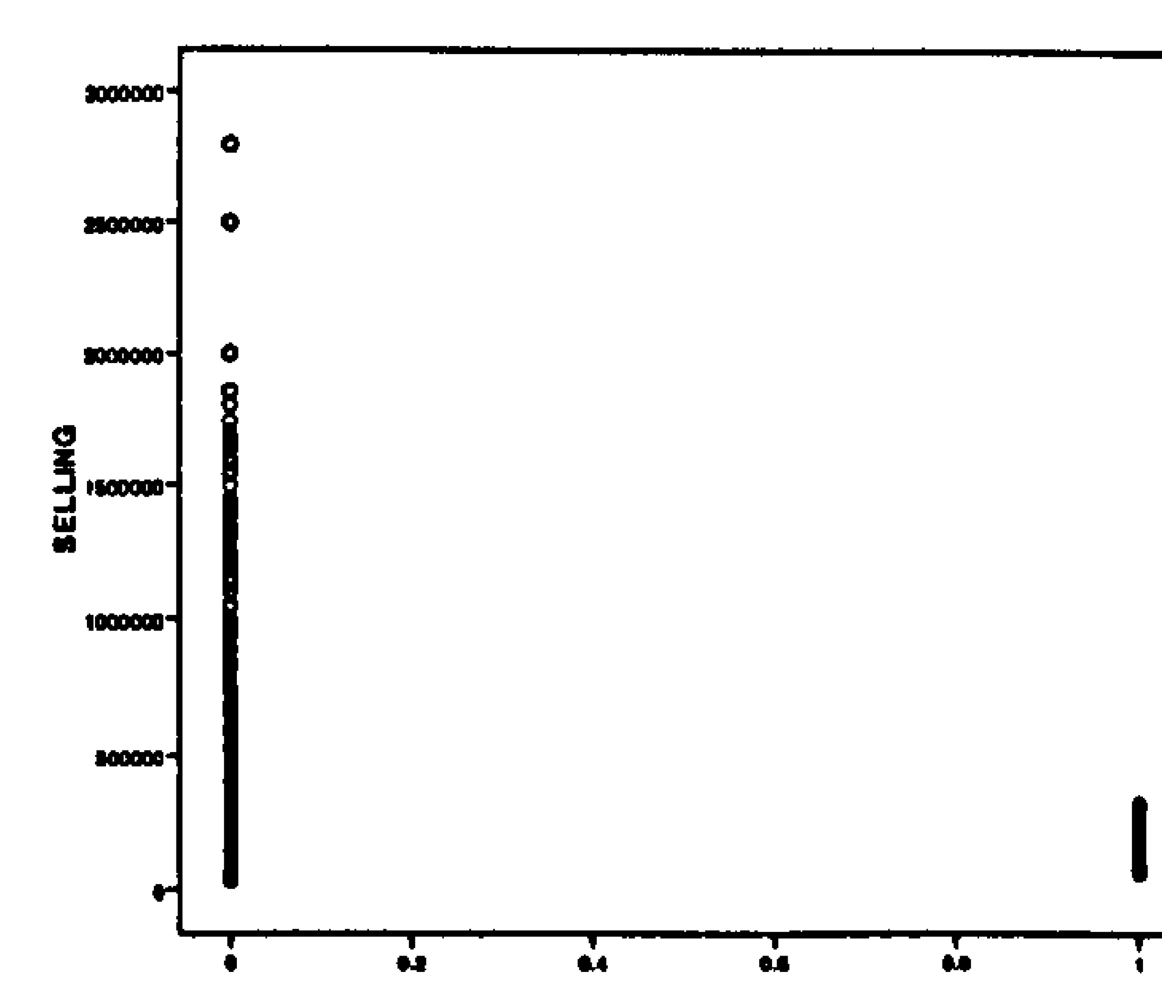



**Figure E.6**: Scatter plot of SELLING and TYPAPT variables

Appendix E

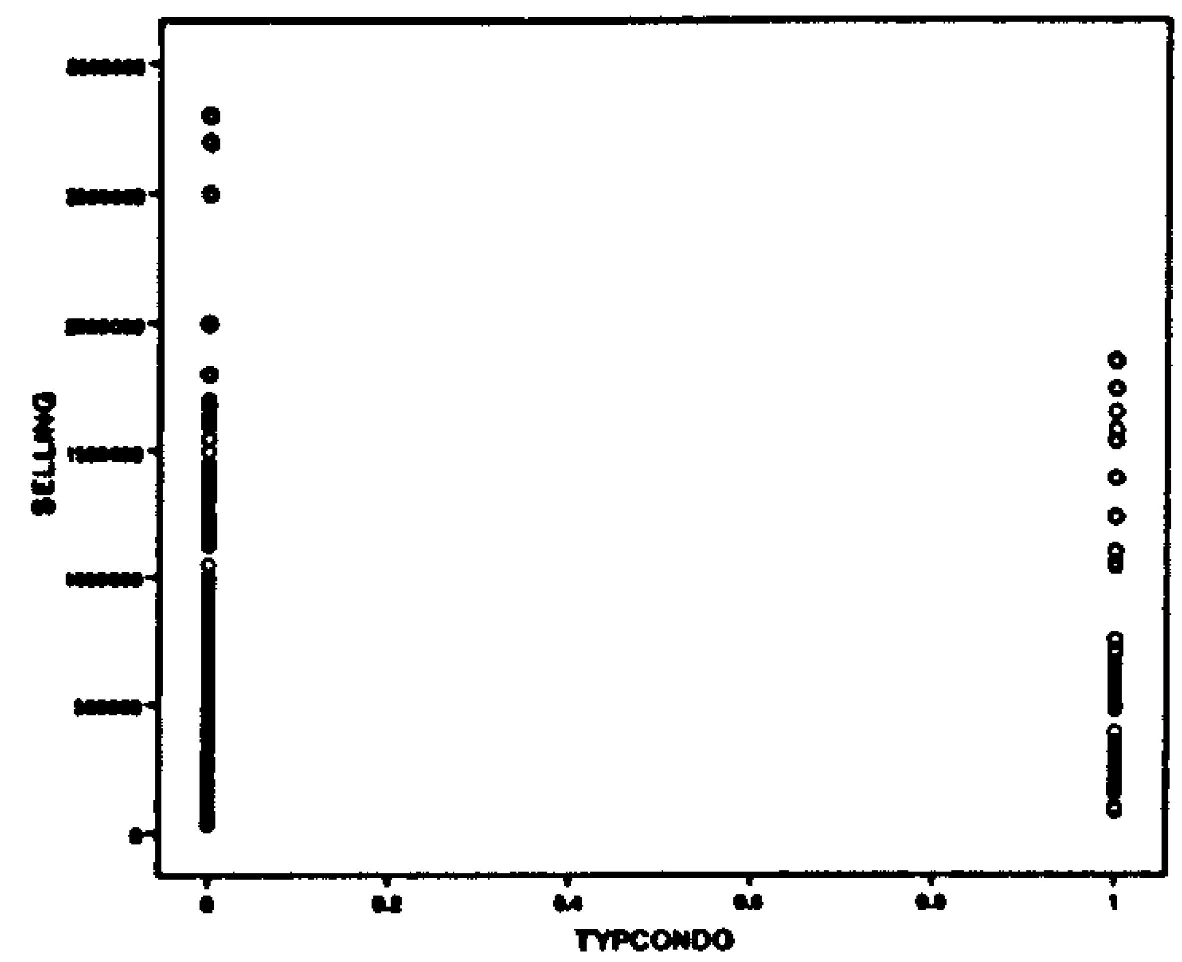



**Figure E.7**: Scatter plot of SELLING and TYPCONDO variables

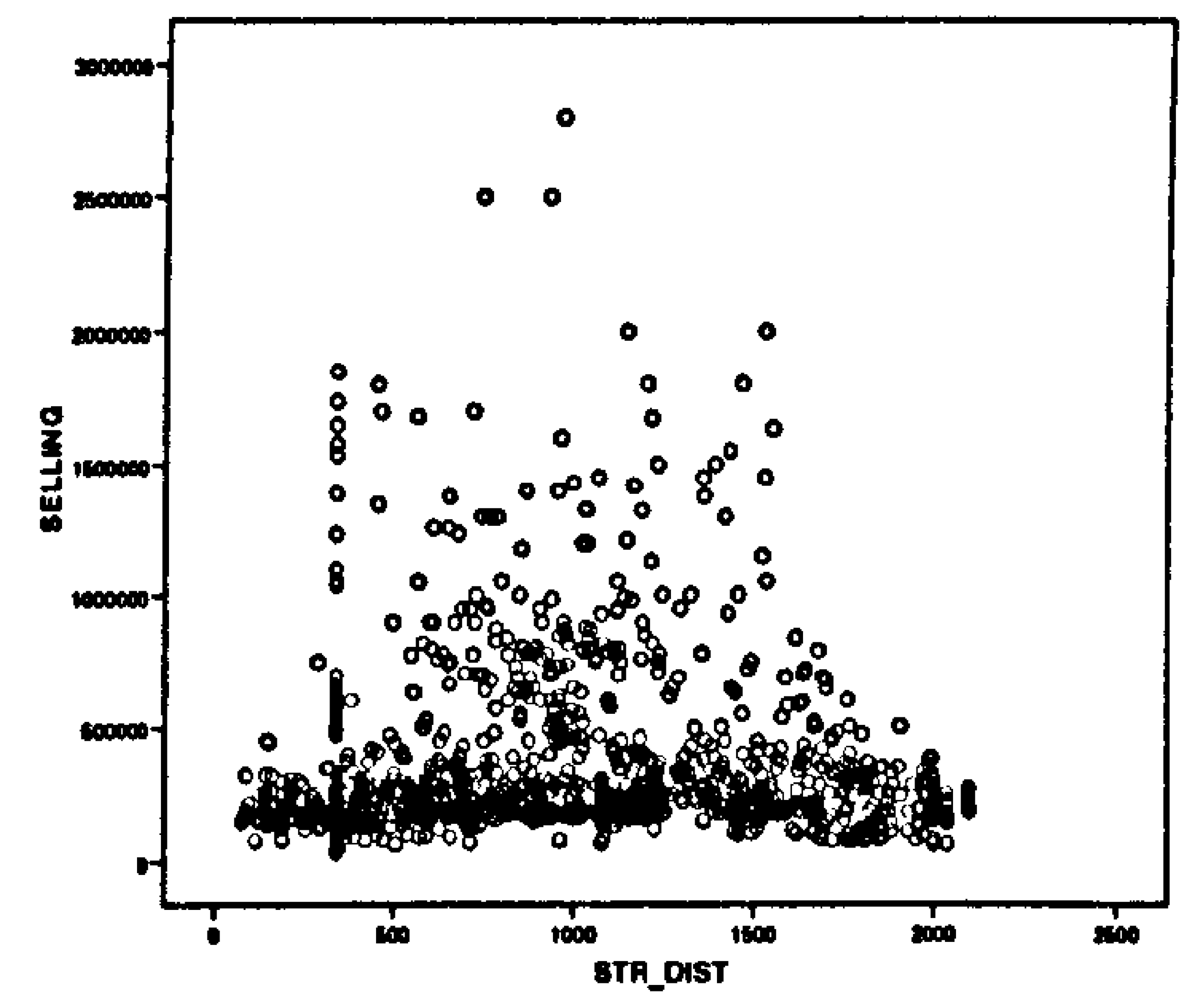



**Figure E.8**: Scatter plot of SELLING and STRDIST variables

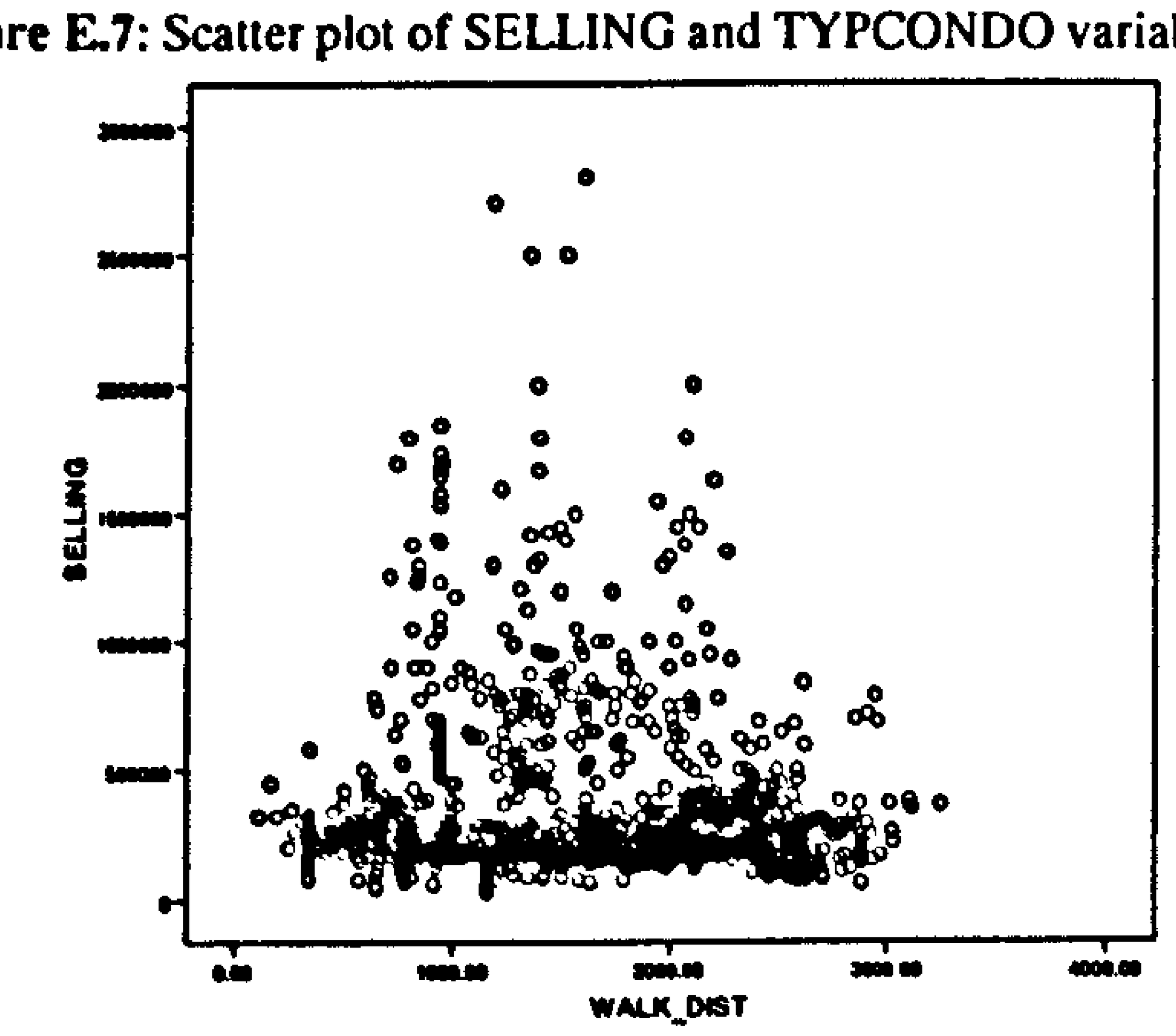



**Figure E.9**: Scatter plot of SELLING and NETDIST variables

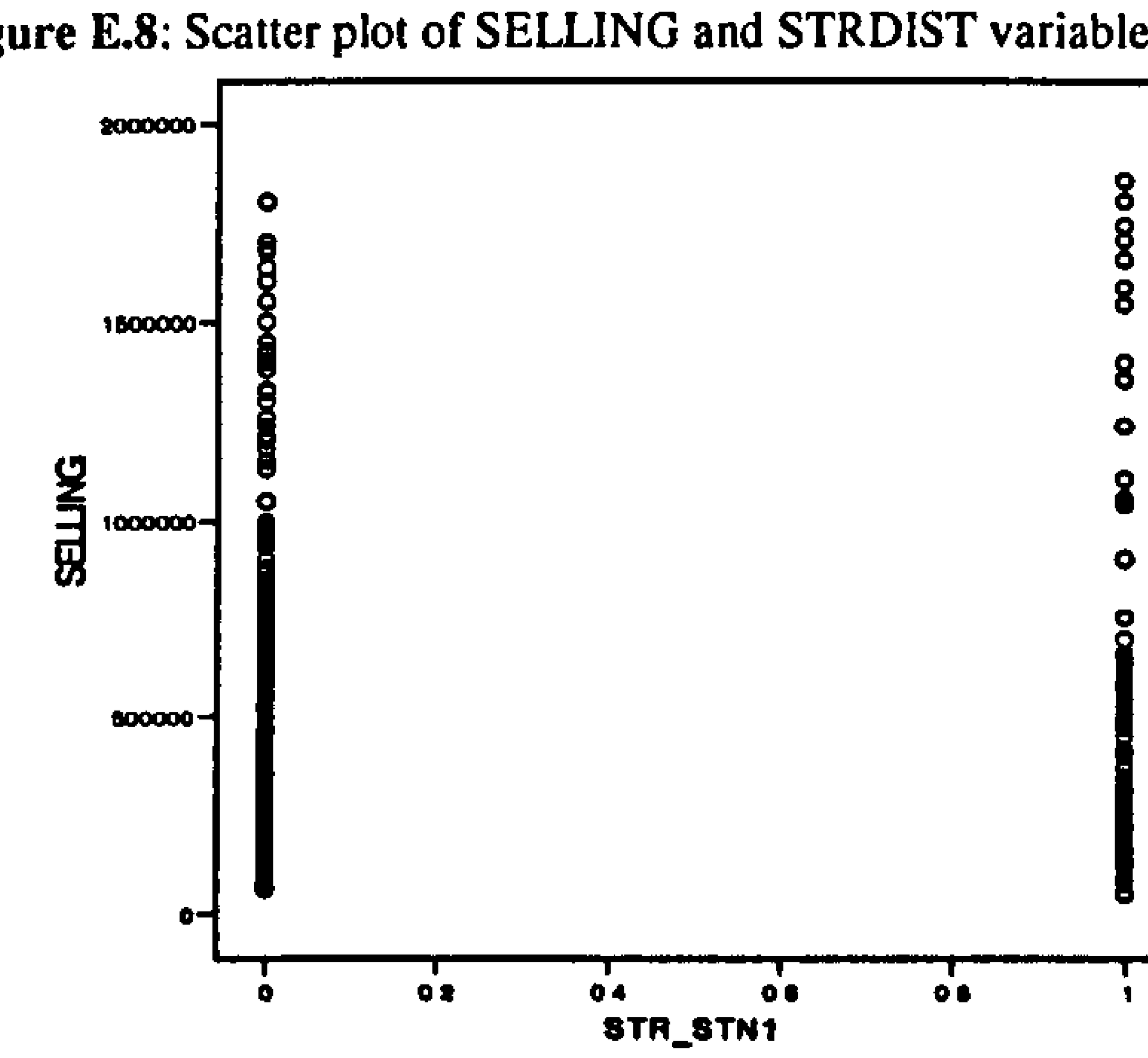



**Figure E.10**: Scatter plot of SELLING and STRSTN1 variables

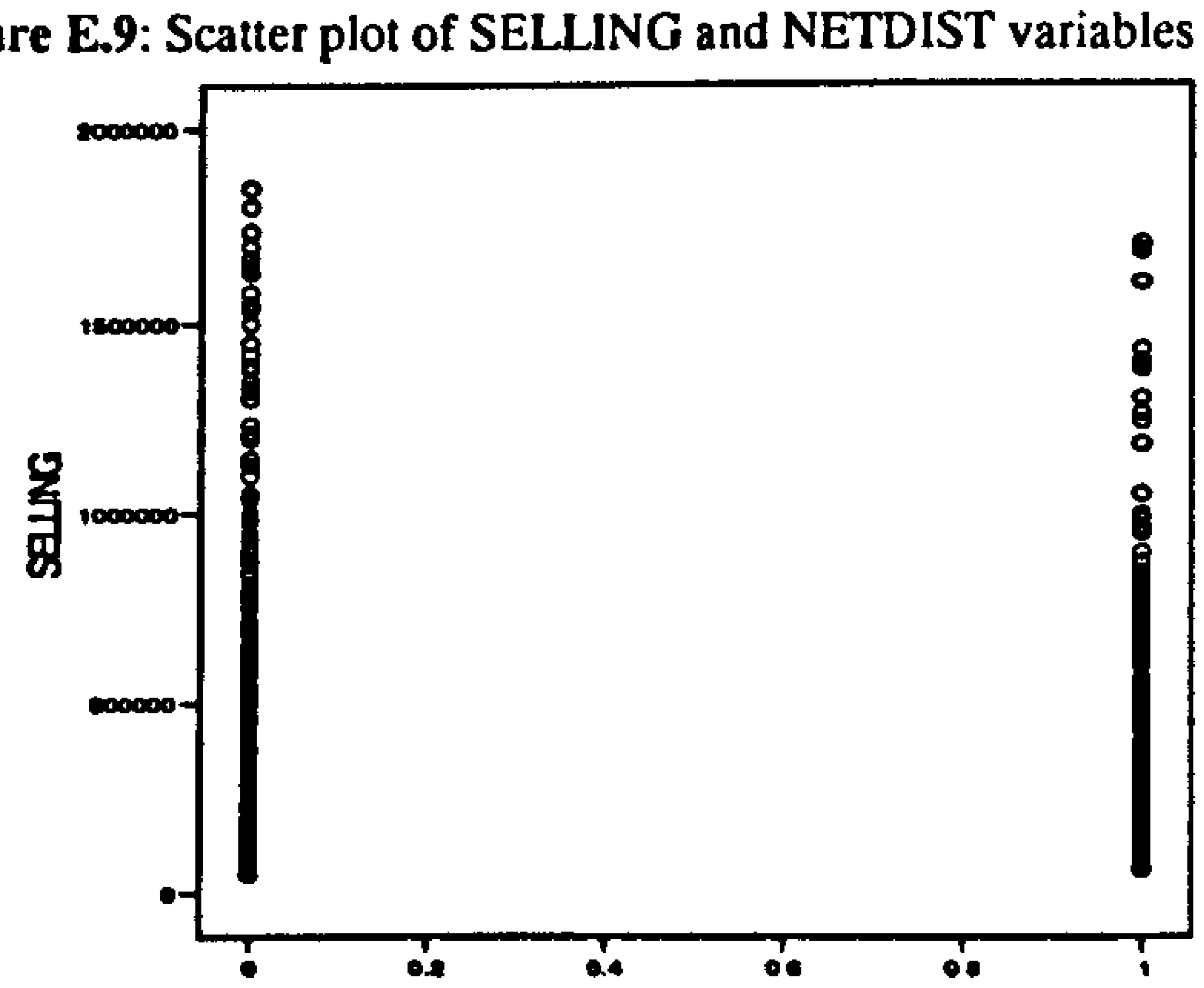



**Figure E.11**: Scatter plot of SELLING and STR_STN2 variables

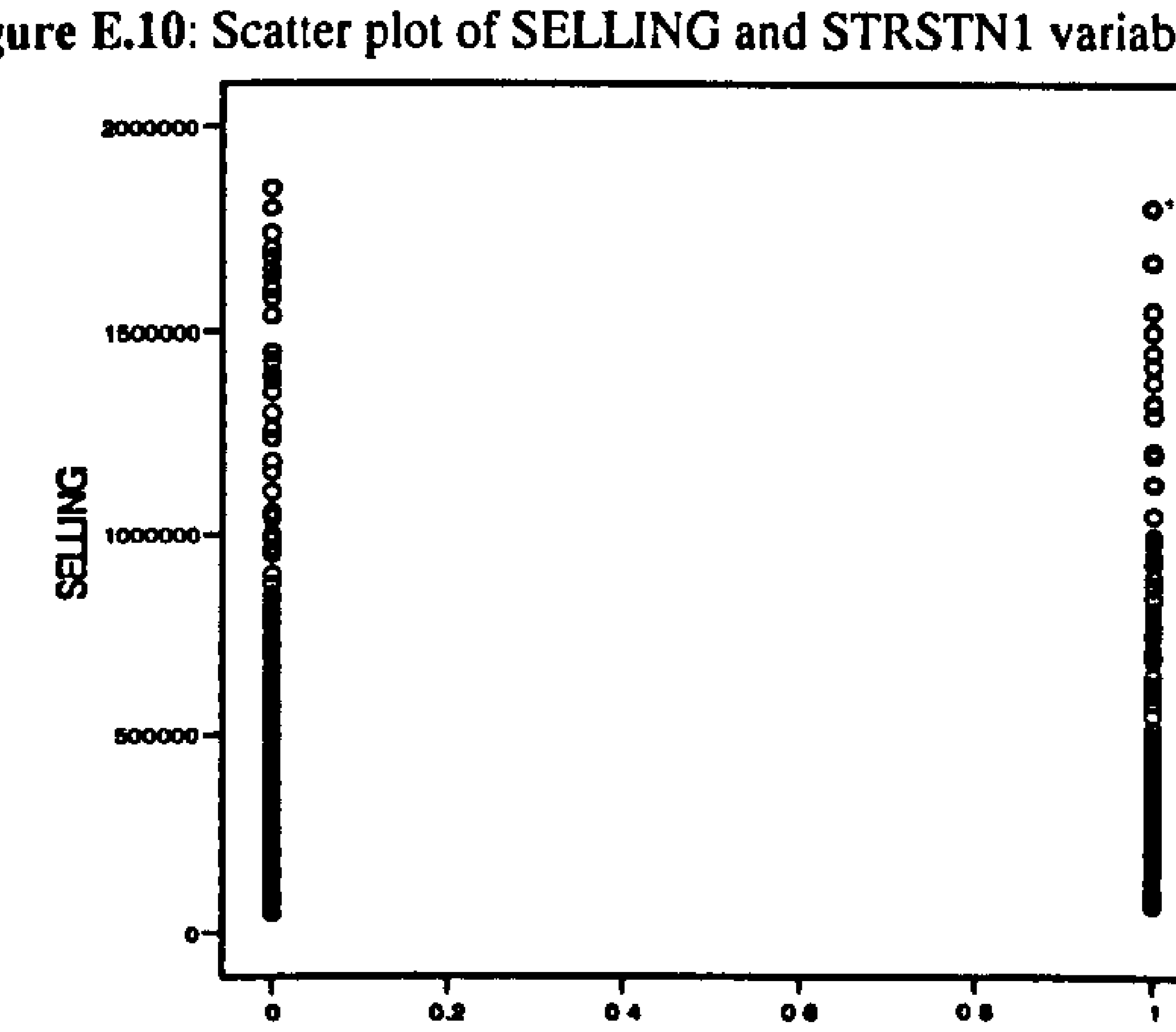



**Figure E.12**: Scatter plot of SELLING and STRSTN3 variables

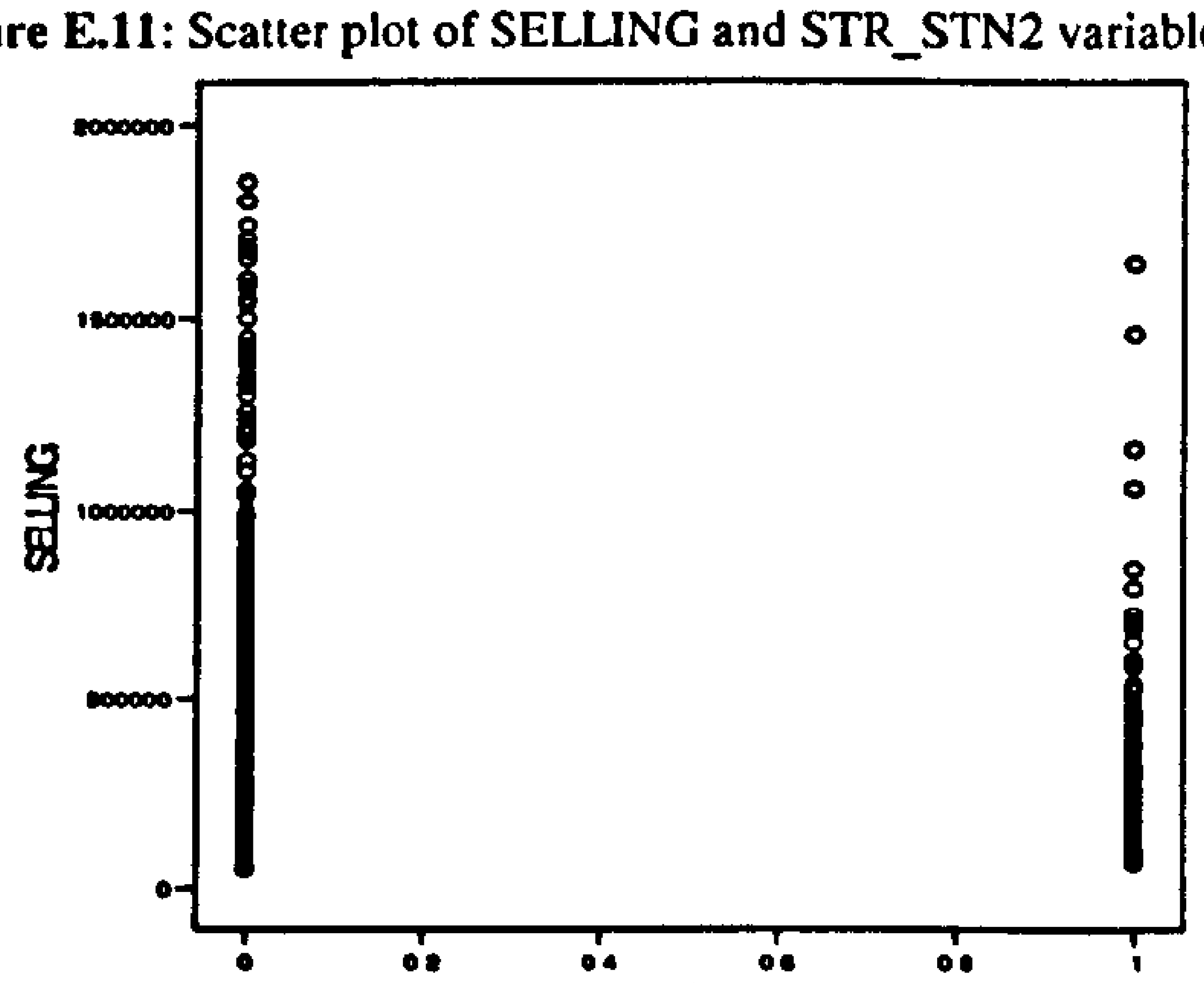



**Figure E.13**: Scatter plot of SELLING and STRSTN4 variables

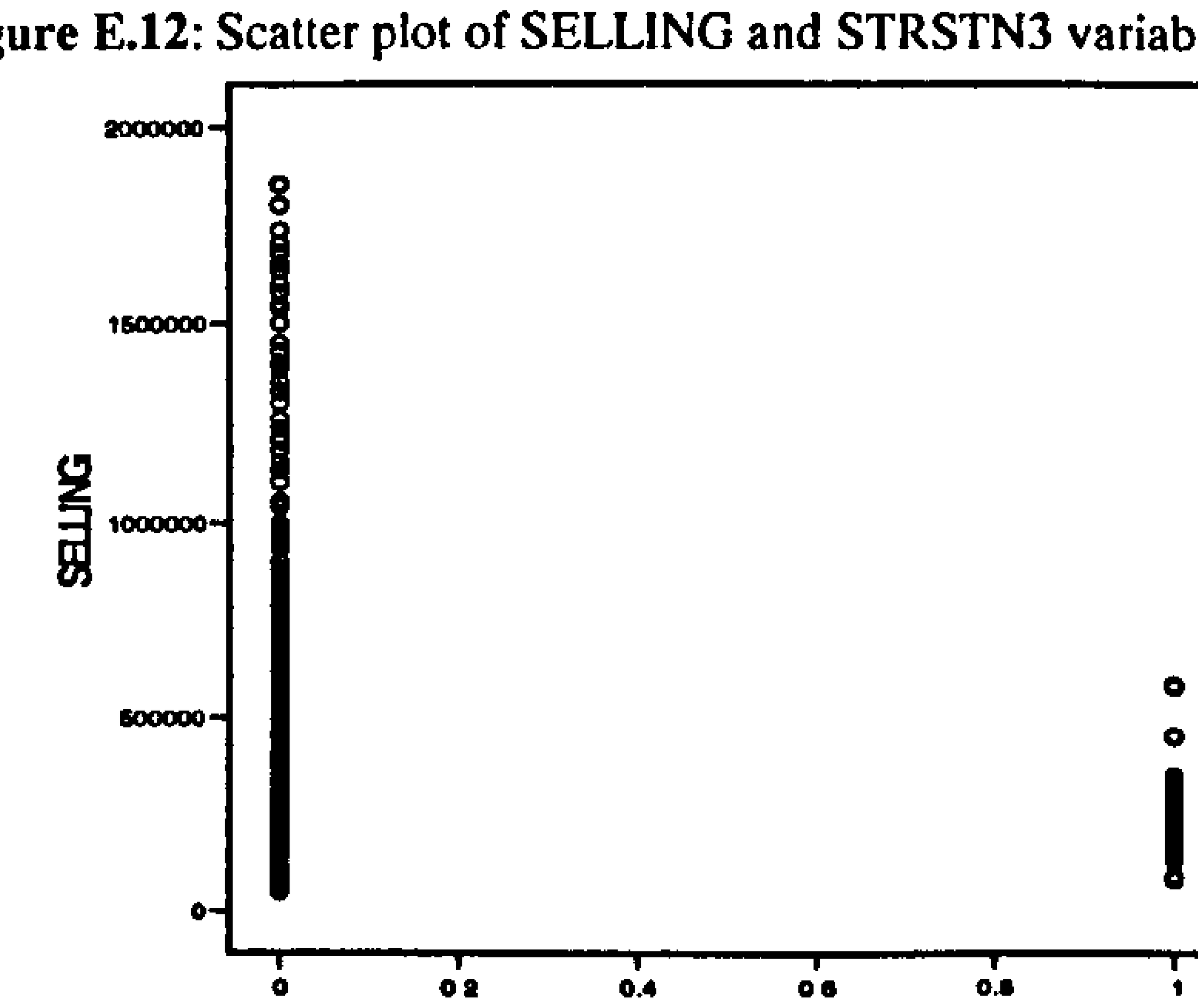



**Figure E.14**: Scatter plot of SELLING and NETSTN1 variables

Appendix E

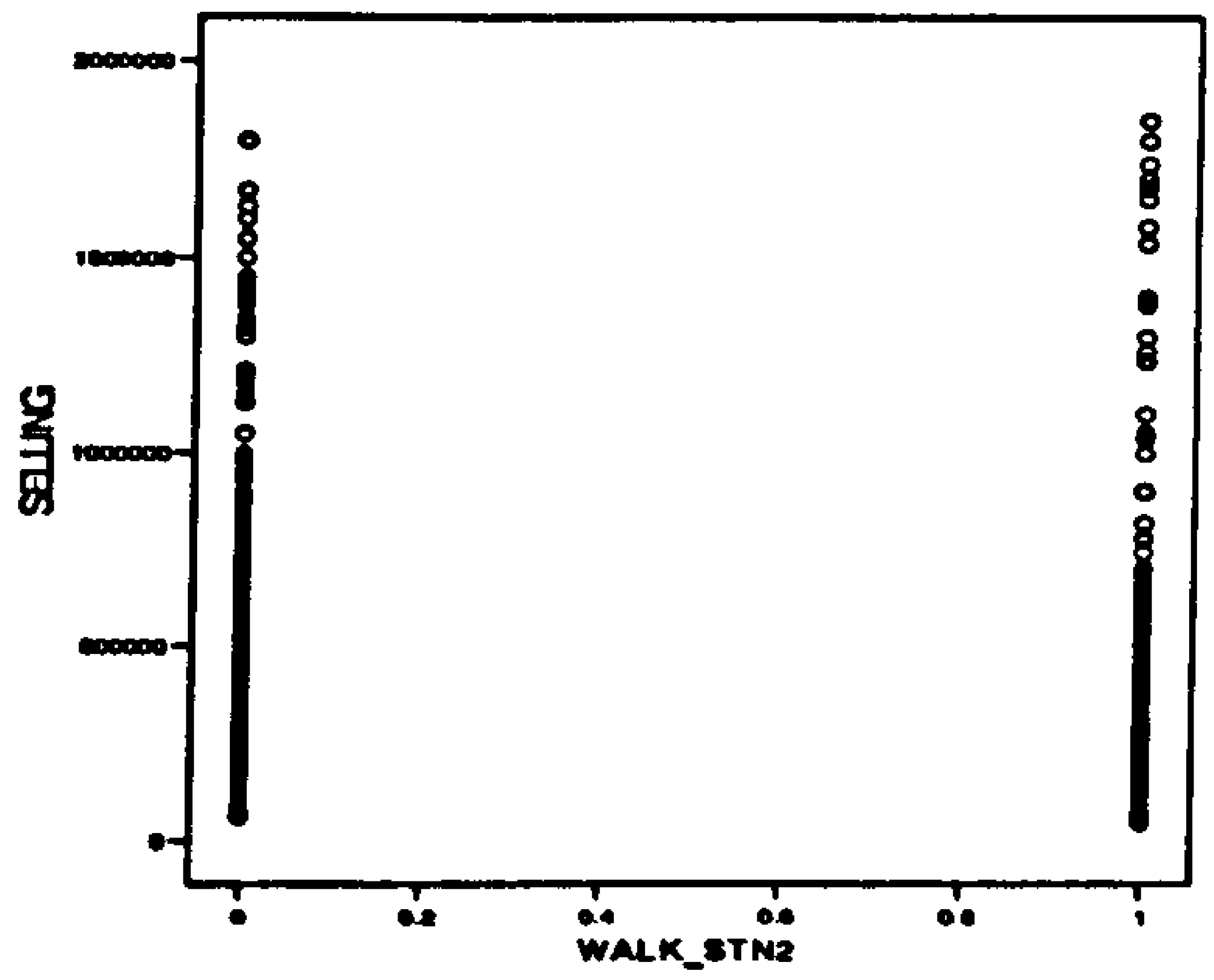



Figure E.15: Scatter plot of SELLING and WALK_STN2 variables

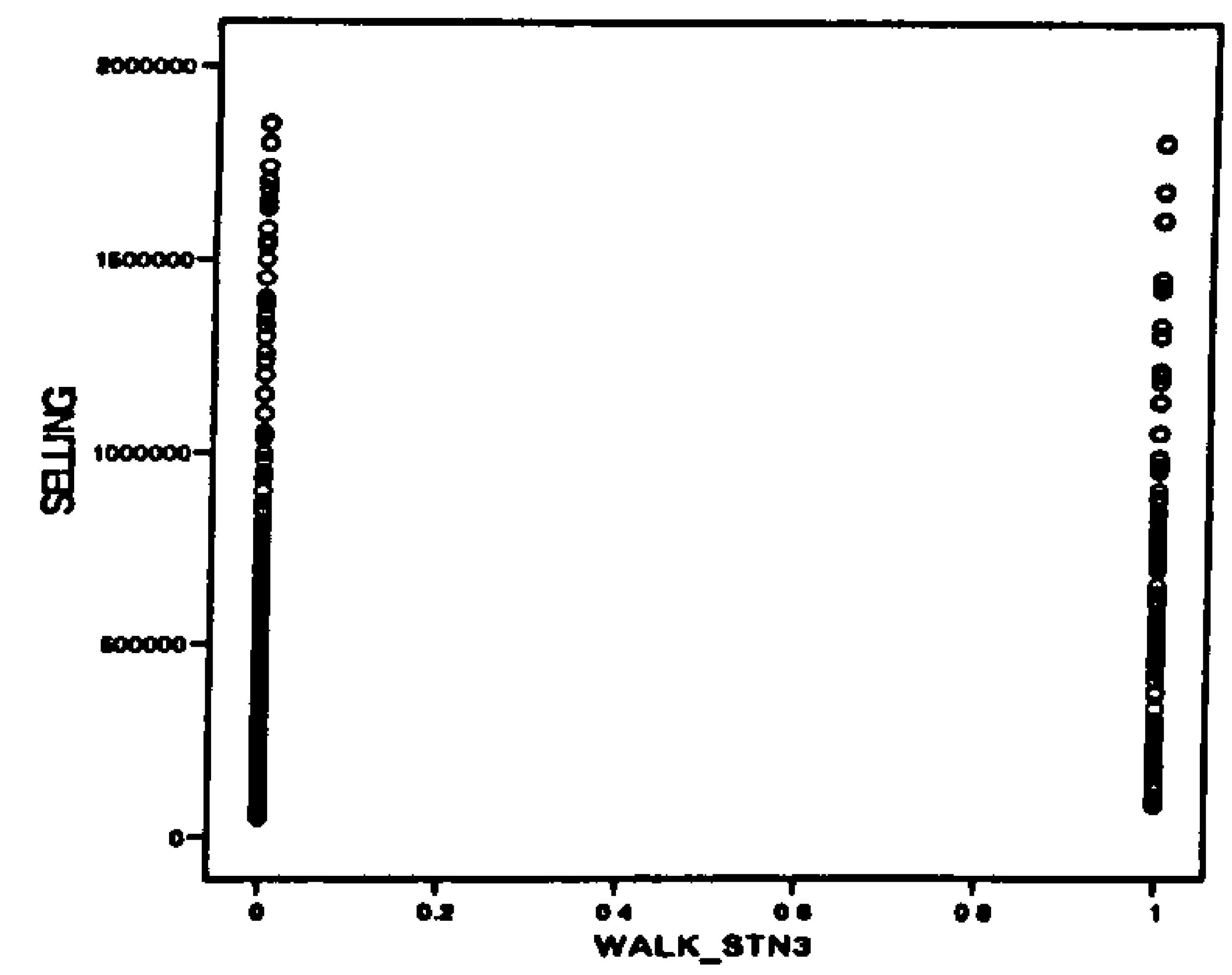



Figure E.16: Scatter plot of SELLING and WALK_STN3 variables

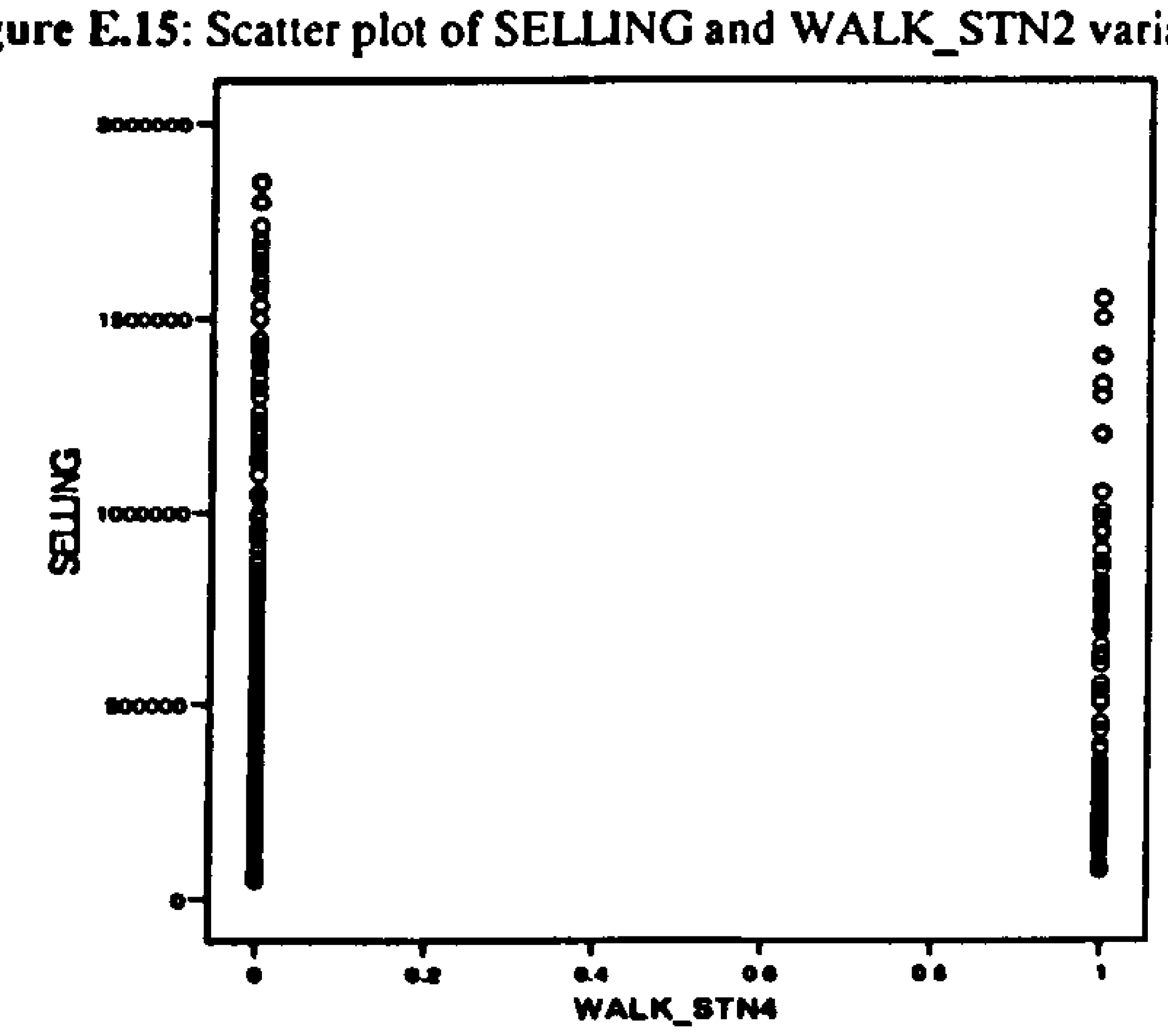



Figure E.17: Scatter plot of SELLING and WALK_STN4 variables

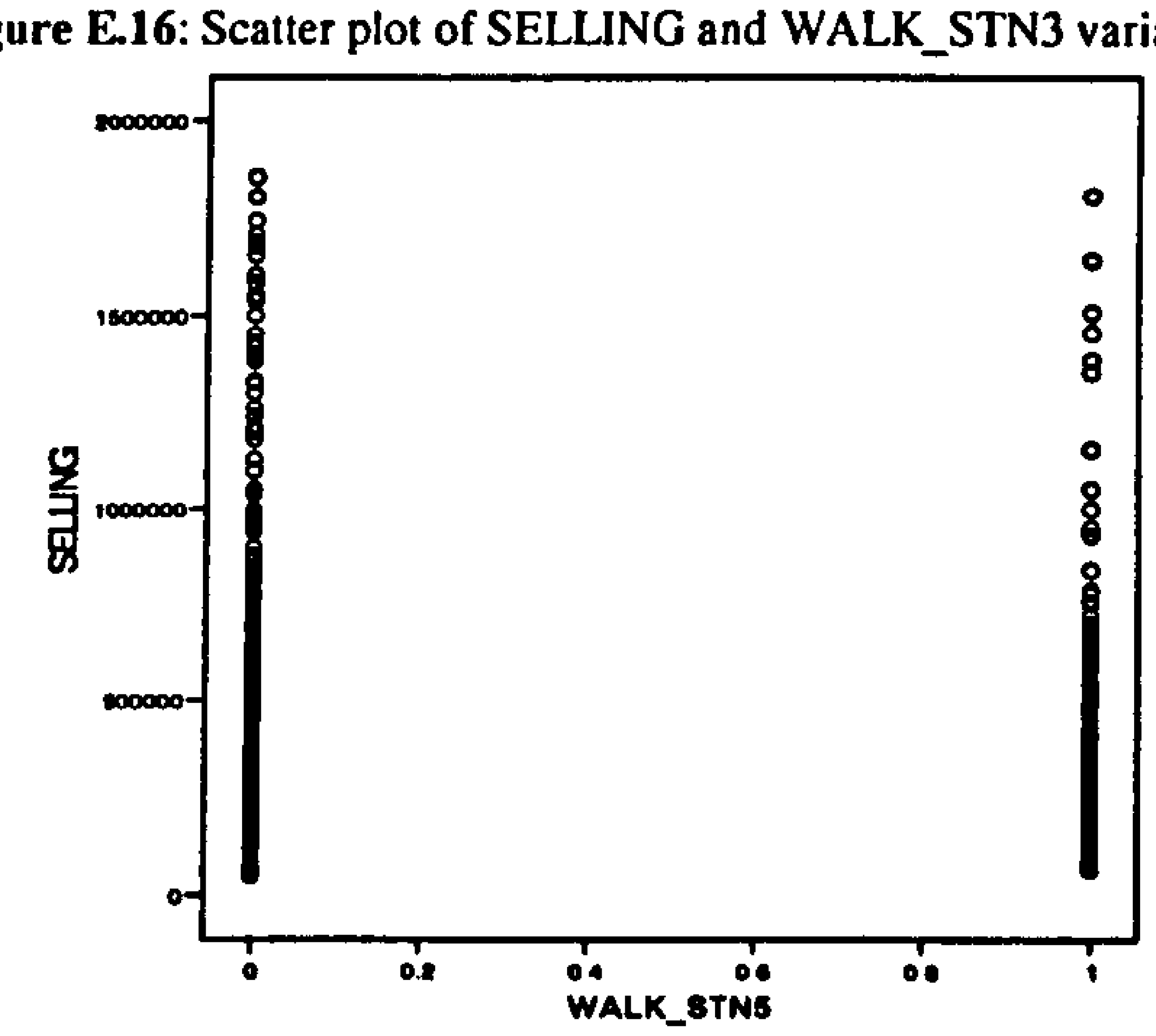



Figure E.18: Scatter plot of SELLING and WALK_STN5 variables

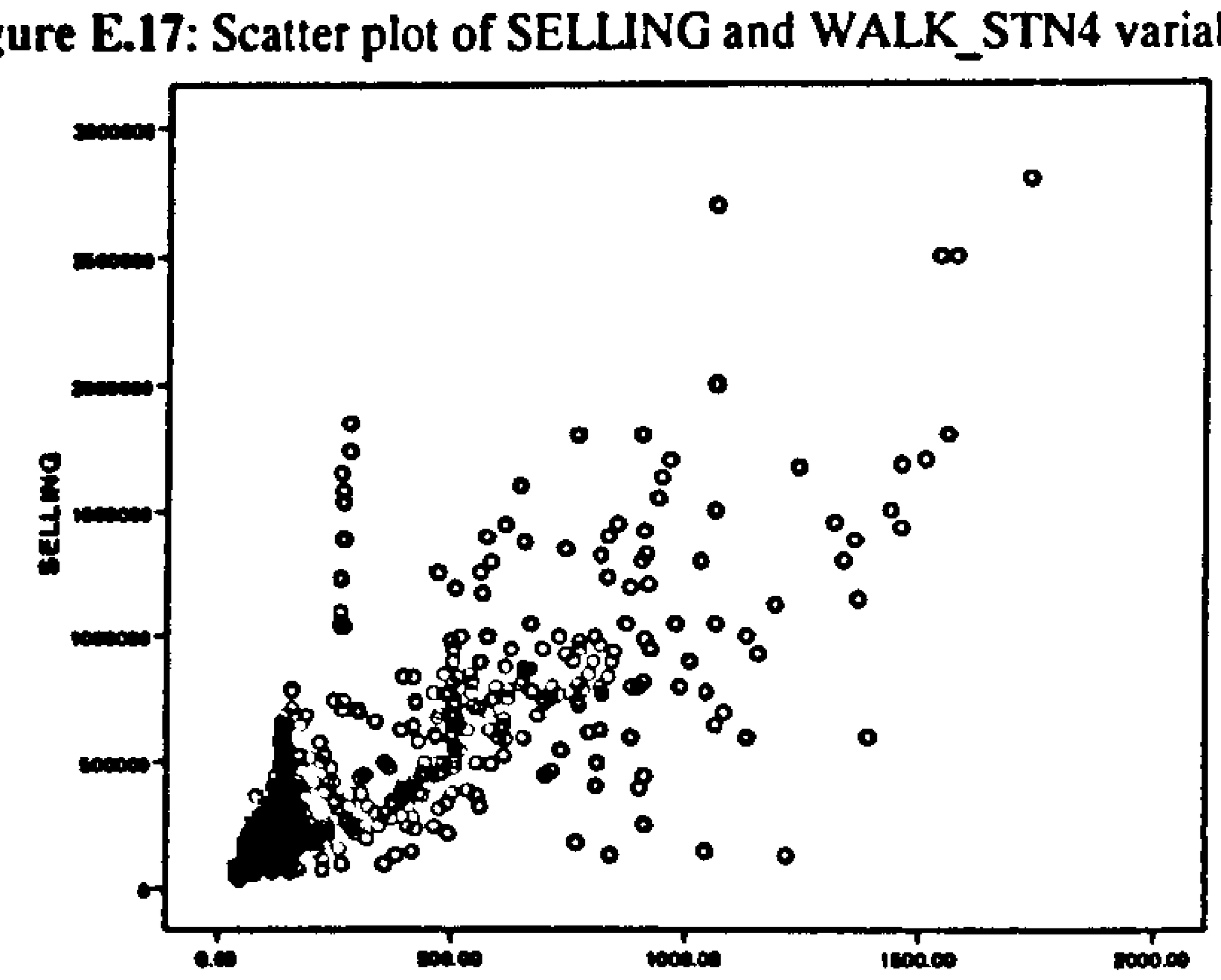



Figure E.19: Scatter plot of SELLING and FLRAREA variables

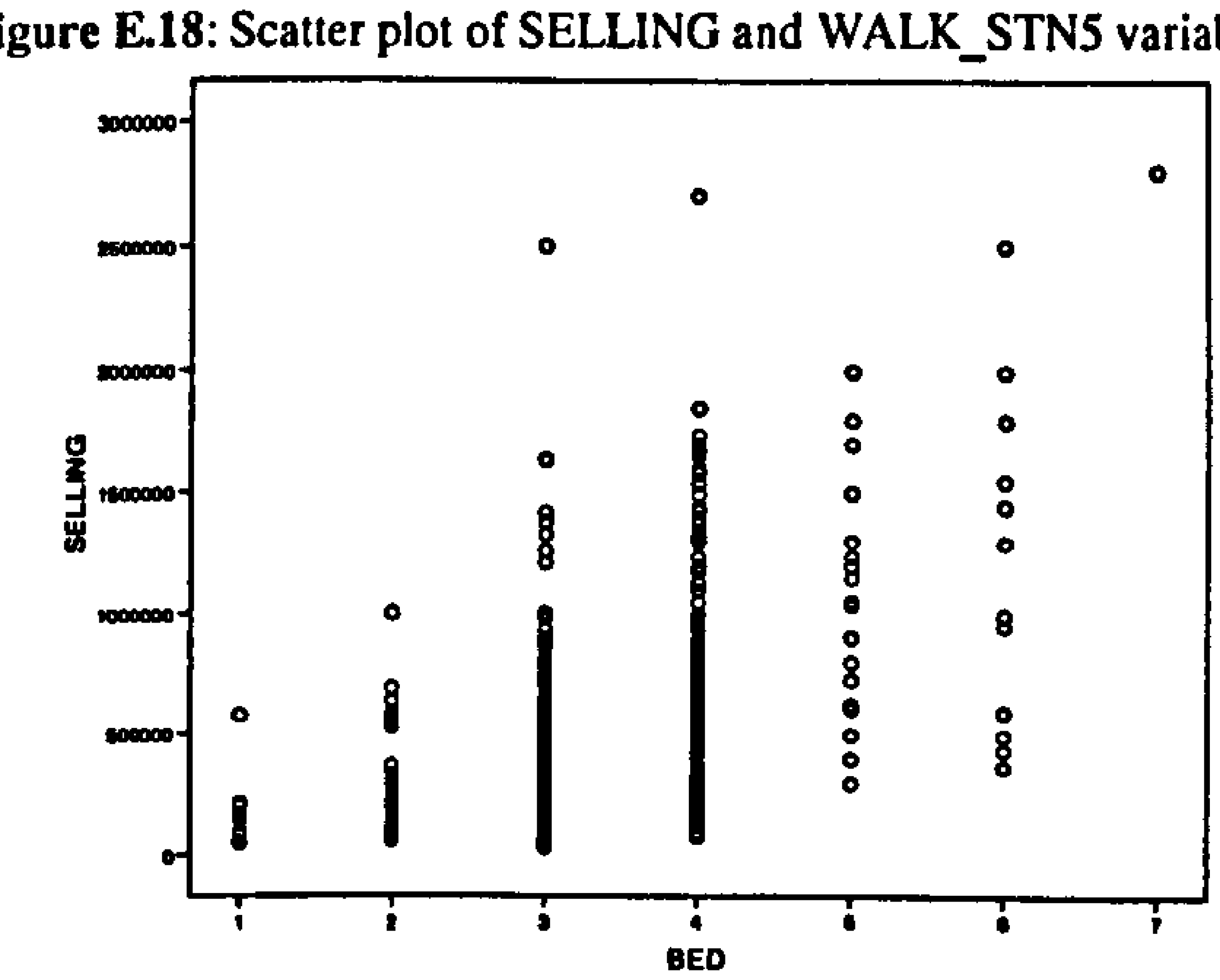



Figure E.20: Scatter plot of SELLING and BED variables

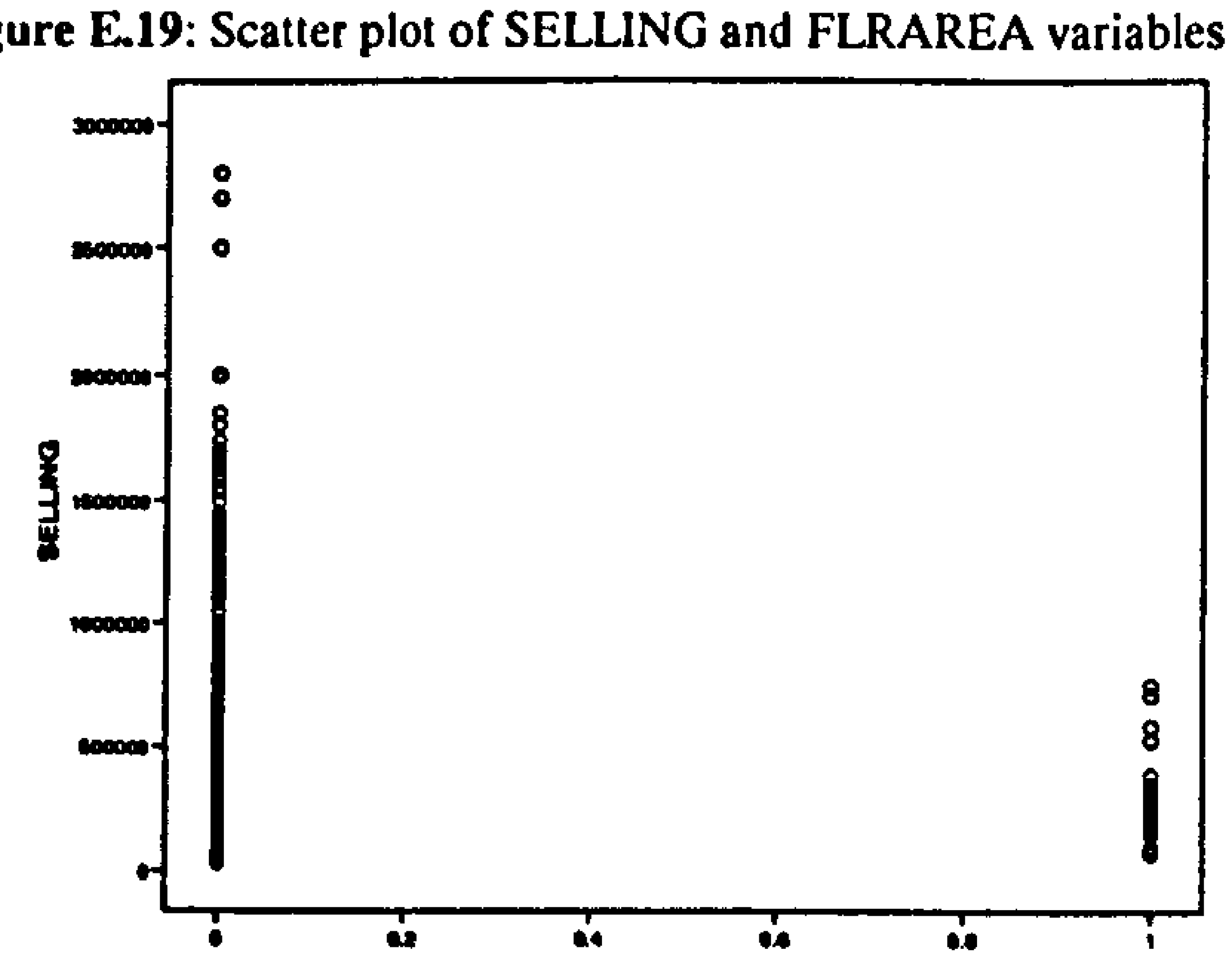



Figure E.21: Scatter plot of SELLING and SAUNA variables

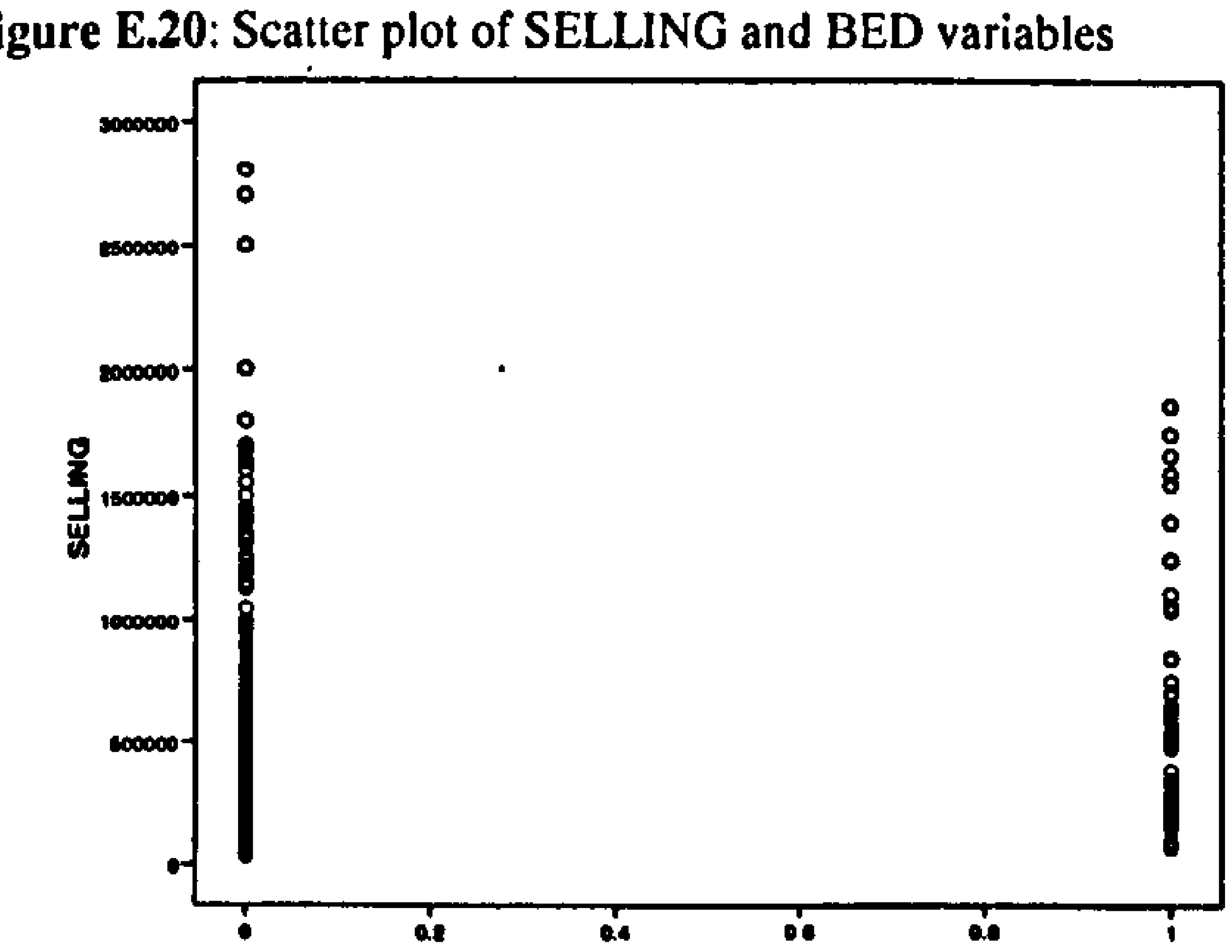



Figure E.22: Scatter plot of SELLING and SWMPOOL variables

## Appendix E

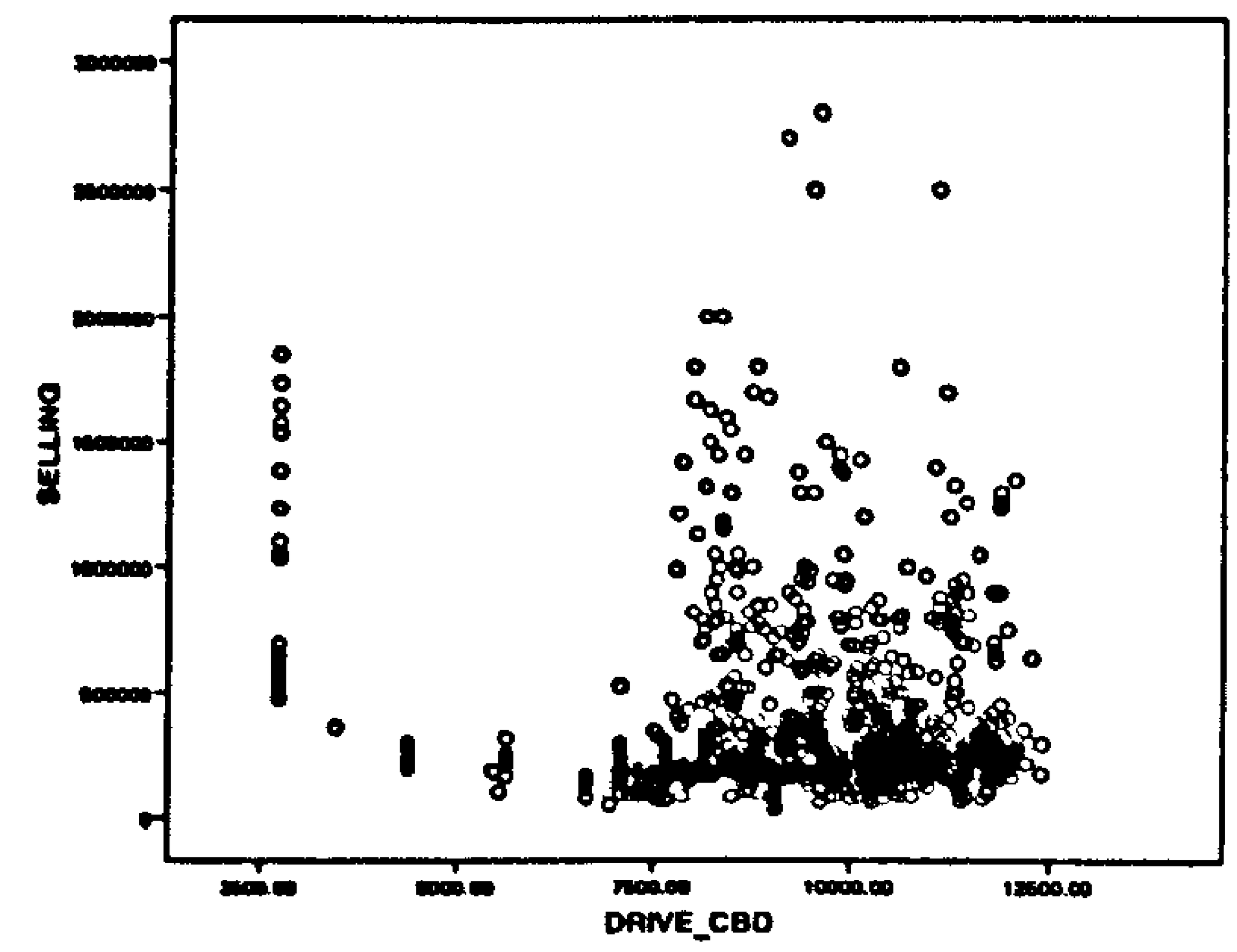



**Figure E.23**: Scatter plot of SELLING and DRIVE_CBD variables

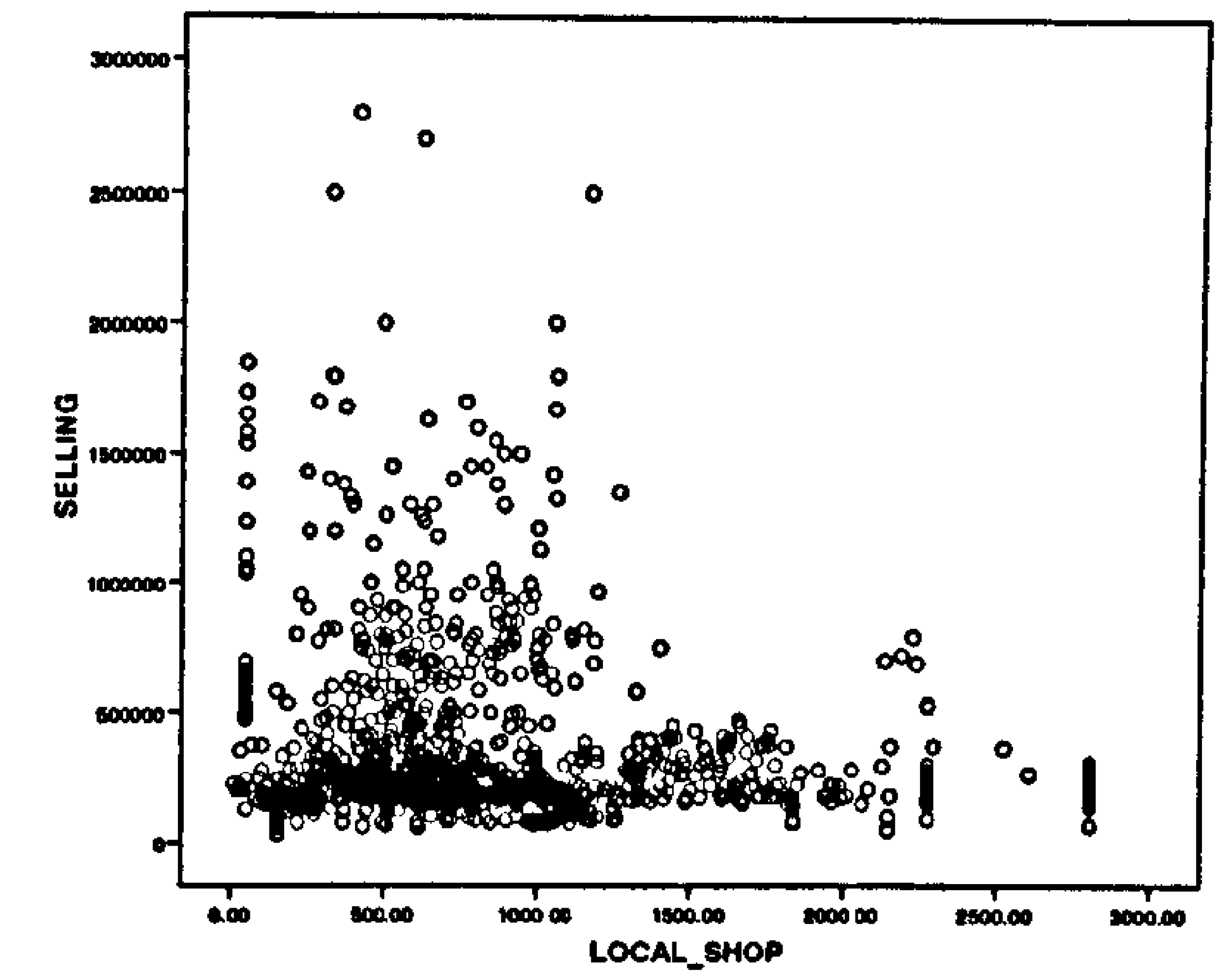



**Figure E.24**: Scatter plot of SELLING and LOCAL_SHOP variables

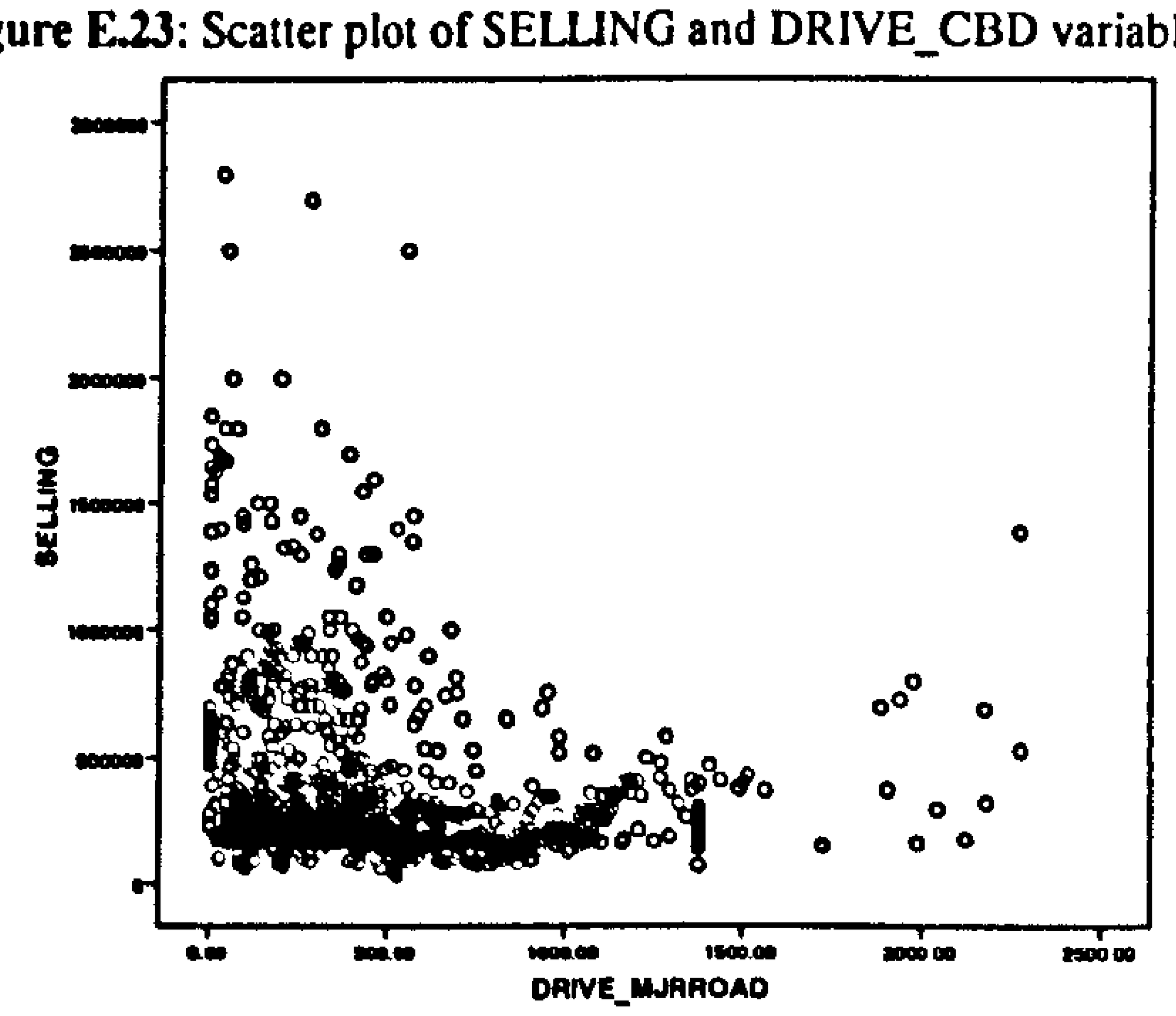



**Figure E.25**: Scatter plot of SELLING and DRIVE_MJRROAD variables

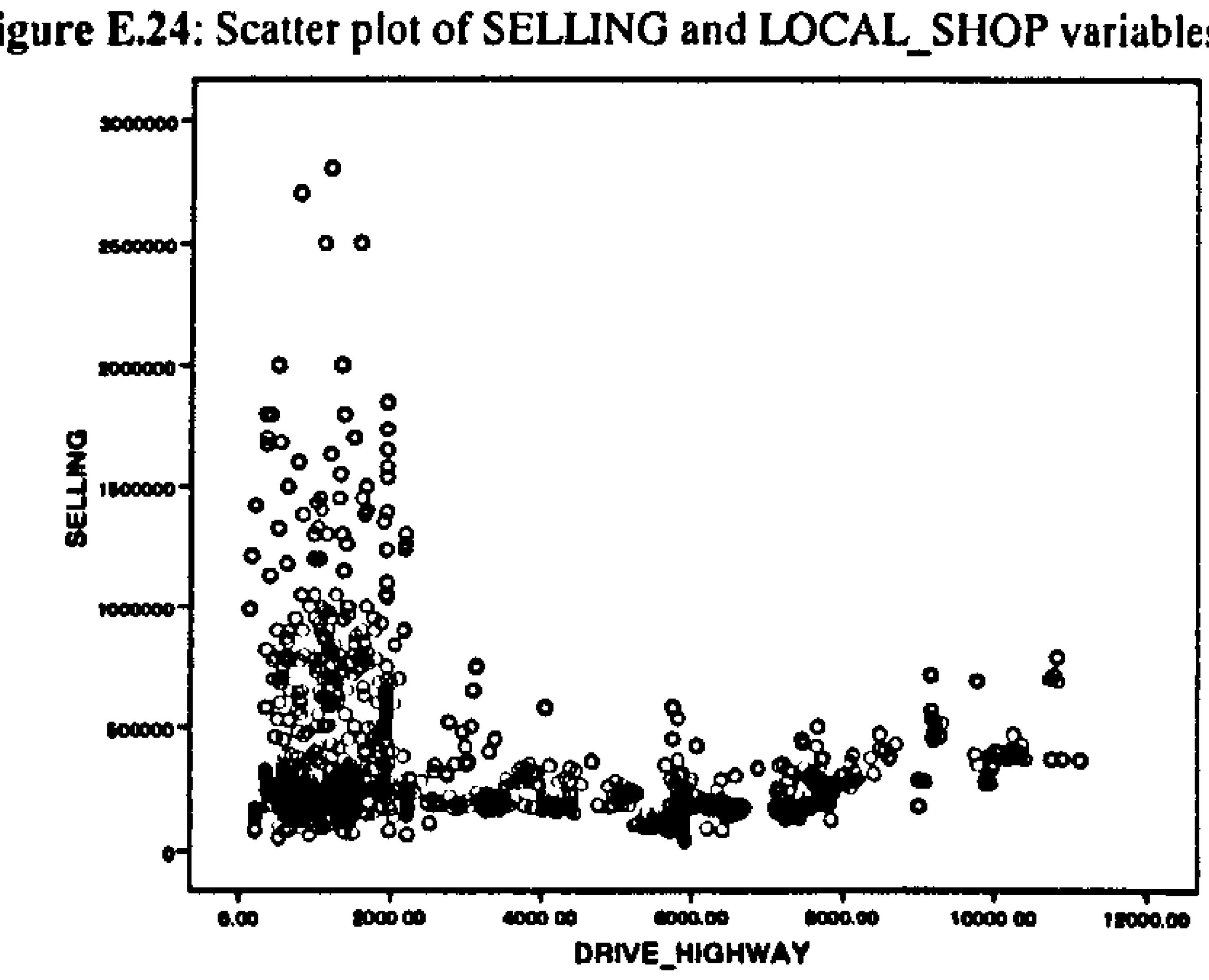



**Figure E.26**: Scatter plot of SELLING and DRIVE_HIGHWAY variables

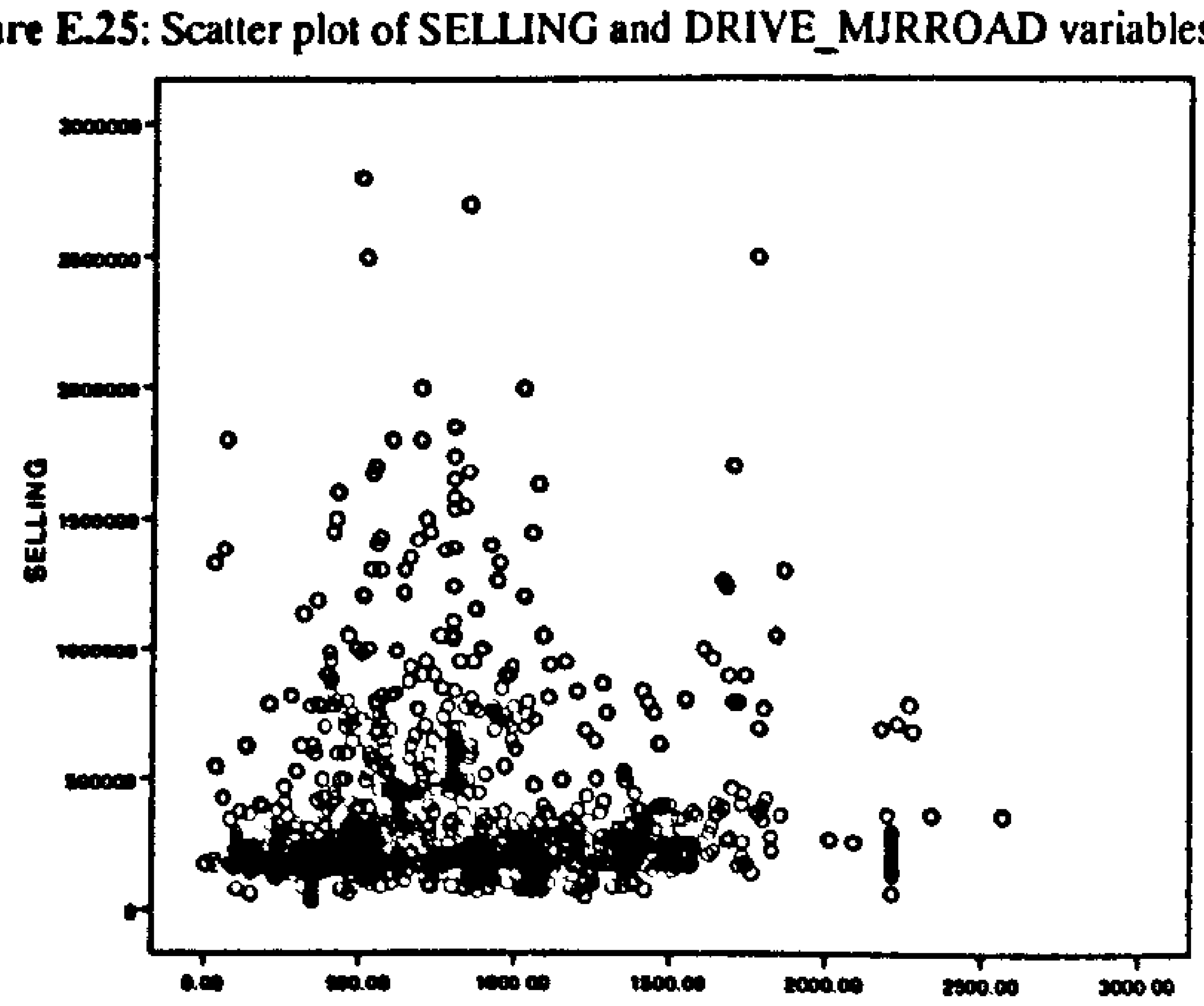



**Figure E.27**: Scatter plot of SELLING and PRIMARY_SCH variables

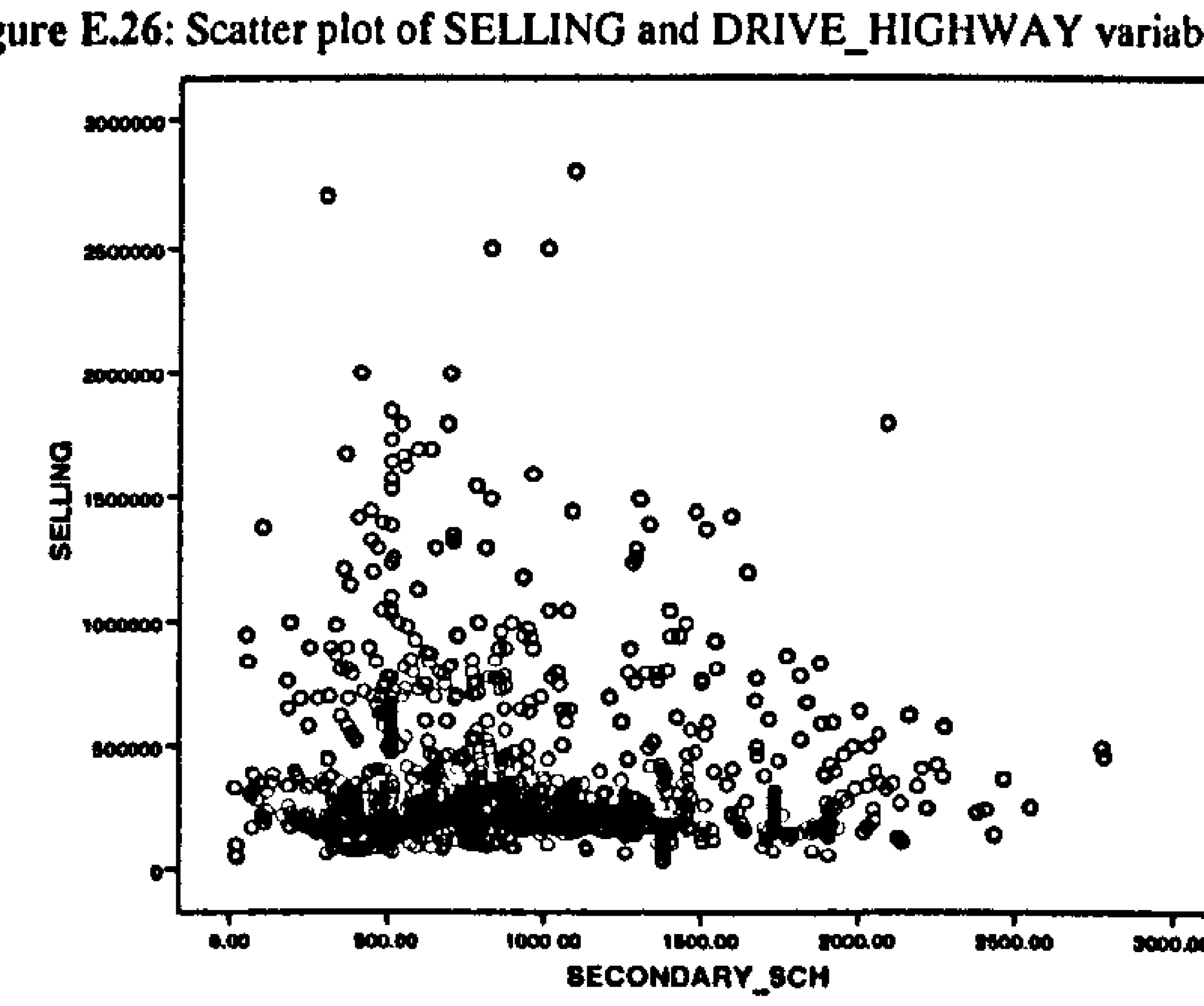



**Figure E.28**: Scatter plot of SELLING and SECONDARY_SCH variables

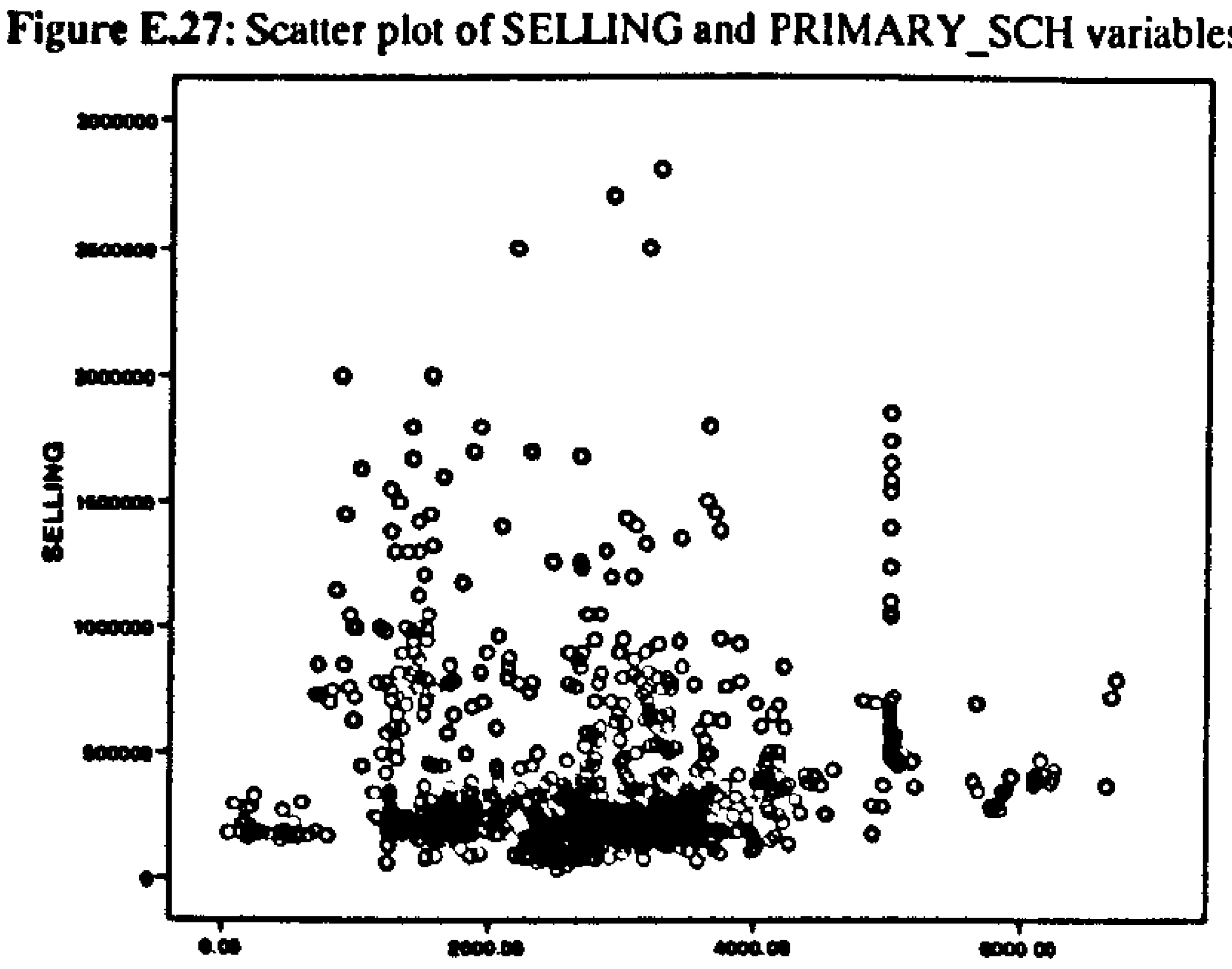



**Figure E.29**: Scatter plot of SELLING and UNIVERSITY variables

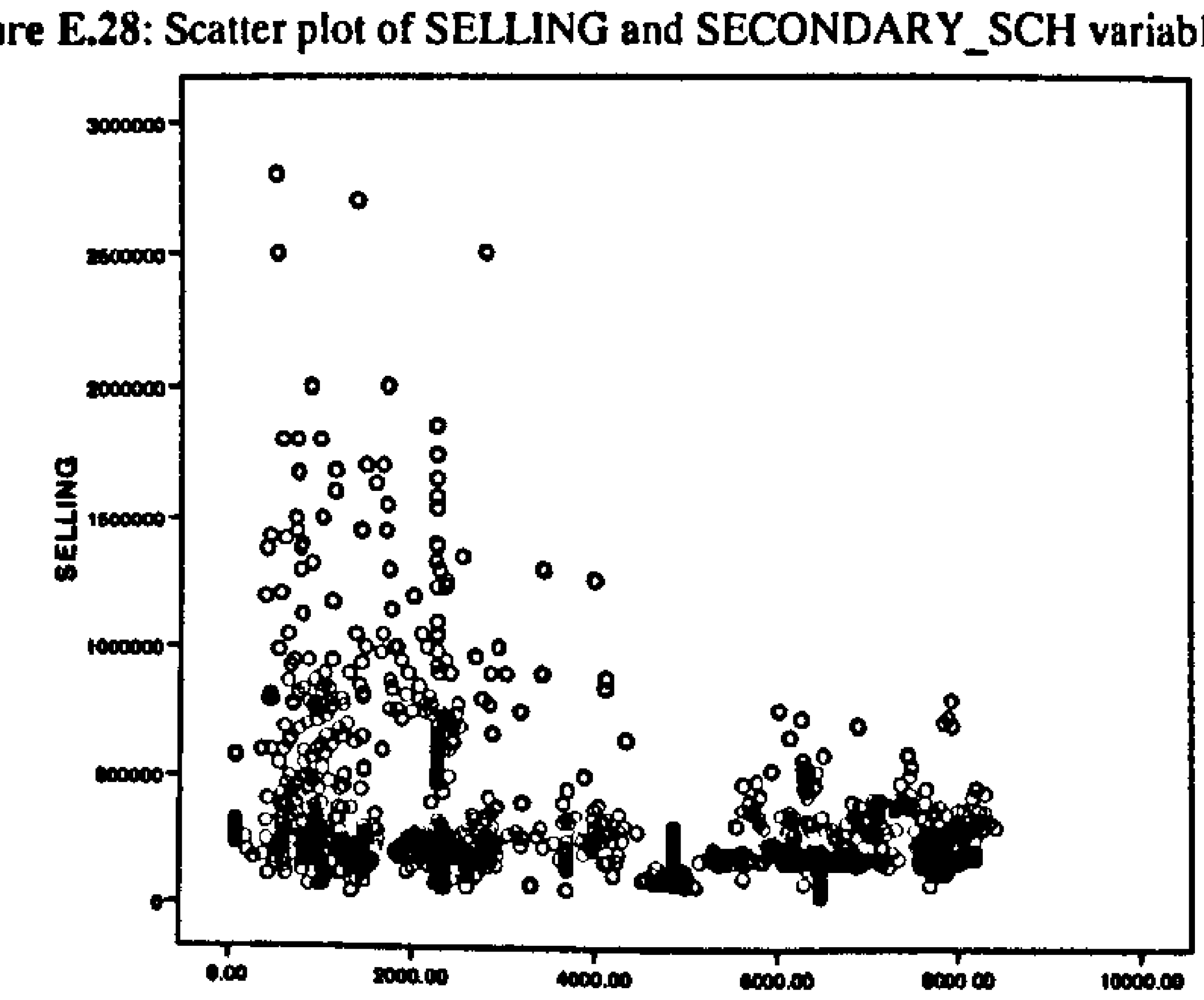



**Figure E.30**: Scatter plot of SELLING and HOSPITALS variables

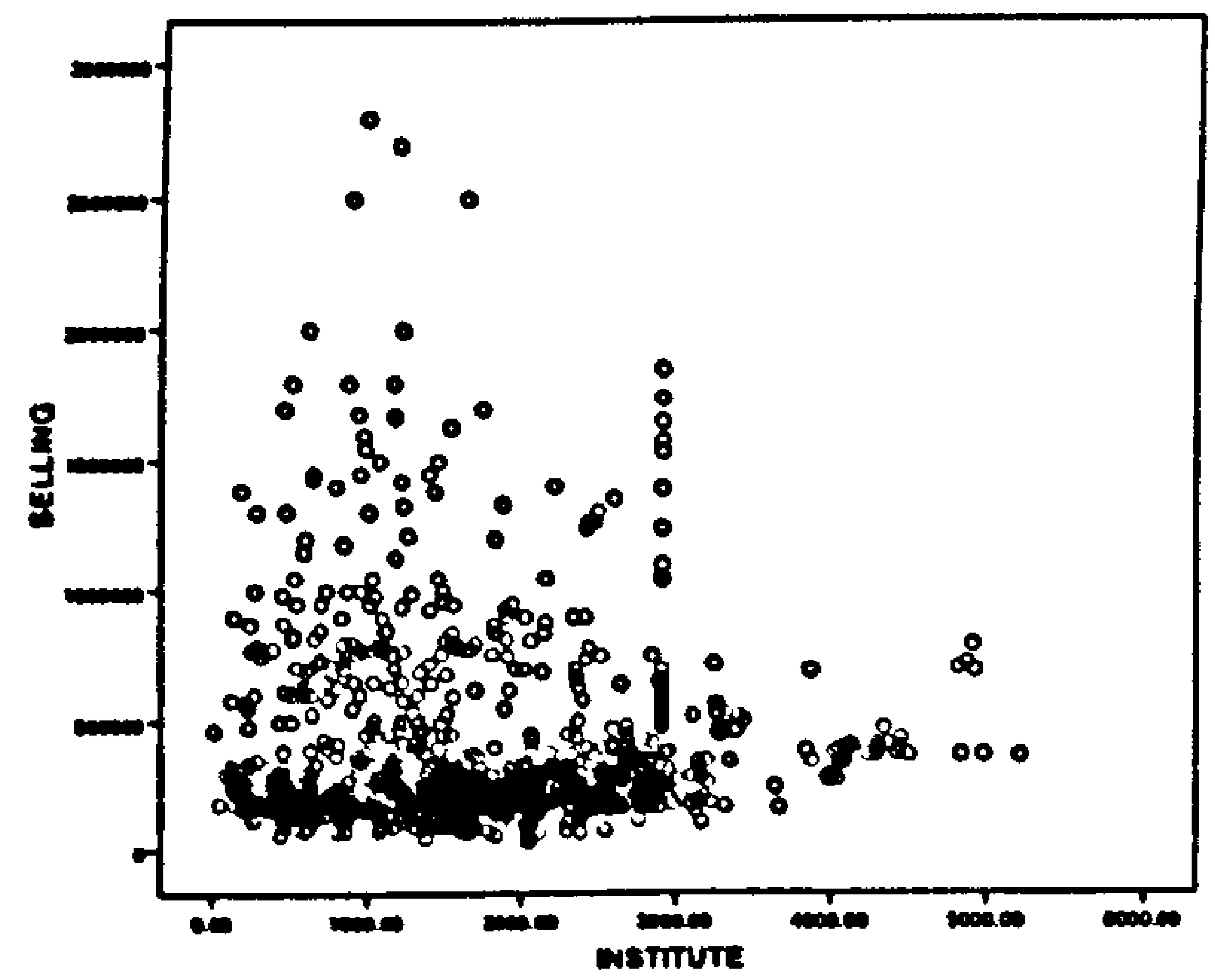



**Figure E.31**: Scatter plot of SELLING and INSTITUTE variables

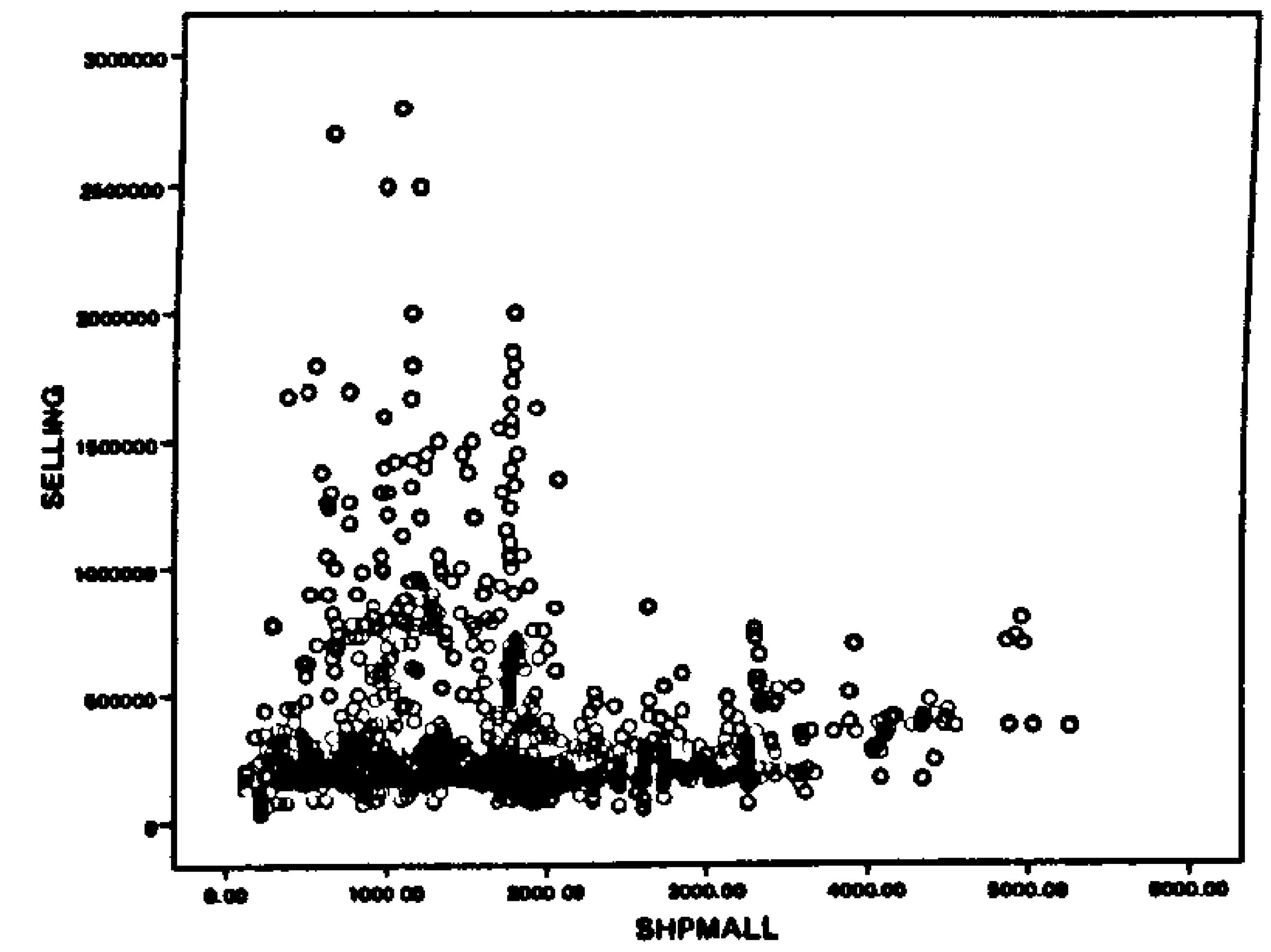



**Figure E.32**: Scatter plot of SELLING and SHPMALL variables

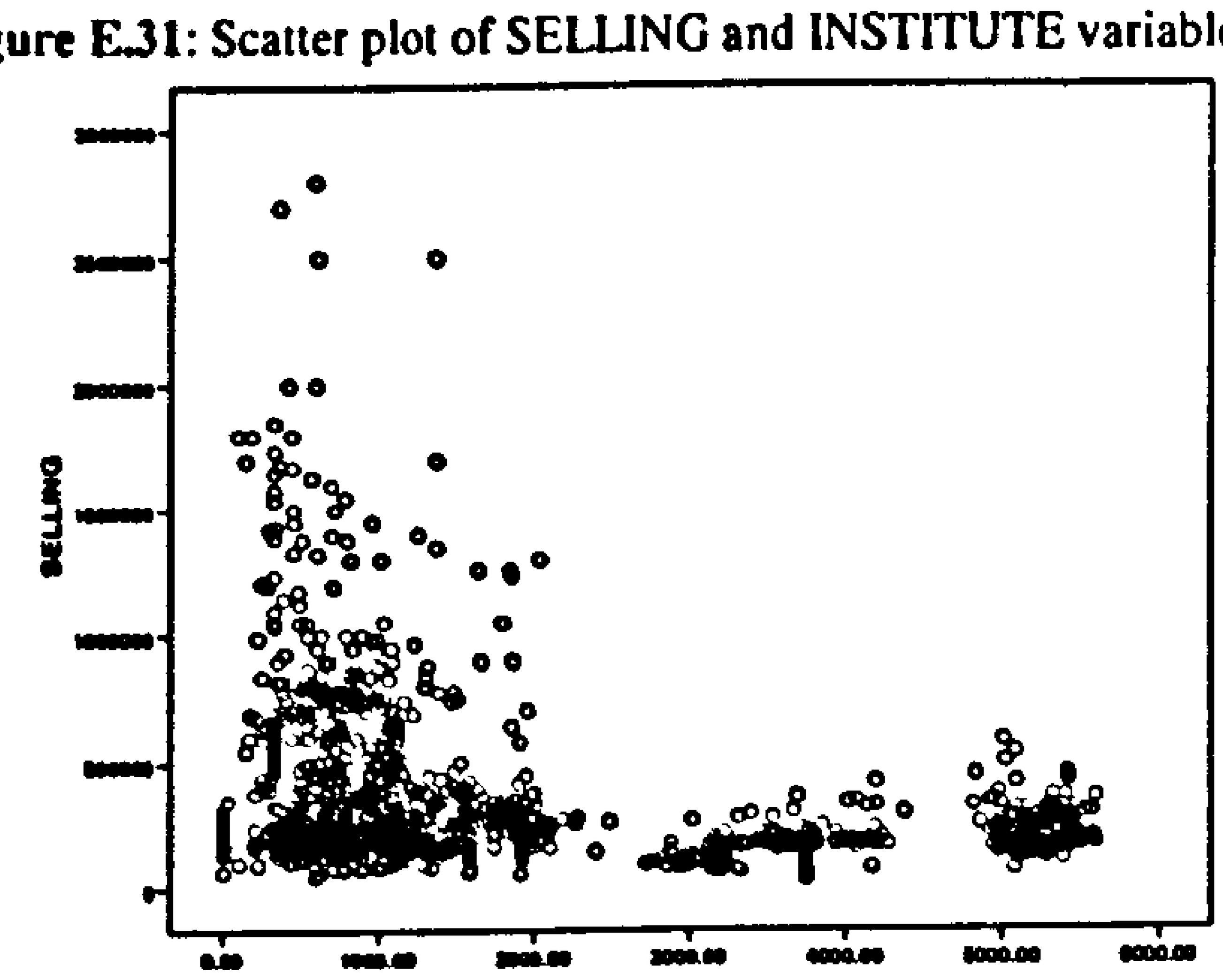



**Figure E.33**: Scatter plot of SELLING and WORSHIP variables

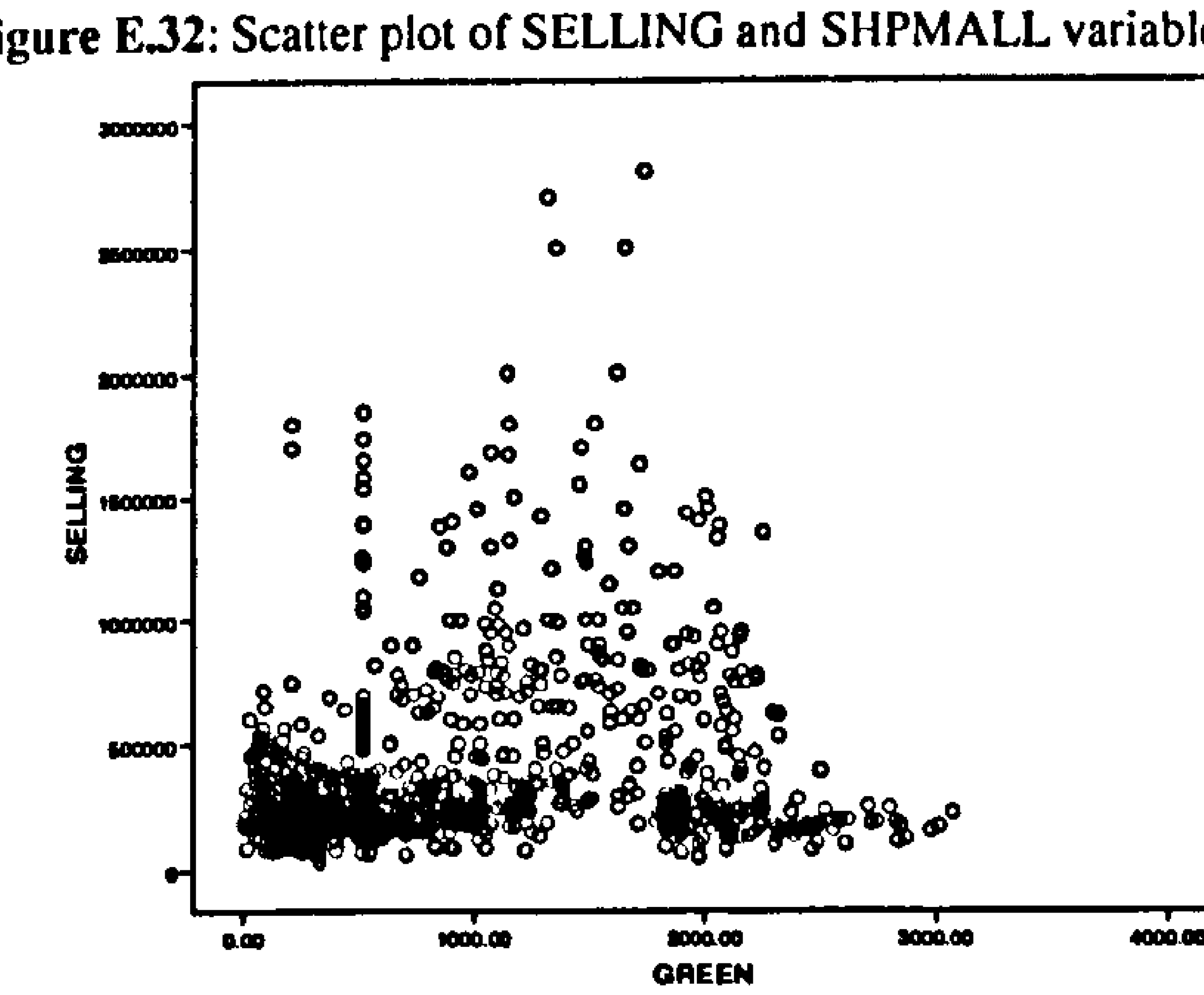



**Figure E.34**: Scatter plot of SELLING and GREEN variables

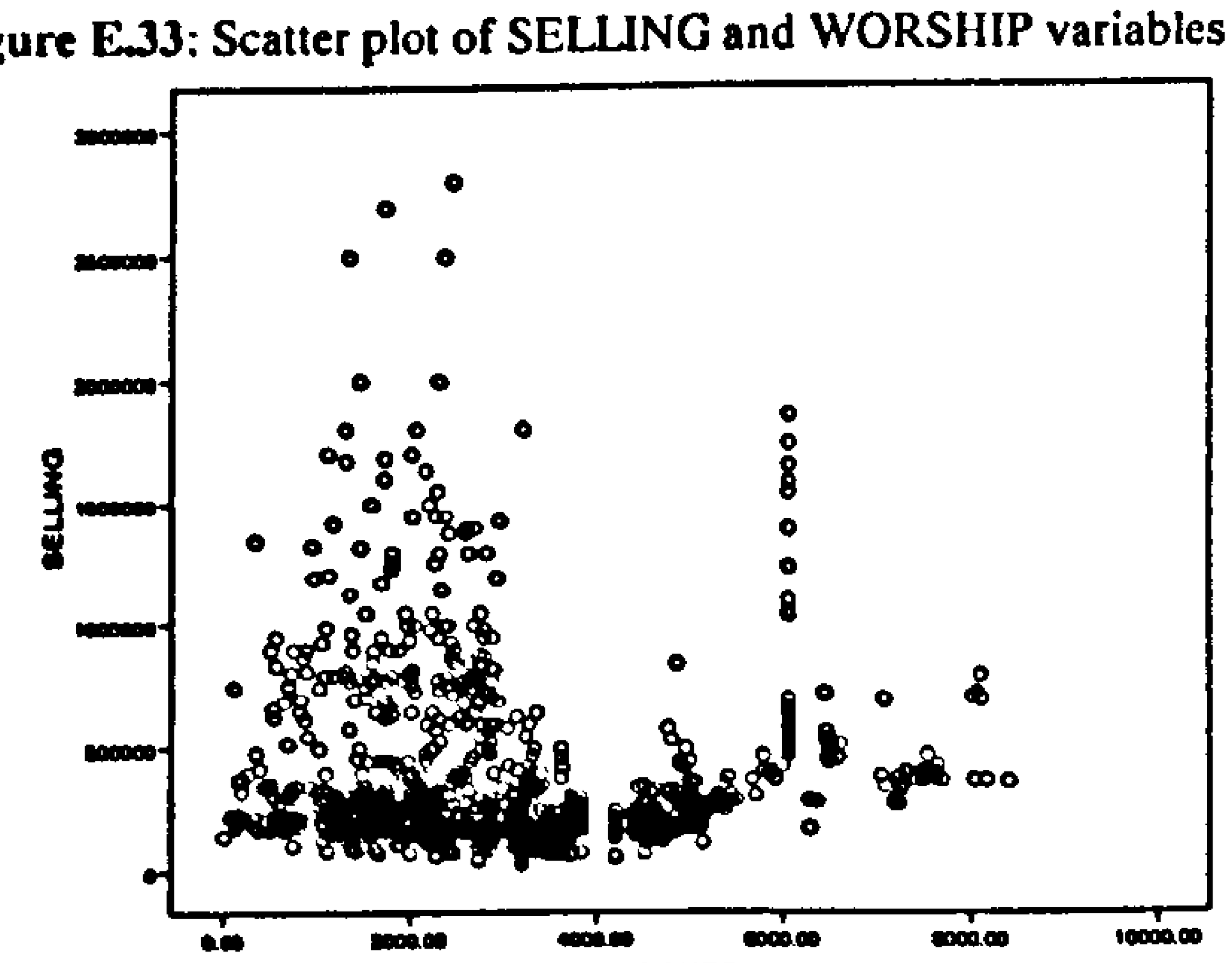



**Figure E.35**: Scatter plot of SELLING and LAKES variables

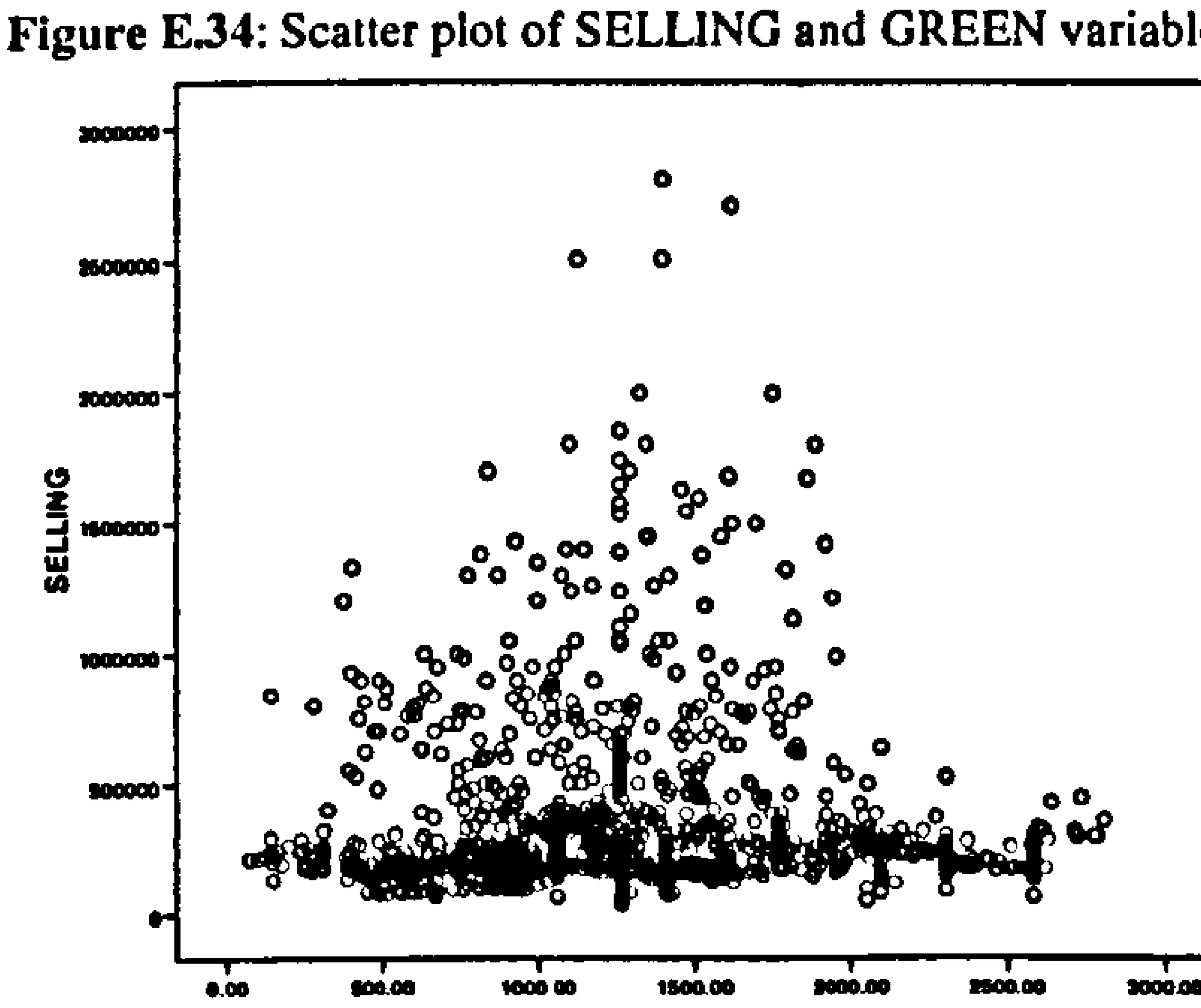



**Figure E.36**: Scatter plot of SELLING and INDUSTRY variables

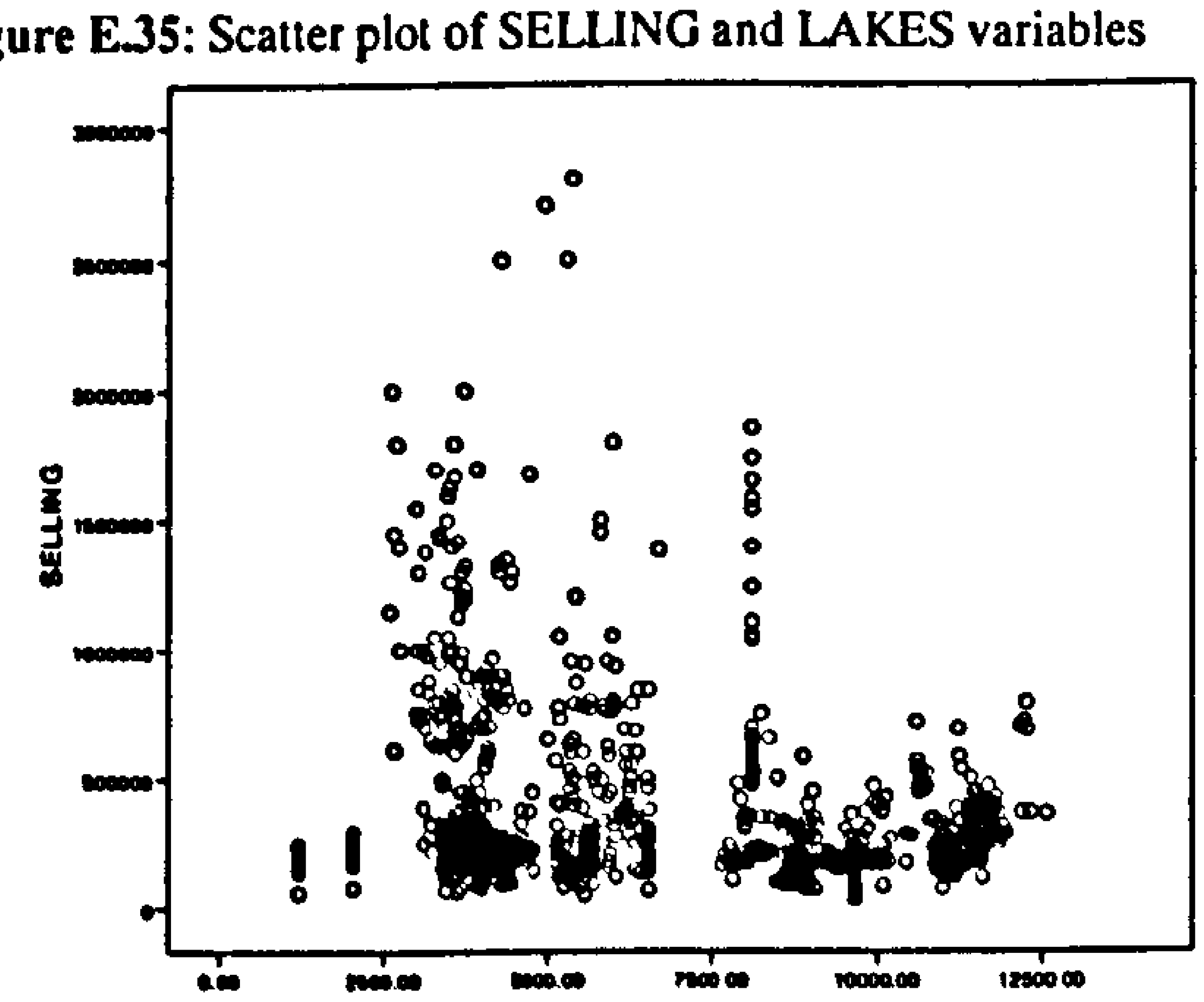



**Figure E.37**: Scatter plot of SELLING and RECREATION variables

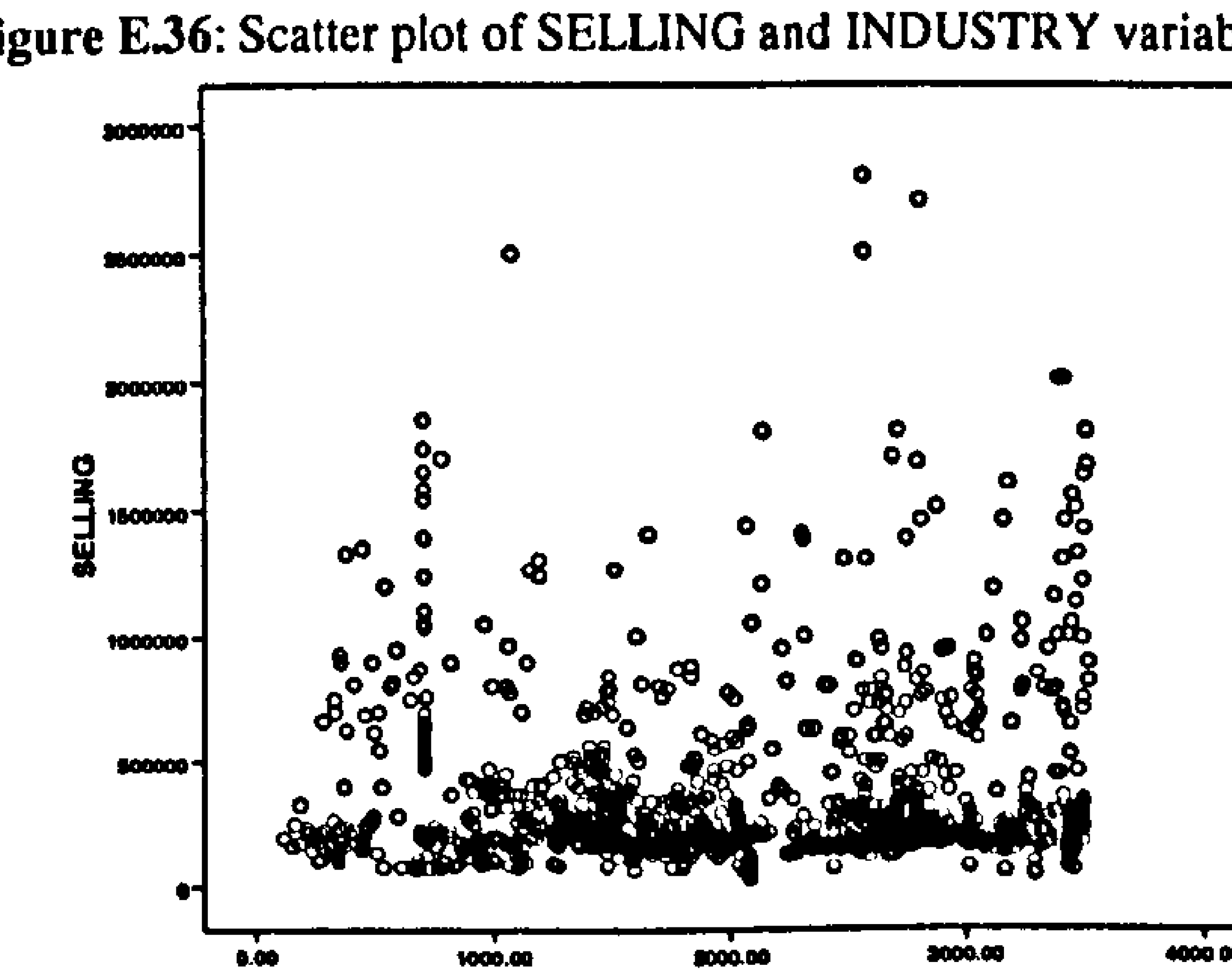



**Figure E.38**: Scatter plot of SELLING and CEMETERY variables

## Appendix E

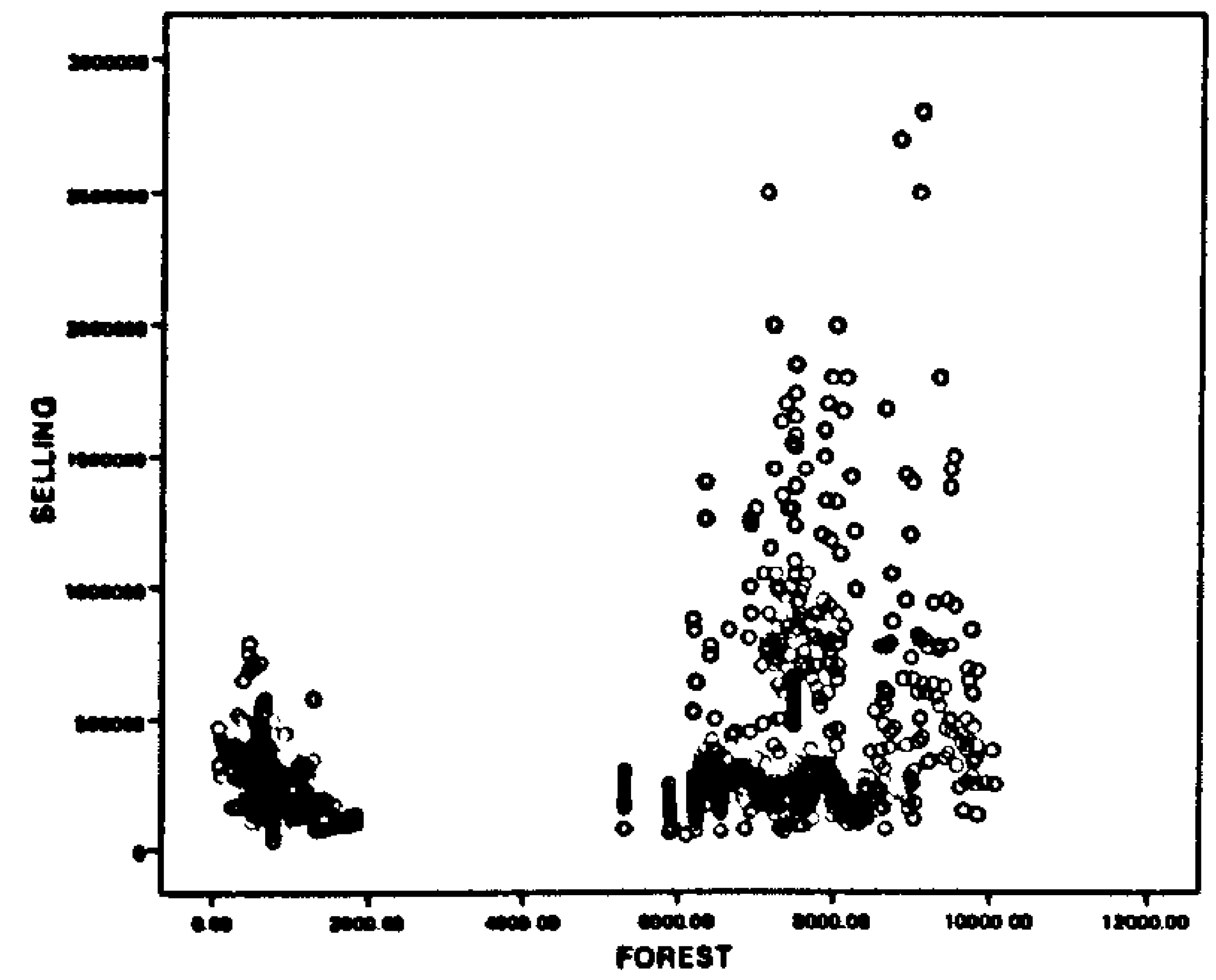



**Figure E.39**: Scatter plot of SELLING and FOREST variables

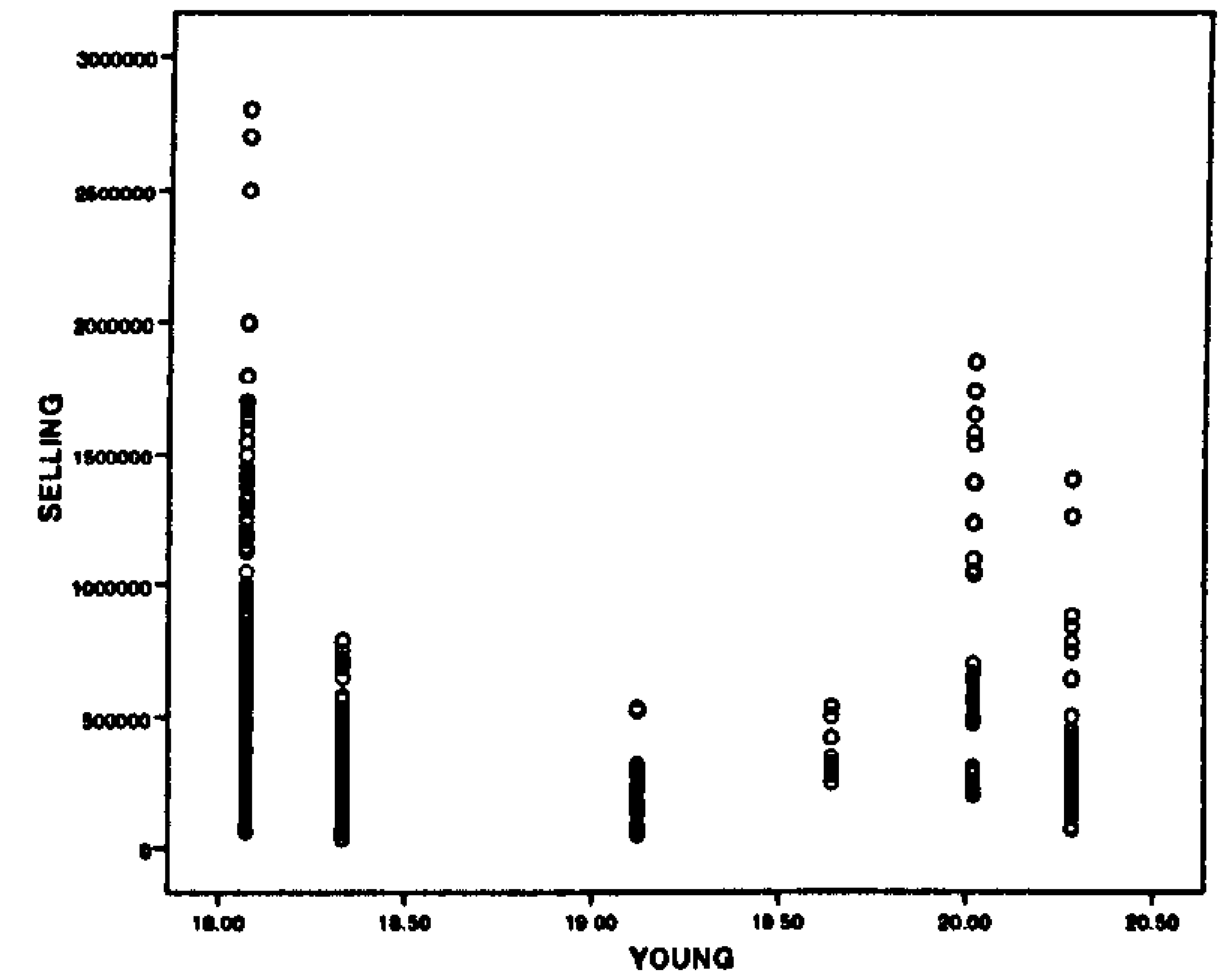



**Figure E.40**: Scatter plot of SELLING and YOUNG variables

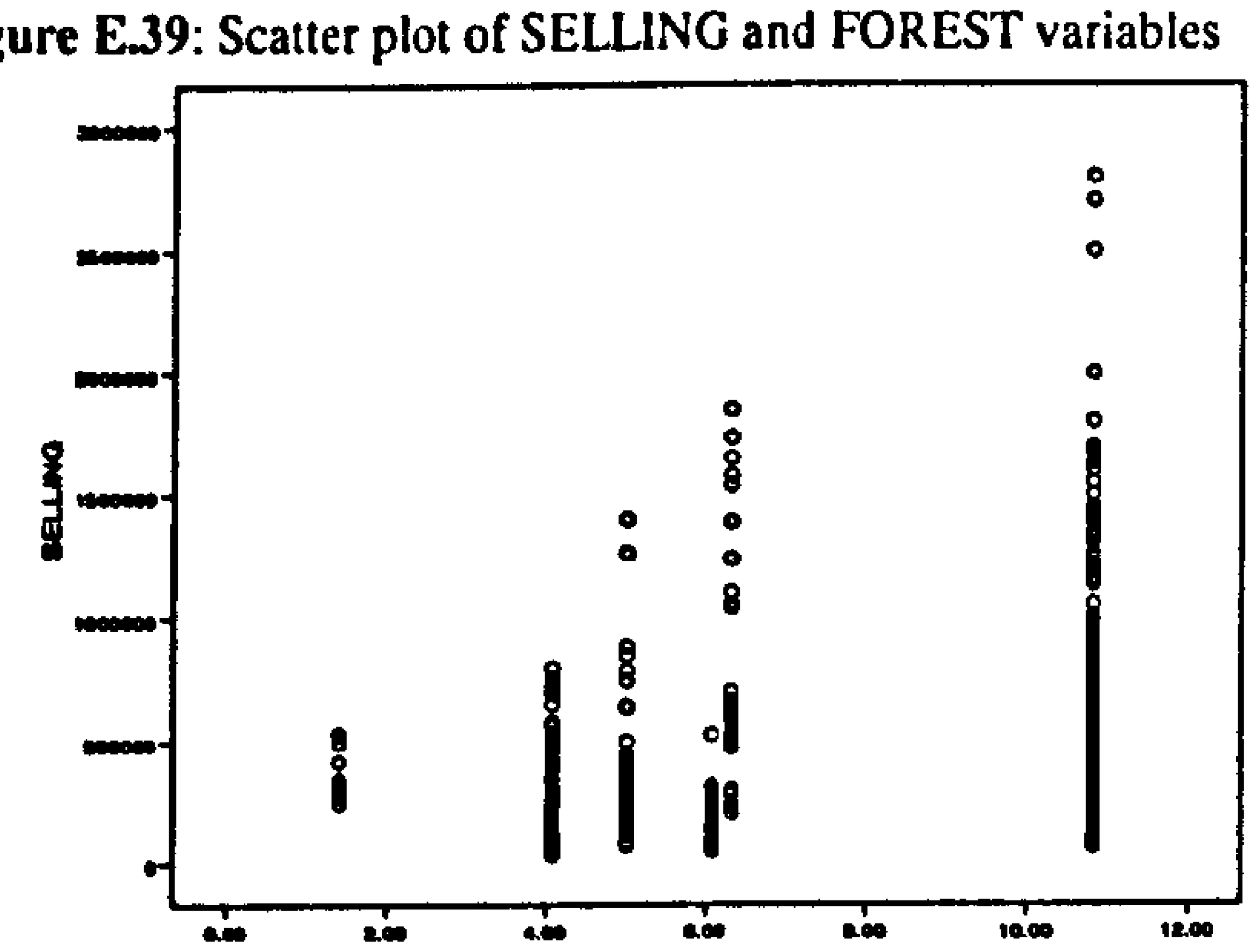



**Figure E.41**: Scatter plot of SELLING and ELDERLY variables

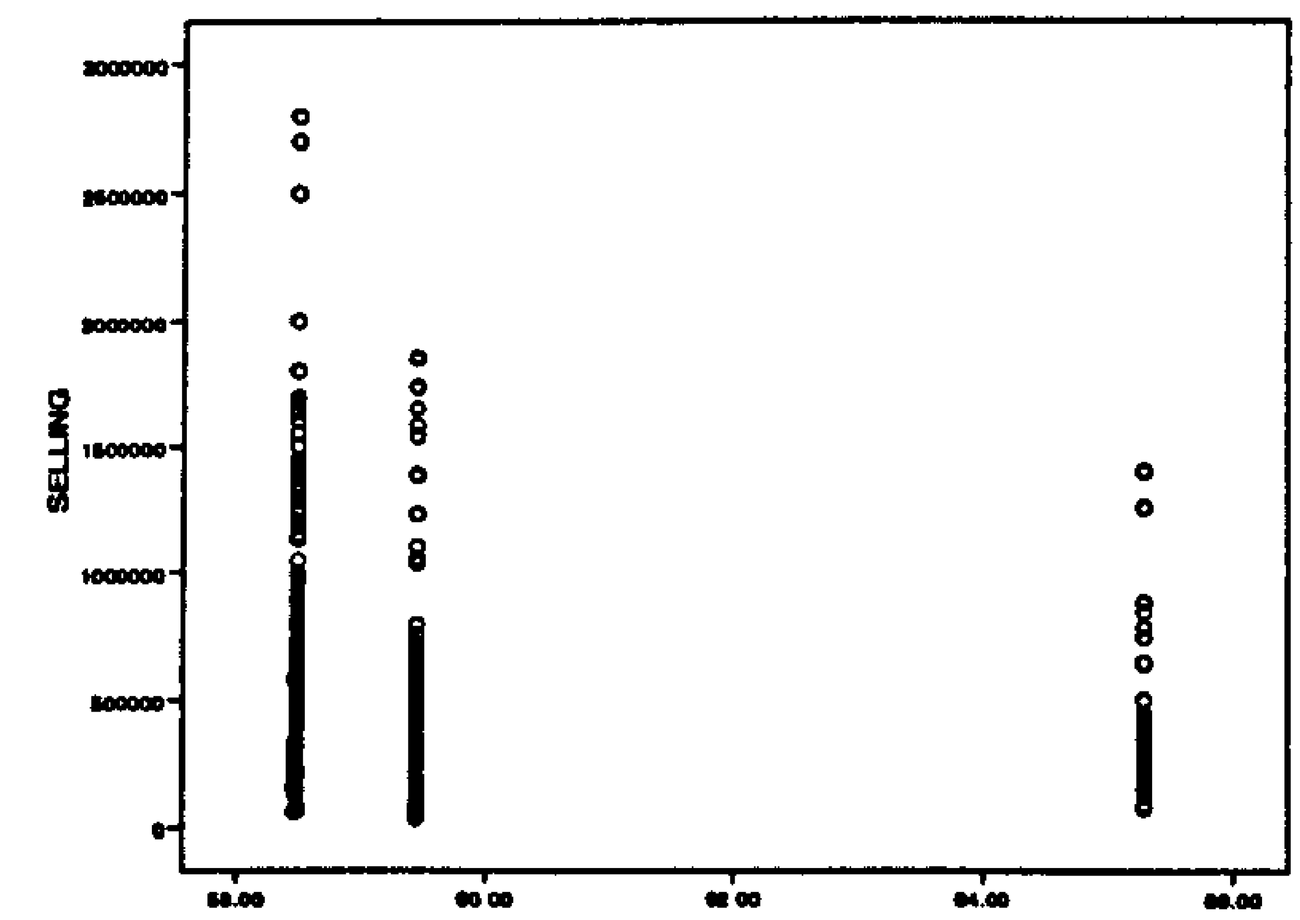



**Figure E.42**: Scatter plot of SELLING and EMPLOY variables

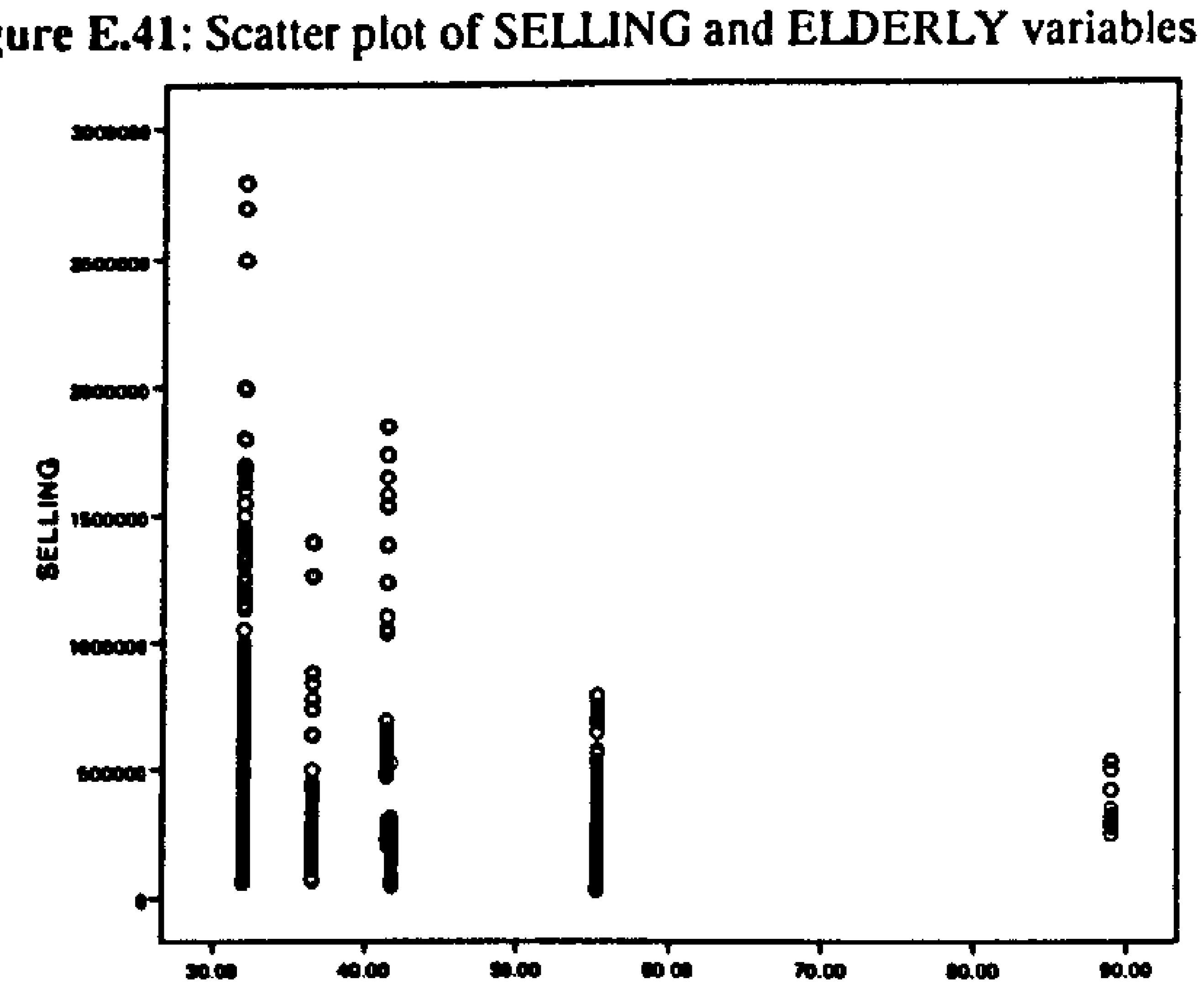



**Figure E.43**: Scatter plot of SELLING and MALAY variables

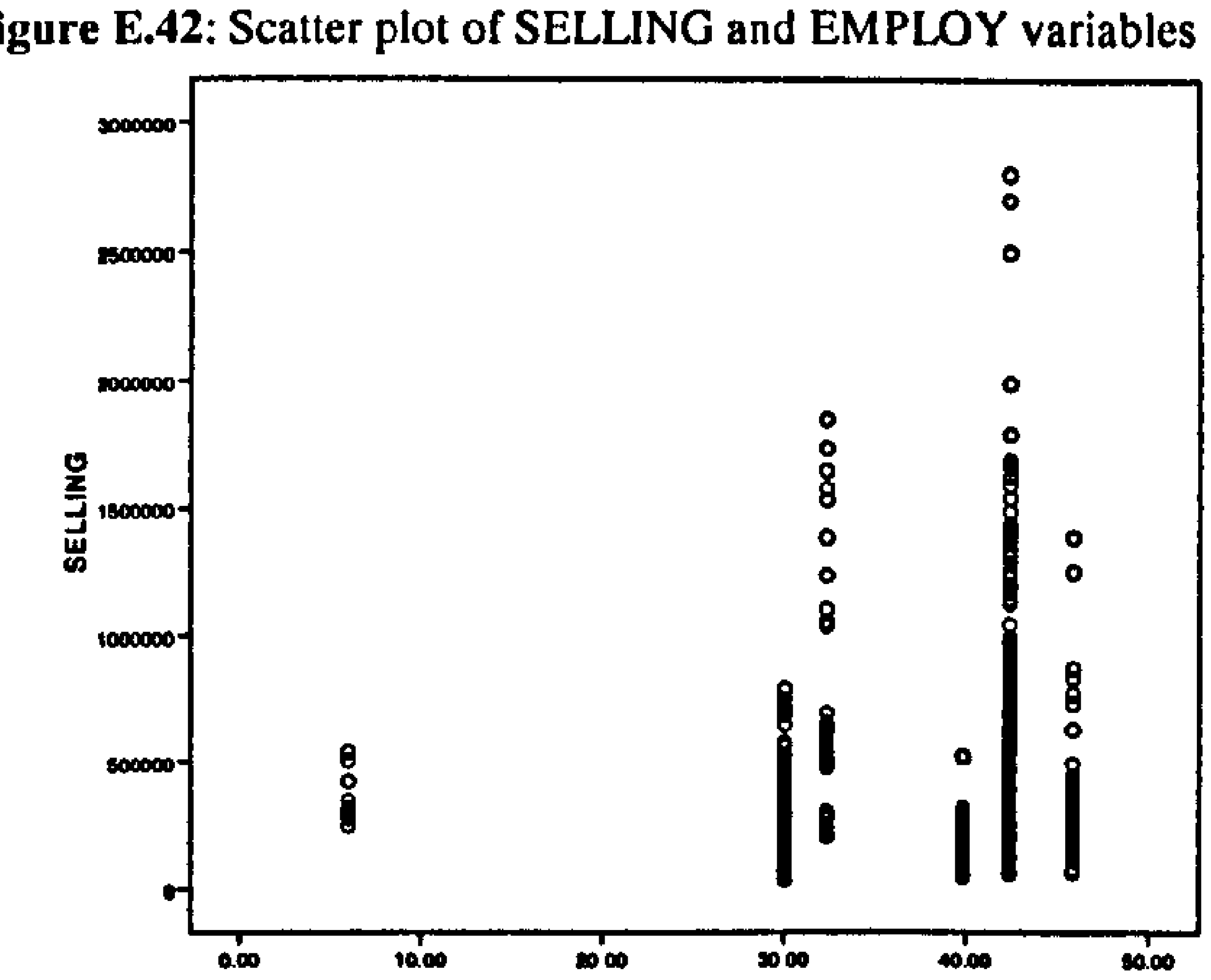



**Figure E.44**: Scatter plot of SELLING and CHI variables

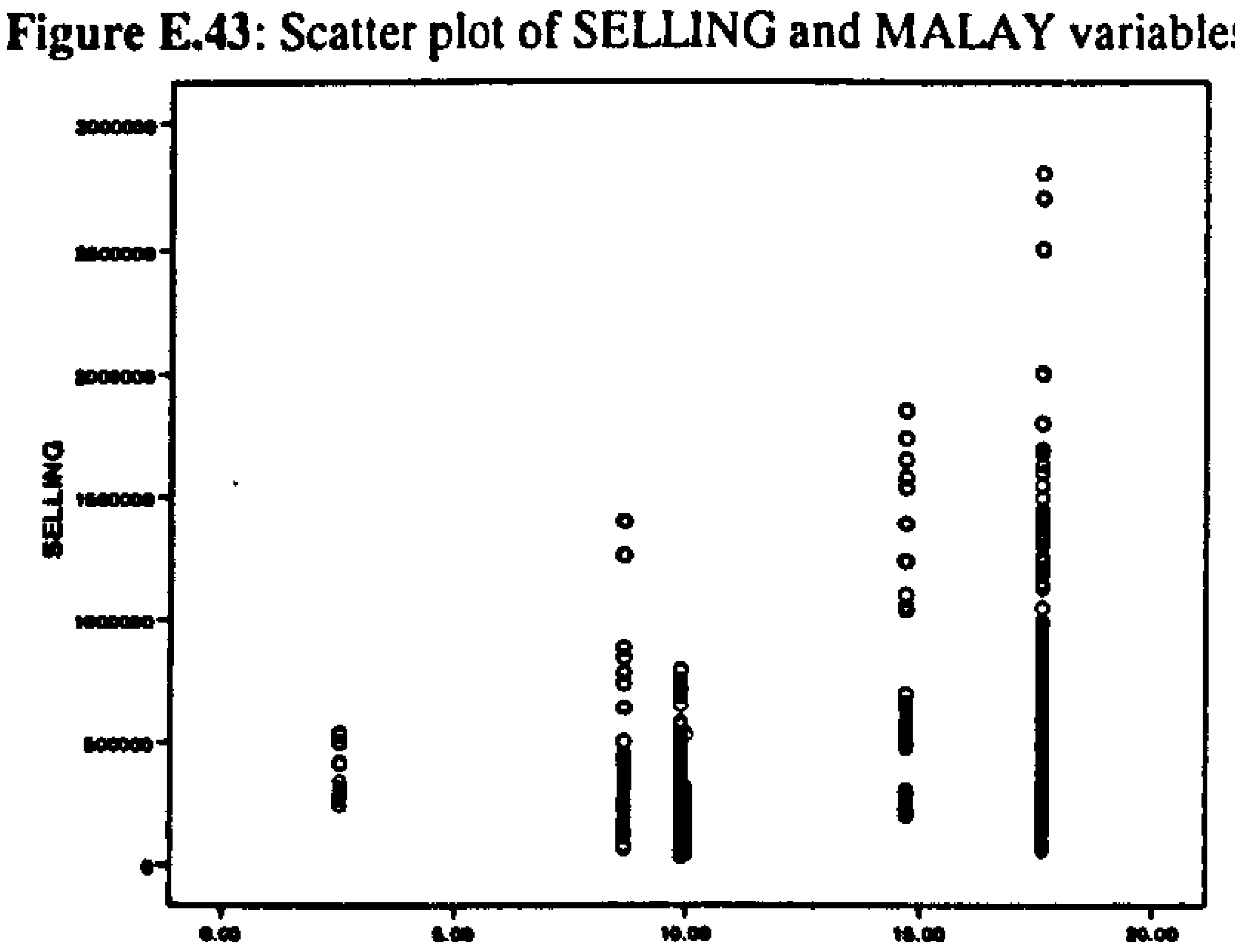



**Figure E.45**: Scatter plot of SELLING and INDIAN variables

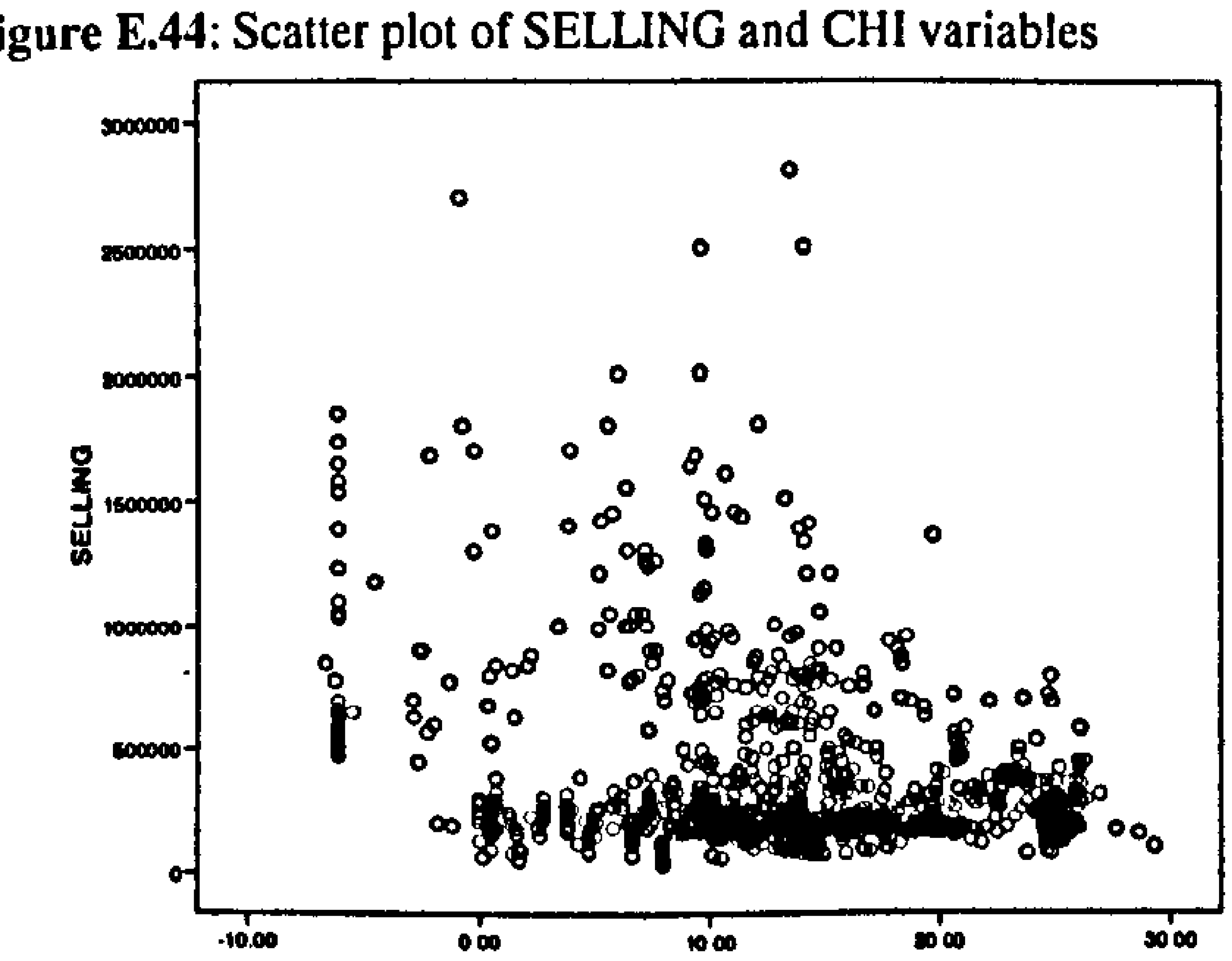



**Figure E.46**: Scatter plot of SELLING and TIME_SAVINGS variables

## Appendix F

**Table A8.1**: The results of highly correlated between pairs of independent variables

| | | STR_DIST | STR_STN1 | STR_STN2 | STR_STN3 | STR_STN4 | WALK_DIST | WALK_STN1 | WALK_STN2 | WALK_STN3 | WALK_STN4 | WALK_STN5 | FLRAREA | BEDS | BATH | TYPTRRD | TYP_CLUSTER | TYPSEMID | TYPDETCH | TYPFLAT | TYPAPT | TYPCONDO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| STR_DIST | Pearson Correlation | 1 | -0.647 | -0.338 | 0.248 | 0.753 | 0.828 | -0.307 | -0.491 | -0.113 | -0.042 | 0.720 | 0.019 | 0.037 | 0.006 | -0.026 | 0.243 | 0.080 | 0.062 | -0.071 | 0.043 | -0.171 |
| | Sig. (2-tailed) | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.095 | 0.000 | 0.439 | 0.145 | 0.799 | 0.304 | 0.000 | 0.001 | 0.014 | 0.005 | 0.085 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| STR_STN1 | Pearson Correlation | -0.647 | 1 | -0.314 | -0.340 | -0.230 | -0.420 | 0.444 | 0.266 | -0.157 | -0.062 | -0.265 | -0.111 | -0.004 | 0.008 | 0.063 | -0.075 | -0.032 | -0.158 | 0.116 | -0.127 | 0.201 |
| | Sig. (2-tailed) | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.014 | 0.000 | 0.000 | 0.878 | 0.759 | 0.012 | 0.003 | 0.203 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| STR_STN2 | Pearson Correlation | -0.338 | -0.314 | 1 | -0.454 | -0.308 | -0.414 | -0.139 | 0.366 | 0.390 | -0.225 | -0.347 | 0.140 | -0.059 | -0.033 | 0.016 | -0.100 | -0.032 | 0.145 | -0.036 | -0.174 | 0.086 |
| | Sig. (2-tailed) | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.018 | 0.196 | 0.536 | 0.000 | 0.198 | 0.000 | 0.147 | 0.000 | 0.001 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| STR_STN3 | Pearson Correlation | 0.248 | -0.340 | -0.454 | 1 | -0.333 | 0.209 | -0.151 | -0.362 | -0.090 | 0.518 | -0.044 | 0.002 | 0.103 | 0.091 | -0.054 | -0.109 | -0.040 | 0.007 | -0.040 | 0.364 | -0.240 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.079 | 0.931 | 0.000 | 0.000 | 0.031 | 0.000 | 0.109 | 0.782 | 0.116 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| STR_STN4 | Pearson Correlation | 0.753 | -0.230 | -0.308 | -0.333 | 1 | 0.659 | -0.102 | -0.260 | -0.191 | -0.300 | 0.730 | -0.054 | -0.052 | -0.080 | -0.016 | 0.326 | 0.119 | -0.019 | -0.027 | -0.108 | -0.014 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.031 | 0.040 | 0.001 | 0.517 | 0.000 | 0.000 | 0.440 | 0.288 | 0.000 | 0.591 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| WALK_DIST | Pearson Correlation | 0.828 | -0.420 | -0.414 | 0.209 | 0.659 | 1 | -0.394 | -0.634 | -0.170 | 0.102 | 0.791 | -0.006 | 0.092 | 0.056 | 0.156 | 0.228 | 0.106 | 0.014 | -0.078 | -0.031 | -0.289 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.810 | 0.000 | 0.025 | 0.000 | 0.000 | 0.000 | 0.568 | 0.002 | 0.220 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| WALK_STN1 | Pearson Correlation | -0.307 | 0.444 | -0.139 | -0.151 | -0.102 | -0.394 | 1 | -0.118 | -0.086 | -0.138 | -0.139 | -0.071 | -0.057 | -0.054 | -0.068 | -0.033 | -0.026 | -0.081 | -0.012 | 0.085 | 0.092 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.001 | 0.000 | 0.000 | 0.005 | 0.022 | 0.031 | 0.007 | 0.185 | 0.299 | 0.001 | 0.630 | 0.001 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| WALK_STN2 | Pearson Correlation | -0.491 | 0.266 | 0.366 | -0.362 | -0.260 | -0.634 | -0.118 | 1 | -0.220 | -0.351 | -0.355 | -0.047 | -0.166 | -0.126 | -0.189 | -0.085 | -0.067 | -0.087 | 0.103 | -0.126 | 0.477 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.060 | 0.000 | 0.000 | 0.000 | 0.001 | 0.008 | 0.001 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| WALK_STN3 | Pearson Correlation | -0.113 | -0.157 | 0.390 | -0.090 | -0.191 | -0.170 | -0.086 | -0.220 | 1 | -0.257 | -0.260 | 0.219 | 0.163 | 0.167 | 0.154 | -0.062 | 0.012 | 0.228 | -0.023 | -0.170 | -0.194 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.014 | 0.622 | 0.000 | 0.369 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| WALK_STN4 | Pearson Correlation | -0.042 | -0.062 | -0.225 | 0.518 | -0.300 | 0.102 | -0.138 | -0.351 | -0.257 | 1 | -0.414 | -0.061 | 0.020 | 0.004 | -0.097 | -0.099 | -0.043 | -0.037 | -0.036 | 0.418 | -0.207 |
| | Sig. (2-tailed) | 0.095 | 0.014 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.015 | 0.423 | 0.864 | 0.000 | 0.000 | 0.089 | 0.145 | 0.152 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| WALK_STN5 | Pearson Correlation | 0.720 | -0.265 | -0.347 | -0.044 | 0.730 | 0.791 | -0.139 | -0.355 | -0.260 | -0.414 | 1 | -0.029 | 0.035 | 0.010 | 0.185 | 0.239 | 0.107 | -0.020 | -0.036 | -0.209 | -0.130 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.079 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.248 | 0.159 | 0.680 | 0.000 | 0.000 | 0.000 | 0.437 | 0.147 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| FLRAREA | Pearson Correlation | 0.019 | -0.111 | 0.140 | 0.002 | -0.054 | -0.006 | -0.071 | -0.047 | 0.219 | -0.061 | -0.029 | 1 | 0.471 | 0.477 | -0.280 | -0.083 | 0.095 | 0.836 | -0.039 | -0.180 | -0.158 |
| | Sig. (2-tailed) | 0.439 | 0.000 | 0.000 | 0.931 | 0.031 | 0.810 | 0.005 | 0.060 | 0.000 | 0.015 | 0.248 | | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.123 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| BEDS | Pearson Correlation | 0.037 | -0.004 | -0.059 | 0.103 | -0.052 | 0.092 | -0.057 | -0.166 | 0.163 | 0.020 | 0.035 | 0.471 | 1 | 0.946 | 0.056 | -0.077 | 0.080 | 0.421 | -0.126 | -0.090 | -0.312 |
| | Sig. (2-tailed) | 0.145 | 0.878 | 0.018 | 0.000 | 0.040 | 0.000 | 0.022 | 0.000 | 0.000 | 0.423 | 0.159 | 0.000 | | 0.000 | 0.025 | 0.002 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| BATH | Pearson Correlation | 0.006 | 0.008 | -0.033 | 0.091 | -0.080 | 0.056 | -0.054 | -0.126 | 0.167 | 0.004 | 0.010 | 0.477 | 0.946 | 1 | 0.041 | -0.089 | 0.086 | 0.430 | -0.072 | -0.102 | -0.292 |
| | Sig. (2-tailed) | 0.799 | 0.759 | 0.196 | 0.000 | 0.001 | 0.025 | 0.031 | 0.000 | 0.000 | 0.864 | 0.680 | 0.000 | 0.000 | | 0.103 | 0.000 | 0.001 | 0.000 | 0.004 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| TYPTRRD | Pearson Correlation | -0.026 | 0.063 | 0.016 | -0.054 | -0.016 | 0.156 | -0.068 | -0.189 | 0.154 | -0.097 | 0.185 | -0.280 | 0.056 | 0.041 | 1 | -0.142 | -0.111 | -0.344 | -0.052 | -0.442 | -0.444 |
| | Sig. (2-tailed) | 0.304 | 0.012 | 0.536 | 0.031 | 0.517 | 0.000 | 0.007 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.025 | 0.103 | | 0.000 | 0.000 | 0.000 | 0.040 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| TYP_CLUSTER | Pearson Correlation | 0.243 | -0.075 | -0.100 | -0.109 | 0.326 | 0.228 | -0.033 | -0.085 | -0.062 | -0.099 | 0.239 | -0.083 | -0.077 | -0.089 | -0.142 | 1 | -0.019 | -0.058 | -0.009 | -0.075 | -0.075 |
| | Sig. (2-tailed) | 0.000 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.185 | 0.001 | 0.014 | 0.000 | 0.000 | 0.001 | 0.002 | 0.000 | 0.000 | | 0.455 | 0.021 | 0.729 | 0.003 | 0.003 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| TYPSEMID | Pearson Correlation | 0.080 | -0.032 | -0.032 | -0.040 | 0.119 | 0.106 | -0.026 | -0.067 | 0.012 | -0.043 | 0.107 | 0.095 | 0.080 | 0.086 | -0.111 | -0.019 | 1 | -0.046 | -0.007 | -0.059 | -0.059 |
| | Sig. (2-tailed) | 0.001 | 0.203 | 0.198 | 0.109 | 0.000 | 0.000 | 0.299 | 0.008 | 0.622 | 0.089 | 0.000 | 0.000 | 0.001 | 0.001 | 0.000 | 0.455 | | 0.070 | 0.786 | 0.020 | 0.019 |

# Appendix F

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| TYPDETCH | Pearson Correlation | 0.062 | -0.158 | 0.145 | 0.007 | -0.019 | 0.014 | -0.081 | -0.087 | 0.228 | -0.037 | -0.020 | 0.836 | 0.421 | 0.430 | -0.344 | -0.058 | -0.046 | 1 | -0.021 | -0.181 | -0.182 |
| | Sig. (2-tailed) | 0.014 | 0.000 | 0.000 | 0.782 | 0.440 | 0.568 | 0.001 | 0.001 | 0.000 | 0.145 | 0.437 | 0.000 | 0.000 | 0.000 | 0.000 | 0.021 | 0.071 | | 0.401 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| TYPFLAT | Pearson Correlation | -0.071 | 0.116 | -0.036 | -0.040 | -0.027 | -0.078 | -0.012 | 0.103 | -0.023 | -0.036 | -0.036 | -0.039 | -0.126 | -0.072 | -0.052 | -0.009 | -0.007 | -0.021 | 1 | -0.027 | -0.027 |
| | Sig. (2-tailed) | 0.005 | 0.000 | 0.147 | 0.116 | 0.288 | 0.002 | 0.630 | 0.000 | 0.369 | 0.152 | 0.147 | 0.123 | 0.000 | 0.004 | 0.040 | 0.729 | 0.786 | 0.401 | | 0.281 | 0.279 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| TYPAPT | Pearson Correlation | 0.043 | -0.127 | -0.174 | 0.364 | -0.108 | -0.031 | 0.085 | -0.126 | -0.170 | 0.418 | -0.209 | -0.180 | -0.090 | -0.102 | -0.442 | -0.075 | -0.059 | -0.181 | -0.027 | 1 | -0.233 |
| | Sig. (2-tailed) | 0.085 | 0.000 | 0.000 | 0.000 | 0.000 | 0.220 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 | 0.021 | 0.000 | 0.281 | | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| TYPCONDO | Pearson Correlation | -0.171 | 0.201 | 0.086 | -0.240 | -0.014 | -0.289 | 0.092 | 0.477 | -0.194 | -0.207 | -0.130 | -0.158 | -0.312 | -0.292 | -0.444 | -0.075 | -0.059 | -0.182 | -0.027 | -0.233 | 1 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.001 | 0.000 | 0.591 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 | 0.019 | 0.000 | 0.279 | 0.000 | |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| STR_CBD | Pearson Correlation | 0.010 | -0.106 | 0.168 | -0.078 | 0.005 | -0.028 | 0.081 | -0.026 | 0.030 | -0.040 | 0.005 | 0.236 | 0.063 | 0.062 | -0.060 | -0.064 | 0.068 | 0.218 | -0.020 | 0.004 | -0.103 |
| | Sig. (2-tailed) | 0.688 | 0.000 | 0.000 | 0.002 | 0.844 | 0.260 | 0.001 | 0.295 | 0.229 | 0.111 | 0.857 | 0.000 | 0.012 | 0.014 | 0.016 | 0.011 | 0.007 | 0.000 | 0.432 | 0.885 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| STR_MIRROAD | Pearson Correlation | 0.184 | -0.332 | -0.055 | 0.345 | -0.017 | 0.086 | -0.130 | -0.123 | -0.159 | 0.378 | -0.084 | -0.297 | -0.209 | -0.210 | -0.258 | 0.102 | 0.004 | -0.250 | -0.012 | 0.525 | -0.024 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.028 | 0.000 | 0.512 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.867 | 0.000 | 0.633 | 0.000 | 0.333 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| STR_HIGHWAY | Pearson Correlation | 0.234 | -0.069 | -0.146 | 0.003 | 0.232 | 0.356 | -0.189 | -0.229 | 0.106 | -0.121 | 0.356 | -0.204 | 0.096 | 0.083 | 0.555 | 0.222 | 0.015 | -0.173 | -0.056 | -0.261 | -0.339 |
| | Sig. (2-tailed) | 0.000 | 0.013 | 0.000 | 0.906 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.003 | 0.000 | 0.000 | 0.596 | 0.000 | 0.045 | 0.000 | 0.000 |
| | N | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 |
| PRIMARY_SCH | Pearson Correlation | -0.067 | -0.204 | -0.025 | 0.387 | -0.233 | -0.125 | -0.027 | 0.025 | -0.145 | 0.327 | -0.226 | -0.141 | -0.046 | -0.036 | -0.216 | -0.009 | -0.037 | -0.149 | 0.020 | 0.565 | -0.152 |
| | Sig. (2-tailed) | 0.008 | 0.000 | 0.323 | 0.000 | 0.000 | 0.000 | 0.279 | 0.318 | 0.000 | 0.000 | 0.000 | 0.000 | 0.066 | 0.158 | 0.000 | 0.712 | 0.142 | 0.000 | 0.419 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| SECONDARY_SCH | Pearson Correlation | 0.453 | -0.267 | -0.199 | 0.151 | 0.323 | 0.363 | -0.117 | -0.345 | 0.051 | 0.136 | 0.198 | 0.072 | 0.126 | 0.104 | -0.109 | -0.082 | 0.090 | 0.102 | -0.104 | 0.263 | -0.192 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.042 | 0.000 | 0.000 | 0.004 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| UNIVERSITY | Pearson Correlation | 0.065 | 0.054 | -0.234 | 0.154 | 0.034 | 0.208 | -0.159 | -0.007 | -0.244 | 0.096 | 0.167 | -0.114 | 0.108 | 0.113 | -0.033 | -0.050 | 0.098 | -0.137 | -0.016 | 0.136 | 0.013 |
| | Sig. (2-tailed) | 0.009 | 0.033 | 0.000 | 0.000 | 0.180 | 0.000 | 0.000 | 0.796 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.190 | 0.047 | 0.000 | 0.000 | 0.535 | 0.000 | 0.603 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| HOSPITALS | Pearson Correlation | 0.315 | -0.073 | -0.192 | -0.005 | 0.307 | 0.441 | -0.200 | -0.277 | 0.015 | -0.064 | 0.399 | -0.345 | -0.022 | -0.044 | 0.619 | 0.083 | -0.029 | -0.303 | -0.051 | -0.241 | -0.308 |
| | Sig. (2-tailed) | 0.000 | 0.004 | 0.000 | 0.849 | 0.000 | 0.000 | 0.000 | 0.000 | 0.564 | 0.011 | 0.000 | 0.000 | 0.382 | 0.083 | 0.000 | 0.001 | 0.248 | 0.000 | 0.043 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| INSTITUTE | Pearson Correlation | 0.227 | -0.194 | -0.079 | 0.169 | 0.086 | 0.204 | -0.207 | 0.031 | -0.180 | -0.017 | 0.218 | -0.202 | 0.100 | 0.102 | 0.086 | -0.042 | 0.043 | -0.238 | -0.025 | 0.114 | -0.017 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.002 | 0.000 | 0.001 | 0.000 | 0.000 | 0.218 | 0.000 | 0.507 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.094 | 0.089 | 0.000 | 0.330 | 0.000 | 0.506 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| COMMERCIAL | Pearson Correlation | 0.036 | -0.321 | -0.015 | 0.448 | -0.201 | -0.063 | -0.046 | -0.067 | -0.139 | 0.402 | -0.213 | -0.215 | -0.247 | -0.232 | -0.341 | -0.001 | -0.022 | -0.188 | 0.068 | 0.603 | -0.012 |
| | Sig. (2-tailed) | 0.153 | 0.000 | 0.557 | 0.000 | 0.000 | 0.012 | 0.070 | 0.008 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.975 | 0.377 | 0.000 | 0.007 | 0.000 | 0.628 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| WORSHIP | Pearson Correlation | 0.121 | 0.087 | -0.096 | -0.195 | 0.261 | 0.273 | -0.057 | -0.169 | 0.027 | -0.132 | 0.293 | -0.228 | -0.078 | -0.102 | 0.560 | 0.142 | -0.057 | -0.184 | -0.033 | -0.335 | -0.255 |
| | Sig. (2-tailed) | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.022 | 0.000 | 0.283 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 | 0.024 | 0.000 | 0.184 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| GREEN | Pearson Correlation | -0.162 | -0.109 | 0.070 | 0.275 | -0.306 | -0.146 | 0.094 | -0.028 | -0.128 | 0.324 | -0.241 | 0.189 | -0.053 | -0.033 | -0.382 | -0.181 | 0.037 | 0.175 | 0.070 | 0.371 | 0.018 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.005 | 0.000 | 0.000 | 0.000 | 0.000 | 0.261 | 0.000 | 0.000 | 0.000 | 0.000 | 0.036 | 0.187 | 0.000 | 0.000 | 0.145 | 0.000 | 0.005 | 0.000 | 0.470 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| LAKES | Pearson Correlation | 0.127 | 0.114 | -0.288 | 0.042 | 0.172 | 0.210 | -0.118 | -0.017 | -0.091 | -0.037 | 0.175 | -0.243 | -0.008 | -0.015 | 0.023 | 0.024 | -0.050 | -0.240 | -0.016 | 0.104 | 0.076 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.094 | 0.000 | 0.000 | 0.000 | 0.499 | 0.000 | 0.140 | 0.000 | 0.000 | 0.750 | 0.545 | 0.358 | 0.331 | 0.046 | 0.000 | 0.527 | 0.000 | 0.002 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| INDUSTRY | Pearson Correlation | 0.018 | -0.177 | -0.078 | 0.315 | -0.111 | -0.087 | -0.061 | 0.044 | -0.198 | 0.331 | -0.193 | -0.222 | -0.236 | -0.231 | -0.264 | -0.169 | -0.046 | -0.204 | 0.046 | 0.466 | 0.114 |
| | Sig. (2-tailed) | 0.466 | 0.000 | 0.002 | 0.000 | 0.000 | 0.001 | 0.015 | 0.081 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.069 | 0.000 | 0.067 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| RECREATION | Pearson Correlation | 0.086 | 0.032 | -0.227 | 0.123 | 0.086 | 0.247 | -0.150 | -0.188 | -0.014 | 0.053 | 0.199 | -0.313 | -0.025 | -0.035 | 0.471 | 0.121 | 0.008 | -0.264 | -0.019 | -0.168 | -0.256 |
| | Sig. (2-tailed) | 0.001 | 0.199 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.568 | 0.036 | 0.000 | 0.000 | 0.318 | 0.161 | 0.000 | 0.000 | 0.760 | 0.000 | 0.445 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |

# Appendix F

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CEMETERY | Pearson Correlation | 0.152 | -0.250 | -0.056 | 0.257 | 0.007 | 0.027 | -0.054 | -0.109 | -0.075 | 0.316 | -0.132 | -0.038 | -0.248 | -0.242 | -0.364 | -0.222 | -0.008 | 0.008 | 0.057 | 0.398 | 0.139 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.027 | 0.000 | 0.770 | 0.281 | 0.032 | 0.000 | 0.003 | 0.000 | 0.000 | 0.133 | 0.000 | 0.000 | 0.000 | 0.000 | 0.752 | 0.745 | 0.024 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| FOREST | Pearson Correlation | -0.260 | 0.091 | 0.139 | -0.002 | -0.254 | -0.323 | 0.121 | 0.227 | -0.033 | 0.085 | -0.324 | 0.403 | 0.113 | 0.128 | -0.551 | -0.179 | 0.053 | 0.350 | 0.018 | 0.202 | 0.254 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.949 | 0.000 | 0.000 | 0.000 | 0.000 | 0.197 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.036 | 0.000 | 0.484 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| YOUNG | Pearson Correlation | -0.083 | 0.103 | 0.012 | -0.109 | 0.014 | -0.245 | 0.035 | 0.411 | -0.250 | -0.072 | -0.134 | -0.266 | -0.133 | -0.130 | -0.289 | -0.077 | -0.090 | -0.269 | 0.033 | 0.281 | 0.365 |
| | Sig. (2-tailed) | 0.001 | 0.000 | 0.639 | 0.000 | 0.580 | 0.000 | 0.169 | 0.000 | 0.000 | 0.004 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | 0.195 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| ELDERLY | Pearson Correlation | -0.165 | 0.058 | 0.140 | -0.030 | -0.186 | -0.130 | 0.090 | -0.011 | 0.147 | 0.024 | -0.166 | 0.518 | 0.209 | 0.219 | -0.268 | -0.150 | 0.079 | 0.459 | -0.016 | -0.058 | 0.049 |
| | Sig. (2-tailed) | 0.000 | 0.022 | 0.000 | 0.233 | 0.000 | 0.000 | 0.000 | 0.674 | 0.000 | 0.336 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.533 | 0.021 | 0.051 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| EMPLOY | Pearson Correlation | 0.078 | -0.036 | 0.098 | -0.179 | 0.139 | -0.092 | 0.033 | 0.233 | -0.135 | -0.173 | 0.044 | -0.188 | -0.081 | -0.094 | -0.016 | -0.020 | -0.059 | -0.182 | -0.007 | 0.068 | 0.132 |
| | Sig. (2-tailed) | 0.002 | 0.151 | 0.000 | 0.000 | 0.000 | 0.000 | 0.188 | 0.000 | 0.000 | 0.000 | 0.077 | 0.000 | 0.001 | 0.000 | 0.526 | 0.430 | 0.019 | 0.000 | 0.774 | 0.007 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| MALAY | Pearson Correlation | 0.239 | -0.071 | -0.194 | 0.038 | 0.254 | 0.296 | -0.123 | -0.173 | -0.046 | -0.034 | 0.285 | -0.396 | -0.112 | -0.122 | 0.436 | 0.176 | -0.040 | -0.343 | -0.005 | -0.122 | -0.200 |
| | Sig. (2-tailed) | 0.000 | 0.005 | 0.000 | 0.129 | 0.000 | 0.000 | 0.000 | 0.000 | 0.066 | 0.177 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.109 | 0.000 | 0.832 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| CHI | Pearson Correlation | -0.187 | -0.029 | 0.228 | -0.007 | -0.231 | -0.299 | 0.137 | 0.166 | 0.002 | 0.065 | -0.281 | 0.293 | 0.018 | 0.024 | -0.434 | -0.165 | 0.020 | 0.257 | 0.019 | 0.226 | 0.165 |
| | Sig. (2-tailed) | 0.000 | 0.245 | 0.000 | 0.788 | 0.000 | 0.000 | 0.000 | 0.000 | 0.947 | 0.010 | 0.000 | 0.000 | 0.482 | 0.331 | 0.000 | 0.000 | 0.432 | 0.000 | 0.443 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| IND | Pearson Correlation | -0.178 | 0.146 | 0.087 | -0.065 | -0.171 | -0.087 | 0.050 | -0.018 | 0.186 | -0.032 | -0.114 | 0.506 | 0.268 | 0.275 | -0.155 | -0.102 | 0.088 | 0.446 | -0.035 | -0.203 | 0.043 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.001 | 0.010 | 0.000 | 0.001 | 0.047 | 0.463 | 0.000 | 0.200 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.160 | 0.000 | 0.090 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix F

| STR_CBD | STR_MJRROAD | STR_HIGHWAY | PRIMARY_SCH | SECONDARY_SCH | UNIVERSITY | HOSPITALS | INSTITUTE | COMMERCIAL | WORSHIP | GREEN | LAKES | INDUSTRY | RECREATION | CEMETERY | FOREST | YOUNG | ELDERLY | EMPLOY | MALAY | CHI | IND |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.010 | 0.184 | 0.234 | -0.067 | 0.453 | 0.065 | 0.315 | 0.227 | 0.036 | 0.121 | -0.162 | 0.127 | 0.018 | 0.086 | 0.152 | -0.260 | -0.083 | -0.165 | 0.078 | 0.239 | -0.187 | -0.178 |
| 0.688 | 0.000 | 0.000 | 0.008 | 0.000 | 0.009 | 0.000 | 0.000 | 0.153 | 0.000 | 0.000 | 0.000 | 0.466 | 0.001 | 0.000 | 0.000 | 0.001 | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.106 | -0.332 | -0.069 | -0.204 | -0.267 | 0.054 | -0.073 | -0.194 | -0.321 | 0.087 | -0.109 | 0.114 | -0.177 | 0.032 | -0.250 | 0.091 | 0.103 | 0.058 | -0.036 | -0.071 | -0.029 | 0.146 |
| 0.000 | 0.000 | 0.013 | 0.000 | 0.000 | 0.033 | 0.004 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.199 | 0.000 | 0.000 | 0.000 | 0.022 | 0.151 | 0.005 | 0.245 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.168 | -0.055 | -0.146 | -0.025 | -0.199 | -0.234 | -0.192 | -0.079 | -0.015 | -0.096 | 0.070 | -0.288 | -0.078 | -0.227 | -0.056 | 0.139 | 0.012 | 0.140 | 0.098 | -0.194 | 0.228 | 0.087 |
| 0.000 | 0.028 | 0.000 | 0.323 | 0.000 | 0.000 | 0.000 | 0.002 | 0.557 | 0.000 | 0.005 | 0.000 | 0.002 | 0.000 | 0.027 | 0.000 | 0.639 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.078 | 0.345 | 0.003 | 0.387 | 0.151 | 0.154 | -0.005 | 0.169 | 0.448 | -0.195 | 0.275 | 0.042 | 0.315 | 0.123 | 0.257 | -0.002 | -0.109 | -0.030 | -0.179 | 0.038 | -0.007 | -0.065 |
| 0.002 | 0.000 | 0.906 | 0.000 | 0.000 | 0.000 | 0.849 | 0.000 | 0.000 | 0.000 | 0.000 | 0.094 | 0.000 | 0.000 | 0.000 | 0.949 | 0.000 | 0.233 | 0.000 | 0.129 | 0.788 | 0.010 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.005 | -0.017 | 0.232 | -0.233 | 0.323 | 0.034 | 0.307 | 0.086 | -0.201 | 0.261 | -0.306 | 0.172 | -0.111 | 0.086 | 0.007 | -0.254 | 0.014 | -0.186 | 0.139 | 0.254 | -0.231 | -0.171 |
| 0.844 | 0.512 | 0.000 | 0.000 | 0.000 | 0.180 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.770 | 0.000 | 0.580 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.028 | 0.086 | 0.356 | -0.125 | 0.363 | 0.208 | 0.441 | 0.204 | -0.063 | 0.273 | -0.146 | 0.210 | -0.087 | 0.247 | 0.027 | -0.323 | -0.245 | -0.130 | -0.092 | 0.296 | -0.299 | -0.087 |
| 0.260 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.012 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.281 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.081 | -0.130 | -0.189 | -0.027 | -0.117 | -0.159 | -0.200 | -0.207 | -0.046 | -0.057 | 0.094 | -0.118 | -0.061 | -0.150 | -0.054 | 0.121 | 0.035 | 0.090 | 0.033 | -0.123 | 0.137 | 0.050 |
| 0.001 | 0.000 | 0.000 | 0.279 | 0.000 | 0.000 | 0.000 | 0.000 | 0.070 | 0.022 | 0.000 | 0.000 | 0.015 | 0.000 | 0.032 | 0.000 | 0.169 | 0.000 | 0.188 | 0.000 | 0.000 | 0.047 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.026 | -0.123 | -0.229 | 0.025 | -0.345 | -0.007 | -0.277 | 0.031 | -0.067 | -0.169 | -0.028 | -0.017 | 0.044 | -0.188 | -0.109 | 0.227 | 0.411 | -0.011 | 0.233 | -0.173 | 0.166 | -0.018 |
| 0.295 | 0.000 | 0.000 | 0.318 | 0.000 | 0.796 | 0.000 | 0.218 | 0.008 | 0.000 | 0.261 | 0.499 | 0.081 | 0.000 | 0.000 | 0.000 | 0.000 | 0.674 | 0.000 | 0.000 | 0.000 | 0.463 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.030 | -0.159 | 0.106 | -0.145 | 0.051 | -0.244 | 0.015 | -0.180 | -0.139 | 0.027 | -0.128 | -0.091 | -0.198 | -0.014 | -0.075 | -0.033 | -0.250 | 0.147 | -0.135 | -0.046 | 0.002 | 0.186 |
| 0.229 | 0.000 | 0.000 | 0.000 | 0.042 | 0.000 | 0.564 | 0.000 | 0.000 | 0.283 | 0.000 | 0.000 | 0.000 | 0.568 | 0.003 | 0.197 | 0.000 | 0.000 | 0.000 | 0.066 | 0.947 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.040 | 0.378 | -0.121 | 0.327 | 0.136 | 0.096 | -0.064 | -0.017 | 0.402 | -0.132 | 0.324 | -0.037 | 0.331 | 0.053 | 0.316 | 0.085 | -0.072 | 0.024 | -0.173 | -0.034 | 0.065 | -0.033 |
| 0.111 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.011 | 0.507 | 0.000 | 0.000 | 0.000 | 0.140 | 0.000 | 0.036 | 0.000 | 0.001 | 0.004 | 0.336 | 0.000 | 0.177 | 0.010 | 0.200 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.005 | -0.084 | 0.356 | -0.226 | 0.198 | 0.167 | 0.399 | 0.218 | -0.213 | 0.293 | -0.241 | 0.175 | -0.193 | 0.199 | -0.132 | -0.324 | -0.134 | -0.166 | 0.044 | 0.285 | -0.281 | -0.114 |
| 0.857 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.077 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.236 | -0.297 | -0.204 | -0.141 | 0.072 | -0.114 | -0.345 | -0.202 | -0.215 | -0.228 | 0.189 | -0.243 | -0.222 | -0.313 | -0.038 | 0.403 | -0.266 | 0.518 | -0.188 | -0.396 | 0.293 | 0.506 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.004 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.133 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.063 | -0.209 | 0.096 | -0.046 | 0.126 | 0.109 | -0.022 | 0.100 | -0.247 | -0.078 | -0.053 | -0.008 | -0.236 | -0.025 | -0.248 | 0.113 | -0.133 | 0.209 | -0.081 | -0.112 | 0.018 | 0.268 |
| 0.012 | 0.000 | 0.001 | 0.066 | 0.000 | 0.000 | 0.382 | 0.000 | 0.000 | 0.002 | 0.036 | 0.750 | 0.000 | 0.318 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.482 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.062 | -0.210 | 0.083 | -0.036 | 0.104 | 0.113 | -0.044 | 0.102 | -0.232 | -0.102 | -0.033 | -0.015 | -0.231 | -0.035 | -0.242 | 0.128 | -0.130 | 0.219 | -0.094 | -0.122 | 0.024 | 0.279 |
| 0.014 | 0.000 | 0.001 | 0.158 | 0.000 | 0.000 | 0.083 | 0.000 | 0.000 | 0.000 | 0.187 | 0.545 | 0.000 | 0.161 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.331 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.060 | -0.258 | 0.555 | -0.216 | -0.109 | -0.033 | 0.619 | 0.086 | -0.341 | 0.560 | -0.382 | 0.023 | -0.264 | 0.471 | -0.364 | -0.551 | -0.289 | -0.268 | -0.016 | 0.436 | -0.434 | -0.155 |
| 0.016 | 0.000 | 0.000 | 0.000 | 0.000 | 0.190 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.358 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.526 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.064 | 0.102 | 0.222 | -0.009 | -0.083 | -0.050 | 0.083 | -0.042 | -0.001 | 0.142 | -0.181 | 0.024 | -0.169 | 0.121 | -0.222 | -0.179 | -0.077 | -0.150 | -0.020 | 0.176 | -0.165 | -0.103 |
| 0.011 | 0.000 | 0.000 | 0.712 | 0.001 | 0.047 | 0.001 | 0.094 | 0.975 | 0.000 | 0.000 | 0.331 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.430 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.064 | 0.004 | 0.015 | -0.037 | 0.090 | 0.098 | -0.029 | 0.043 | -0.023 | -0.057 | 0.037 | -0.050 | -0.046 | 0.006 | -0.006 | 0.057 | -0.090 | 0.079 | -0.059 | -0.040 | 0.020 | 0.084 |
| 0.007 | 0.867 | 0.596 | 0.142 | 0.007 | 0.001 | 0.248 | 0.089 | 0.377 | 0.024 | 0.145 | 0.046 | 0.069 | 0.760 | 0.752 | 0.036 | 0.000 | 0.003 | 0.019 | 0.109 | 0.432 | 0.000 |

Appendix F

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.218 | -0.250 | -0.173 | -0.149 | 0.102 | -0.137 | -0.303 | -0.238 | -0.188 | -0.184 | 0.175 | -0.240 | -0.204 | -0.264 | 0.008 | 0.350 | -0.269 | 0.459 | -0.182 | -0.343 | 0.257 | 0.446 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.745 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.020 | -0.012 | -0.056 | 0.020 | -0.104 | -0.016 | -0.051 | -0.025 | 0.068 | -0.033 | 0.070 | -0.016 | 0.046 | -0.019 | 0.057 | 0.018 | 0.033 | -0.016 | -0.007 | -0.005 | 0.019 | -0.035 |
| 0.432 | 0.633 | 0.045 | 0.419 | 0.000 | 0.535 | 0.043 | 0.330 | 0.007 | 0.184 | 0.005 | 0.527 | 0.067 | 0.445 | 0.024 | 0.484 | 0.195 | 0.533 | 0.774 | 0.832 | 0.443 | 0.160 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.004 | 0.525 | -0.261 | 0.565 | 0.263 | 0.136 | -0.241 | 0.114 | 0.603 | -0.335 | 0.371 | 0.104 | 0.466 | -0.168 | 0.398 | 0.202 | 0.281 | -0.058 | 0.068 | -0.122 | 0.226 | -0.203 |
| 0.885 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.021 | 0.007 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.103 | -0.024 | -0.339 | -0.152 | -0.192 | 0.013 | -0.308 | -0.017 | -0.012 | -0.255 | 0.018 | 0.076 | 0.114 | -0.256 | 0.139 | 0.254 | 0.365 | 0.049 | 0.132 | -0.200 | 0.165 | 0.047 |
| 0.000 | 0.333 | 0.000 | 0.000 | 0.000 | 0.603 | 0.000 | 0.506 | 0.628 | 0.000 | 0.470 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.051 | 0.000 | 0.000 | 0.000 | 0.090 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 1 | -0.172 | -0.155 | -0.018 | 0.194 | -0.078 | -0.348 | -0.142 | -0.108 | -0.202 | 0.289 | -0.415 | -0.219 | -0.543 | -0.118 | 0.442 | -0.037 | 0.459 | 0.179 | -0.490 | 0.521 | 0.328 |
| | 0.000 | 0.000 | 0.466 | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.139 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.172 | 1 | -0.093 | 0.551 | 0.129 | 0.237 | 0.028 | 0.367 | 0.766 | -0.323 | 0.229 | 0.003 | 0.567 | 0.090 | 0.445 | -0.138 | 0.207 | -0.349 | 0.021 | 0.189 | -0.044 | -0.447 |
| 0.000 | | 0.001 | 0.000 | 0.000 | 0.000 | 0.268 | 0.000 | 0.000 | 0.000 | 0.000 | 0.891 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.408 | 0.000 | 0.080 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.155 | -0.093 | 1 | -0.150 | -0.141 | 0.386 | 0.845 | 0.283 | -0.232 | 0.706 | -0.642 | 0.589 | -0.086 | 0.862 | -0.293 | -0.860 | -0.195 | -0.622 | -0.080 | 0.817 | -0.810 | -0.437 |
| 0.000 | 0.001 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.004 | 0.000 | 0.000 | 0.000 |
| 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 | 1,295 |
| -0.018 | 0.551 | -0.150 | 1 | 0.005 | 0.241 | -0.214 | 0.262 | 0.766 | -0.360 | 0.464 | 0.073 | 0.513 | 0.021 | 0.207 | 0.179 | 0.229 | -0.098 | -0.044 | -0.021 | 0.107 | -0.236 |
| 0.466 | 0.000 | 0.000 | | 0.854 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.004 | 0.000 | 0.408 | 0.000 | 0.000 | 0.000 | 0.000 | 0.081 | 0.395 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.194 | 0.129 | -0.141 | 0.005 | 1 | 0.104 | -0.089 | 0.002 | 0.071 | -0.154 | 0.206 | 0.037 | 0.012 | -0.198 | 0.163 | 0.189 | -0.025 | 0.172 | 0.048 | -0.190 | 0.215 | 0.106 |
| 0.000 | 0.000 | 0.000 | 0.854 | | 0.000 | 0.000 | 0.922 | 0.005 | 0.000 | 0.000 | 0.139 | 0.628 | 0.000 | 0.000 | 0.000 | 0.318 | 0.000 | 0.054 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.078 | 0.237 | 0.386 | 0.241 | 0.104 | 1 | 0.106 | 0.662 | 0.112 | -0.206 | 0.100 | 0.547 | 0.083 | 0.332 | -0.248 | -0.056 | 0.257 | -0.250 | 0.023 | 0.178 | -0.198 | -0.198 |
| 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.026 | 0.000 | 0.000 | 0.360 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.348 | 0.028 | 0.845 | -0.214 | -0.089 | 0.106 | 1 | 0.296 | -0.193 | 0.770 | -0.682 | 0.441 | 0.057 | 0.762 | -0.084 | -0.937 | -0.048 | -0.745 | 0.159 | 0.822 | -0.740 | -0.607 |
| 0.000 | 0.268 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.024 | 0.000 | 0.001 | 0.000 | 0.054 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.142 | 0.367 | 0.283 | 0.262 | 0.002 | 0.662 | 0.296 | 1 | 0.143 | -0.188 | -0.159 | 0.320 | 0.139 | 0.188 | -0.230 | -0.248 | 0.411 | -0.412 | 0.368 | 0.216 | -0.138 | -0.379 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.922 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.108 | 0.766 | -0.232 | 0.766 | 0.071 | 0.112 | -0.193 | 0.143 | 1 | -0.376 | 0.527 | 0.026 | 0.708 | 0.012 | 0.596 | 0.089 | 0.136 | -0.155 | -0.114 | 0.022 | 0.110 | -0.314 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.005 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.309 | 0.000 | 0.621 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.376 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.303 | -0.323 | 0.706 | -0.360 | -0.154 | -0.206 | 0.770 | -0.188 | -0.376 | 1 | -0.576 | 0.295 | 0.008 | 0.637 | -0.067 | -0.712 | -0.172 | -0.490 | 0.040 | 0.648 | -0.619 | -0.379 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.752 | 0.000 | 0.008 | 0.000 | 0.000 | 0.000 | 0.109 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.289 | 0.229 | -0.642 | 0.464 | 0.206 | 0.100 | -0.682 | -0.159 | 0.527 | -0.576 | 1 | -0.313 | 0.215 | -0.447 | 0.248 | 0.489 | -0.034 | 0.506 | -0.243 | -0.552 | 0.548 | 0.330 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.181 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.415 | 0.003 | 0.589 | 0.073 | 0.037 | 0.547 | 0.441 | 0.320 | 0.026 | 0.295 | -0.313 | 1 | 0.247 | 0.594 | 0.025 | -0.395 | 0.224 | -0.481 | 0.024 | 0.464 | -0.472 | -0.387 |
| 0.000 | 0.891 | 0.001 | 0.004 | 0.139 | 0.000 | 0.000 | 0.000 | 0.309 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.324 | 0.000 | 0.000 | 0.000 | 0.335 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.219 | 0.567 | -0.086 | 0.513 | 0.012 | 0.083 | 0.057 | 0.139 | 0.708 | 0.008 | 0.215 | 0.247 | 1 | 0.209 | 0.764 | -0.074 | 0.354 | -0.385 | 0.107 | 0.222 | -0.080 | -0.506 |
| 0.000 | 0.000 | 0.002 | 0.000 | 0.628 | 0.001 | 0.024 | 0.000 | 0.000 | 0.752 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.007 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.547 | 0.091 | 0.862 | 0.021 | -0.198 | 0.332 | 0.762 | 0.188 | 0.012 | 0.637 | -0.447 | 0.594 | 0.209 | 1 | -0.855 | -0.804 | -0.144 | -0.701 | -0.209 | 0.862 | -0.867 | -0.539 |
| 0.000 | 0.000 | 0.000 | 0.408 | 0.000 | 0.000 | 0.000 | 0.000 | 0.621 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.030 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |

Appendix F

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| -0.118 | 0.445 | -0.293 | 0.207 | 0.163 | -0.248 | -0.084 | -0.230 | 0.596 | -0.067 | 0.248 | 0.025 | 0.764 | -0.055 | 1 | 0.051 | 0.076 | -0.092 | -0.040 | 0.022 | 0.090 | -0.233 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.008 | 0.000 | 0.324 | 0.000 | 0.030 | | 0.044 | 0.002 | 0.000 | 0.113 | 0.389 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.442 | -0.138 | -0.860 | 0.179 | 0.189 | -0.056 | -0.933 | -0.248 | 0.089 | -0.712 | 0.689 | -0.395 | -0.074 | -0.806 | 0.051 | 1 | 0.108 | 0.799 | -0.059 | -0.887 | 0.795 | 0.659 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.026 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.003 | 0.000 | 0.044 | | 0.000 | 0.000 | 0.018 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.037 | 0.207 | -0.195 | 0.229 | -0.025 | 0.257 | -0.048 | 0.411 | 0.138 | -0.172 | -0.034 | 0.224 | 0.354 | -0.146 | 0.076 | 0.108 | 1 | -0.458 | 0.791 | 0.046 | 0.106 | -0.560 |
| 0.139 | 0.000 | 0.000 | 0.000 | 0.318 | 0.000 | 0.054 | 0.000 | 0.000 | 0.000 | 0.181 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | | 0.000 | 0.000 | 0.066 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.459 | -0.349 | -0.622 | -0.098 | 0.172 | -0.250 | -0.745 | -0.412 | -0.155 | -0.490 | 0.506 | -0.481 | -0.385 | -0.701 | -0.092 | 0.799 | -0.458 | 1 | -0.425 | -0.844 | 0.664 | 0.951 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.179 | 0.021 | -0.080 | -0.044 | 0.048 | 0.023 | 0.159 | 0.368 | -0.114 | 0.040 | -0.243 | 0.024 | 0.103 | -0.209 | -0.040 | -0.059 | 0.791 | -0.425 | 1 | -0.004 | 0.238 | -0.519 |
| 0.000 | 0.408 | 0.004 | 0.081 | 0.054 | 0.360 | 0.000 | 0.000 | 0.000 | 0.109 | 0.000 | 0.335 | 0.000 | 0.000 | 0.113 | 0.018 | 0.000 | 0.000 | | 0.869 | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| -0.490 | 0.189 | 0.817 | -0.021 | -0.190 | 0.178 | 0.822 | 0.216 | 0.022 | 0.648 | -0.552 | 0.464 | 0.222 | 0.862 | 0.022 | -0.887 | 0.046 | -0.844 | -0.004 | 1 | -0.944 | -0.750 |
| 0.000 | 0.000 | 0.000 | 0.395 | 0.000 | 0.000 | 0.000 | 0.000 | 0.376 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.389 | 0.000 | 0.066 | 0.000 | 0.869 | | 0.000 | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.521 | -0.044 | -0.810 | 0.107 | 0.215 | -0.198 | -0.740 | -0.138 | 0.110 | -0.619 | 0.548 | -0.472 | -0.080 | -0.863 | 0.090 | 0.795 | 0.106 | 0.664 | 0.238 | -0.944 | 1 | 0.516 |
| 0.000 | 0.080 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| 0.328 | -0.447 | -0.433 | -0.236 | 0.106 | -0.198 | -0.607 | -0.379 | -0.314 | -0.375 | 0.330 | -0.387 | -0.508 | -0.535 | -0.233 | 0.659 | -0.560 | 0.951 | -0.519 | -0.750 | 0.516 | 1 |
| 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | |
| 1,580 | 1,580 | 1,295 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |

Appendix G

**Table A8.2**: The results of a high correlation between local parameter estimates

| | | Intercept | Strdist | Flrarea | Beds | Typtrrd | Typsemid | Typdetch | Typcondo | CBD | Primarysch | Secondarysch | Hospitals | Commercial | Lakes | Industry | Recreation | Malay | Timesavings |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Intercept | Pearson Correlation | 1 | -0.108 | -0.118 | 0.388 | -0.490 | -0.283 | -0.180 | -0.680 | -0.630 | 0.140 | 0.391 | 0.025 | -0.333 | 0.422 | -0.141 | -0.541 | -0.466 | -0.242 |
| | Sig. (2-tailed) | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.330 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Strdist | Pearson Correlation | -0.108 | 1 | 0.353 | -0.622 | -0.083 | -0.123 | -0.285 | 0.075 | -0.282 | -0.247 | 0.005 | -0.308 | 0.237 | -0.219 | 0.390 | 0.353 | -0.376 | -0.164 |
| | Sig. (2-tailed) | 0.000 | | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 | 0.839 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Flrarea | Pearson Correlation | -0.118 | 0.353 | 1 | -0.568 | -0.496 | -0.653 | -0.808 | -0.015 | -0.333 | -0.863 | 0.378 | 0.195 | 0.633 | 0.044 | 0.212 | -0.020 | -0.406 | -0.094 |
| | Sig. (2-tailed) | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.541 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.079 | 0.000 | 0.417 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Beds | Pearson Correlation | 0.388 | -0.622 | -0.568 | 1 | 0.202 | 0.339 | 0.503 | -0.036 | -0.012 | 0.431 | -0.288 | 0.029 | -0.461 | 0.412 | -0.208 | -0.289 | 0.175 | 0.393 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.154 | 0.625 | 0.000 | 0.000 | 0.254 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Typtrrd | Pearson Correlation | -0.490 | -0.083 | -0.496 | 0.202 | 1 | 0.947 | 0.888 | 0.799 | 0.645 | 0.499 | -0.775 | -0.078 | -0.504 | 0.112 | 0.438 | 0.250 | 0.303 | 0.601 |
| | Sig. (2-tailed) | 0.000 | 0.001 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Typsemid | Pearson Correlation | -0.283 | -0.123 | -0.653 | 0.339 | 0.947 | 1 | 0.954 | 0.667 | 0.546 | 0.668 | -0.794 | 0.002 | -0.683 | 0.174 | 0.346 | 0.158 | 0.259 | 0.544 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.945 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Typdetch | Pearson Correlation | -0.180 | -0.285 | -0.808 | 0.503 | 0.888 | 0.954 | 1 | 0.523 | 0.569 | 0.750 | -0.690 | -0.050 | -0.704 | 0.213 | 0.173 | 0.052 | 0.370 | 0.536 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.049 | 0.000 | 0.000 | 0.000 | 0.040 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Typcondo | Pearson Correlation | -0.680 | 0.075 | -0.015 | -0.036 | 0.799 | 0.667 | 0.523 | 1 | 0.403 | 0.039 | -0.775 | 0.138 | -0.127 | 0.020 | 0.535 | 0.487 | 0.042 | 0.594 |
| | Sig. (2-tailed) | 0.000 | 0.003 | 0.541 | 0.154 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.119 | 0.000 | 0.000 | 0.000 | 0.421 | 0.000 | 0.000 | 0.097 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| CBD | Pearson Correlation | -0.630 | -0.282 | -0.333 | -0.012 | 0.645 | 0.546 | 0.569 | 0.403 | 1 | 0.280 | -0.265 | 0.000 | -0.188 | 0.051 | 0.034 | -0.099 | 0.702 | 0.435 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.625 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.990 | 0.000 | 0.044 | 0.176 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Primarysch | Pearson Correlation | 0.140 | -0.247 | -0.863 | 0.431 | 0.499 | 0.668 | 0.750 | 0.039 | 0.280 | 1 | -0.317 | -0.070 | -0.626 | 0.040 | -0.189 | -0.048 | 0.296 | 0.091 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.119 | 0.000 | | 0.000 | 0.005 | 0.000 | 0.116 | 0.000 | 0.057 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Secondarysch | Pearson Correlation | 0.391 | 0.005 | 0.378 | -0.288 | -0.775 | -0.794 | -0.690 | -0.775 | -0.265 | -0.317 | 1 | 0.080 | 0.368 | 0.085 | -0.445 | -0.496 | -0.097 | -0.454 |
| | Sig. (2-tailed) | 0.000 | 0.839 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.002 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Hospitals | Pearson Correlation | 0.025 | -0.308 | 0.195 | 0.029 | -0.078 | 0.002 | -0.050 | 0.138 | 0.000 | -0.070 | 0.080 | 1 | -0.153 | 0.398 | -0.236 | -0.332 | -0.099 | 0.193 |
| | Sig. (2-tailed) | 0.330 | 0.000 | 0.000 | 0.254 | 0.002 | 0.945 | 0.049 | 0.000 | 0.990 | 0.005 | 0.002 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Commercial | Pearson Correlation | -0.333 | 0.237 | 0.633 | -0.461 | -0.504 | -0.683 | -0.704 | -0.127 | -0.188 | -0.626 | 0.368 | -0.153 | 1 | -0.400 | -0.281 | 0.212 | 0.094 | -0.222 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Lakes | Pearson Correlation | 0.422 | -0.219 | 0.044 | 0.412 | 0.112 | 0.174 | 0.213 | 0.020 | 0.051 | 0.040 | 0.085 | 0.398 | -0.400 | 1 | 0.099 | -0.767 | -0.122 | 0.663 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.079 | 0.000 | 0.000 | 0.000 | 0.000 | 0.421 | 0.044 | 0.116 | 0.001 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Industry | Pearson Correlation | -0.141 | 0.390 | 0.212 | -0.208 | 0.438 | 0.346 | 0.173 | 0.535 | 0.034 | -0.189 | -0.445 | -0.236 | -0.281 | 0.099 | 1 | 0.327 | -0.533 | 0.210 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.176 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Recreation | Pearson Correlation | -0.541 | 0.353 | -0.020 | -0.289 | 0.250 | 0.158 | 0.052 | 0.487 | -0.099 | -0.048 | -0.496 | -0.332 | 0.212 | -0.767 | 0.327 | 1 | -0.158 | -0.275 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.417 | 0.000 | 0.000 | 0.000 | 0.040 | 0.000 | 0.000 | 0.057 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Malay | Pearson Correlation | -0.466 | -0.376 | -0.406 | 0.175 | 0.303 | 0.259 | 0.370 | 0.042 | 0.702 | 0.296 | -0.097 | -0.099 | 0.094 | -0.122 | -0.533 | -0.158 | 1 | 0.280 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.097 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Timesavings | Pearson Correlation | -0.242 | -0.164 | -0.094 | 0.393 | 0.601 | 0.544 | 0.536 | 0.594 | 0.435 | 0.091 | -0.454 | 0.193 | -0.222 | 0.663 | 0.210 | -0.275 | 0.280 | 1 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix G

**Table A8.3:** The results of a high correlation between local parameter estimates

| | | Intercept | Nexdist | Fltarea | Beds | Typurd | Typsemid | Typdetch | Typcondo | CBD | Primarysch | Secondarysch | Hospitals | Commercial | Lakes | Industry | Recreation | Malay | Timesavings |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Intercept | Pearson Correlation | 1 | -0.448 | -0.253 | 0.340 | -0.481 | -0.238 | -0.143 | -0.653 | -0.757 | 0.194 | 0.332 | 0.241 | -0.284 | 0.145 | -0.210 | -0.314 | -0.603 | -0.269 |
| | Sig. (2-tailed) | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Nexdist | Pearson Correlation | -0.448 | 1 | 0.400 | -0.627 | 0.182 | -0.059 | -0.180 | 0.195 | 0.077 | -0.323 | -0.147 | -0.569 | 0.509 | -0.139 | 0.604 | 0.560 | -0.123 | -0.315 |
| | Sig. (2-tailed) | 0.000 | | 0.000 | 0.000 | 0.000 | 0.019 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Fltarea | Pearson Correlation | -0.253 | 0.400 | 1 | -0.567 | -0.437 | -0.625 | -0.793 | -0.107 | -0.156 | -0.756 | 0.318 | -0.129 | 0.677 | 0.191 | 0.339 | 0.110 | -0.382 | -0.114 |
| | Sig. (2-tailed) | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Beds | Pearson Correlation | 0.340 | -0.627 | -0.567 | 1 | 0.119 | 0.290 | 0.458 | 0.088 | -0.103 | 0.354 | -0.233 | 0.251 | -0.543 | 0.228 | -0.300 | -0.221 | 0.129 | 0.486 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Typurd | Pearson Correlation | -0.481 | 0.182 | -0.437 | 0.119 | 1 | 0.927 | 0.865 | 0.766 | 0.589 | 0.491 | -0.802 | -0.438 | -0.489 | -0.014 | 0.440 | 0.367 | 0.461 | 0.369 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.585 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Typsemid | Pearson Correlation | -0.238 | -0.059 | -0.625 | 0.290 | 0.927 | 1 | 0.955 | 0.638 | 0.464 | 0.687 | -0.809 | -0.317 | -0.718 | 0.063 | 0.298 | 0.250 | 0.411 | 0.439 |
| | Sig. (2-tailed) | 0.000 | 0.019 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.012 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Typdetch | Pearson Correlation | -0.143 | -0.180 | -0.793 | 0.458 | 0.865 | 0.955 | 1 | 0.570 | 0.462 | 0.724 | -0.709 | -0.171 | -0.763 | 0.050 | 0.101 | 0.103 | 0.477 | 0.448 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.047 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Typcondo | Pearson Correlation | -0.653 | 0.195 | -0.107 | 0.088 | 0.766 | 0.638 | 0.570 | 1 | 0.461 | 0.156 | -0.700 | -0.054 | -0.213 | 0.116 | 0.278 | 0.417 | 0.296 | 0.455 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.031 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| CBD | Pearson Correlation | -0.757 | 0.077 | -0.156 | -0.103 | 0.589 | 0.464 | 0.462 | 0.461 | 1 | 0.135 | -0.272 | -0.187 | -0.157 | -0.013 | 0.034 | -0.142 | 0.819 | 0.430 |
| | Sig. (2-tailed) | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.607 | 0.179 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Primarysch | Pearson Correlation | 0.194 | -0.323 | -0.756 | 0.354 | 0.491 | 0.687 | 0.724 | 0.156 | 0.135 | 1 | -0.331 | 0.033 | -0.686 | 0.018 | -0.152 | -0.090 | 0.266 | 0.193 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.190 | 0.000 | 0.476 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Secondarysch | Pearson Correlation | 0.332 | -0.147 | 0.318 | -0.233 | -0.802 | -0.809 | -0.709 | -0.700 | -0.272 | -0.331 | 1 | 0.472 | 0.403 | 0.071 | -0.519 | -0.597 | -0.225 | -0.348 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.005 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Hospitals | Pearson Correlation | 0.241 | -0.569 | -0.129 | 0.251 | -0.438 | -0.317 | -0.171 | -0.054 | -0.187 | 0.033 | 0.472 | 1 | -0.082 | 0.162 | -0.836 | -0.540 | -0.052 | 0.044 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.031 | 0.000 | 0.190 | 0.000 | | 0.001 | 0.000 | 0.000 | 0.000 | 0.038 | 0.078 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Commercial | Pearson Correlation | -0.284 | 0.509 | 0.677 | -0.543 | -0.489 | -0.718 | -0.763 | -0.213 | -0.157 | -0.686 | 0.403 | -0.082 | 1 | -0.324 | 0.021 | 0.205 | -0.140 | -0.462 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | | 0.000 | 0.415 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Lakes | Pearson Correlation | 0.145 | -0.139 | 0.191 | 0.228 | -0.014 | 0.063 | 0.050 | 0.116 | -0.013 | 0.018 | 0.071 | 0.162 | -0.324 | 1 | 0.098 | -0.471 | -0.194 | 0.668 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.585 | 0.012 | 0.047 | 0.000 | 0.607 | 0.476 | 0.005 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Industry | Pearson Correlation | -0.210 | 0.604 | 0.339 | -0.300 | 0.440 | 0.298 | 0.101 | 0.278 | 0.034 | -0.152 | -0.519 | -0.836 | 0.021 | 0.098 | 1 | 0.613 | -0.293 | 0.016 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.179 | 0.000 | 0.000 | 0.000 | 0.415 | 0.000 | | 0.000 | 0.000 | 0.534 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Recreation | Pearson Correlation | -0.314 | 0.560 | 0.110 | -0.221 | 0.367 | 0.250 | 0.103 | 0.417 | -0.142 | -0.090 | -0.597 | -0.540 | 0.205 | -0.471 | 0.613 | 1 | -0.219 | -0.284 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Malay | Pearson Correlation | -0.603 | -0.123 | -0.382 | 0.129 | 0.461 | 0.411 | 0.477 | 0.296 | 0.819 | 0.266 | -0.225 | -0.052 | -0.140 | -0.194 | -0.293 | -0.219 | 1 | 0.390 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.038 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Timesavings | Pearson Correlation | -0.269 | -0.315 | -0.114 | 0.486 | 0.369 | 0.439 | 0.448 | 0.455 | 0.430 | 0.193 | -0.348 | 0.044 | -0.462 | 0.668 | 0.016 | -0.284 | 0.390 | 1 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.078 | 0.000 | 0.000 | 0.534 | 0.000 | 0.000 | |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |

**. Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

**Table A8.4**: The results of a high correlation between local parameter estimates

| | | Intercept | Strstn1 | Strstn3 | Flrarea | Beds | Typtrrd | Typsemid | Typdetch | Typcondo | CBD | Primarysch | Secondarysch | Hospitals | Commercial | Lakes | Industry | Recreation | Malay | Timesavings |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Intercept | Pearson Correlation | 1 | 0.512 | -0.113 | 0.039 | 0.338 | -0.536 | -0.414 | -0.294 | -0.647 | -0.702 | 0.124 | 0.538 | 0.261 | 0.193 | 0.537 | -0.247 | -0.561 | -0.590 | -0.237 |
| | Sig. (2-tailed) | | 0.000 | 0.000 | 0.123 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Strstn1 | Pearson Correlation | 0.512 | 1 | 0.046 | -0.097 | 0.279 | -0.502 | -0.479 | -0.268 | -0.733 | -0.283 | 0.185 | 0.646 | 0.146 | 0.286 | 0.160 | -0.666 | -0.439 | -0.034 | -0.471 |
| | Sig. (2-tailed) | 0.000 | | 0.068 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.180 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Strstn3 | Pearson Correlation | -0.113 | 0.046 | 1 | -0.200 | 0.100 | -0.207 | -0.102 | -0.078 | -0.228 | -0.041 | 0.199 | -0.149 | -0.367 | 0.128 | -0.398 | -0.612 | 0.216 | 0.371 | -0.244 |
| | Sig. (2-tailed) | 0.000 | 0.068 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.105 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Flrarea | Pearson Correlation | 0.039 | -0.097 | -0.200 | 1 | -0.605 | -0.495 | -0.650 | -0.804 | 0.085 | -0.467 | -0.842 | 0.326 | 0.349 | 0.782 | 0.136 | 0.239 | 0.032 | -0.537 | 0.011 |
| | Sig. (2-tailed) | 0.123 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.205 | 0.000 | 0.654 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Beds | Pearson Correlation | 0.338 | 0.279 | 0.100 | -0.605 | 1 | 0.255 | 0.353 | 0.532 | -0.104 | 0.138 | 0.470 | -0.240 | 0.017 | -0.452 | 0.406 | -0.350 | -0.451 | 0.290 | 0.281 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.498 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Typtrrd | Pearson Correlation | -0.536 | -0.502 | -0.207 | -0.495 | 0.255 | 1 | 0.943 | 0.897 | 0.754 | 0.797 | 0.403 | -0.683 | -0.048 | -0.790 | 0.102 | 0.420 | 0.031 | 0.508 | 0.666 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.059 | 0.000 | 0.000 | 0.000 | 0.213 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Typsemid | Pearson Correlation | -0.414 | -0.479 | -0.102 | -0.650 | 0.353 | 0.943 | 1 | 0.953 | 0.642 | 0.718 | 0.564 | -0.747 | -0.016 | -0.896 | 0.072 | 0.320 | 0.034 | 0.481 | 0.563 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.513 | 0.000 | 0.004 | 0.000 | 0.180 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Typdetch | Pearson Correlation | -0.294 | -0.268 | -0.078 | -0.804 | 0.532 | 0.897 | 0.953 | 1 | 0.459 | 0.728 | 0.682 | -0.617 | -0.096 | -0.925 | 0.128 | 0.151 | -0.098 | 0.565 | 0.507 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Typcondo | Pearson Correlation | -0.647 | -0.733 | -0.228 | 0.085 | -0.104 | 0.754 | 0.642 | 0.459 | 1 | 0.491 | -0.204 | -0.763 | 0.169 | -0.307 | 0.042 | 0.629 | 0.283 | 0.171 | 0.685 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.094 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| CBD | Pearson Correlation | -0.702 | -0.283 | -0.041 | -0.467 | 0.138 | 0.797 | 0.718 | 0.728 | 0.491 | 1 | 0.372 | -0.438 | -0.112 | -0.673 | -0.054 | 0.105 | -0.054 | 0.821 | 0.518 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.105 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.032 | 0.000 | 0.033 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Primarysch | Pearson Correlation | 0.124 | 0.185 | 0.199 | -0.842 | 0.470 | 0.403 | 0.564 | 0.682 | -0.204 | 0.372 | 1 | -0.095 | -0.199 | -0.725 | 0.043 | -0.297 | -0.220 | 0.394 | -0.013 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.089 | 0.000 | 0.000 | 0.000 | 0.595 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Secondarysch | Pearson Correlation | 0.538 | 0.646 | -0.149 | 0.326 | -0.240 | -0.683 | -0.747 | -0.617 | -0.763 | -0.438 | -0.095 | 1 | 0.090 | 0.486 | 0.184 | -0.351 | -0.409 | -0.314 | -0.456 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Hospitals | Pearson Correlation | 0.261 | 0.146 | -0.367 | 0.349 | 0.017 | -0.048 | -0.016 | -0.096 | 0.169 | -0.112 | -0.199 | 0.090 | 1 | 0.043 | 0.641 | -0.009 | -0.553 | -0.243 | 0.348 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.498 | 0.059 | 0.513 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.085 | 0.000 | 0.712 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Commercial | Pearson Correlation | 0.193 | 0.286 | 0.128 | 0.782 | -0.452 | -0.790 | -0.896 | -0.925 | -0.307 | -0.673 | -0.725 | 0.486 | 0.043 | 1 | -0.140 | -0.151 | 0.179 | -0.518 | -0.440 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.085 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Lakes | Pearson Correlation | 0.537 | 0.160 | -0.398 | 0.136 | 0.406 | 0.102 | 0.072 | 0.128 | 0.042 | -0.054 | 0.043 | 0.184 | 0.641 | -0.140 | 1 | 0.020 | -0.871 | -0.172 | 0.629 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.004 | 0.000 | 0.094 | 0.032 | 0.089 | 0.000 | 0.000 | 0.000 | | 0.423 | 0.000 | 0.000 | 0.001 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Industry | Pearson Correlation | -0.247 | -0.666 | -0.612 | 0.239 | -0.350 | 0.420 | 0.320 | 0.151 | 0.629 | 0.105 | -0.297 | -0.351 | -0.009 | -0.151 | 0.020 | 1 | 0.318 | -0.364 | 0.319 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.712 | 0.000 | 0.423 | | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Recreation | Pearson Correlation | -0.561 | -0.439 | 0.216 | 0.032 | -0.451 | 0.031 | 0.034 | -0.098 | 0.283 | -0.054 | -0.220 | -0.409 | -0.553 | 0.179 | -0.871 | 0.318 | 1 | -0.078 | -0.409 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.205 | 0.000 | 0.213 | 0.180 | 0.000 | 0.000 | 0.033 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.002 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Malay | Pearson Correlation | -0.590 | -0.034 | 0.371 | -0.537 | 0.290 | 0.508 | 0.481 | 0.565 | 0.171 | 0.821 | 0.394 | -0.314 | -0.243 | -0.518 | -0.172 | -0.364 | -0.078 | 1 | 0.311 |
| | Sig. (2-tailed) | 0.000 | 0.180 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Timesavings | Pearson Correlation | -0.237 | -0.471 | -0.244 | 0.011 | 0.281 | 0.666 | 0.563 | 0.507 | 0.685 | 0.518 | -0.013 | -0.456 | 0.348 | -0.440 | 0.629 | 0.319 | -0.409 | 0.311 | 1 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.654 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.595 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |

** Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix G

**Table A8.5:** The results of a high correlation between local parameter estimates

| | | Intercept | Netstn1 | Netstn2 | Netstn3 | Netstn4 | Firarea | Beds | Typrnd | Typsemd | Typdetch | Typcondo |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Intercept | Pearson Correlation | 1 | 0.047 | -0.161 | -0.045 | -0.489 | -0.152 | 0.161 | -0.465 | -0.271 | -0.223 | -0.721 |
| | Sig. (2-tailed) | | 0.062 | 0.000 | 0.074 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Netstn1 | Pearson Correlation | 0.047 | 1 | 0.783 | 0.719 | 0.522 | -0.482 | 0.404 | -0.098 | 0.047 | 0.202 | -0.123 |
| | Sig. (2-tailed) | 0.062 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.061 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Netstn2 | Pearson Correlation | -0.161 | 0.783 | 1 | 0.909 | 0.687 | -0.298 | 0.424 | -0.120 | -0.009 | 0.146 | -0.116 |
| | Sig. (2-tailed) | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.714 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Netstn3 | Pearson Correlation | -0.045 | 0.719 | 0.909 | 1 | 0.659 | -0.190 | 0.267 | -0.286 | -0.211 | -0.054 | -0.342 |
| | Sig. (2-tailed) | 0.074 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.032 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Netstn4 | Pearson Correlation | -0.489 | 0.522 | 0.687 | 0.659 | 1 | -0.467 | 0.299 | 0.330 | 0.334 | 0.468 | 0.189 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Firarea | Pearson Correlation | -0.152 | -0.482 | -0.298 | -0.190 | -0.467 | 1 | -0.578 | -0.437 | -0.631 | -0.798 | -0.129 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Beds | Pearson Correlation | 0.161 | 0.404 | 0.424 | 0.267 | 0.299 | -0.578 | 1 | 0.087 | 0.257 | 0.432 | 0.018 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.001 | 0.000 | 0.000 | 0.485 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Typrnd | Pearson Correlation | -0.465 | -0.098 | -0.120 | -0.286 | 0.330 | -0.437 | 0.087 | 1 | 0.933 | 0.868 | 0.753 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Typsemd | Pearson Correlation | -0.271 | 0.047 | -0.009 | -0.211 | 0.336 | -0.631 | 0.257 | 0.933 | 1 | 0.957 | 0.629 |
| | Sig. (2-tailed) | 0.000 | 0.061 | 0.714 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Typdetch | Pearson Correlation | -0.223 | 0.202 | 0.146 | -0.054 | 0.468 | -0.798 | 0.432 | 0.868 | 0.957 | 1 | 0.561 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.032 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Typcondo | Pearson Correlation | -0.721 | -0.123 | -0.116 | -0.342 | 0.189 | -0.129 | 0.018 | 0.753 | 0.629 | 0.561 | 1 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.485 | 0.000 | 0.000 | 0.000 | |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| CBD | Pearson Correlation | -0.780 | 0.114 | 0.277 | 0.195 | 0.688 | -0.196 | -0.085 | 0.663 | 0.539 | 0.528 | 0.506 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Primarysch | Pearson Correlation | 0.045 | 0.278 | 0.266 | 0.145 | 0.380 | -0.726 | 0.532 | 0.531 | 0.693 | 0.768 | 0.283 |
| | Sig. (2-tailed) | 0.071 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Secondarysch | Pearson Correlation | 0.261 | 0.218 | 0.274 | 0.498 | -0.080 | 0.357 | -0.338 | -0.760 | -0.786 | -0.718 | -0.666 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Hospitals | Pearson Correlation | 0.073 | 0.672 | 0.509 | 0.425 | 0.082 | -0.144 | 0.202 | -0.446 | -0.328 | -0.199 | -0.058 |
| | Sig. (2-tailed) | 0.003 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.021 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Commercial | Pearson Correlation | -0.067 | -0.386 | -0.375 | -0.195 | -0.316 | 0.707 | -0.532 | -0.525 | -0.724 | -0.787 | -0.209 |
| | Sig. (2-tailed) | 0.008 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Lakes | Pearson Correlation | 0.107 | -0.206 | 0.161 | 0.115 | -0.065 | 0.208 | 0.117 | 0.036 | 0.107 | 0.040 | -0.038 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.010 | 0.000 | 0.000 | 0.153 | 0.000 | 0.111 | 0.135 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Industry | Pearson Correlation | -0.045 | -0.776 | -0.632 | -0.604 | -0.428 | 0.356 | -0.374 | 0.416 | 0.270 | 0.082 | 0.233 |
| | Sig. (2-tailed) | 0.076 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Recreation | Pearson Correlation | -0.412 | -0.508 | -0.446 | -0.578 | -0.247 | 0.119 | -0.048 | 0.346 | 0.347 | 0.165 | 0.671 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.058 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Malev | Pearson Correlation | -0.619 | 0.349 | 0.363 | 0.317 | 0.814 | -0.398 | 0.156 | 0.486 | 0.436 | 0.495 | 0.303 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Timesavings | Pearson Correlation | -0.453 | 0.231 | 0.654 | 0.457 | 0.590 | -0.156 | 0.463 | 0.284 | 0.350 | 0.395 | 0.297 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |

| | | CBD | Primarysch | Secondarysch | Hospitals | Commercial | Lakes | Industry | Recreation | Malev | Timesavings |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Intercept | Pearson Correlation | -0.780 | 0.045 | 0.261 | 0.073 | -0.067 | 0.107 | -0.045 | -0.412 | -0.619 | -0.453 |
| | Sig. (2-tailed) | 0.000 | 0.071 | 0.000 | 0.003 | 0.008 | 0.000 | 0.076 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Netstn1 | Pearson Correlation | 0.114 | 0.278 | 0.218 | 0.672 | -0.386 | -0.206 | -0.776 | -0.508 | 0.349 | 0.231 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Netstn2 | Pearson Correlation | 0.277 | 0.266 | 0.274 | 0.509 | -0.375 | 0.161 | -0.632 | -0.446 | 0.363 | 0.654 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Netstn3 | Pearson Correlation | 0.195 | 0.145 | 0.498 | 0.425 | -0.195 | 0.115 | -0.604 | -0.578 | 0.317 | 0.457 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Netstn4 | Pearson Correlation | 0.688 | 0.380 | -0.080 | 0.082 | -0.316 | -0.065 | -0.428 | -0.247 | 0.814 | 0.590 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.002 | 0.001 | 0.000 | 0.010 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Firarea | Pearson Correlation | -0.196 | -0.726 | 0.357 | -0.144 | 0.707 | 0.208 | 0.356 | 0.119 | -0.398 | -0.156 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Beds | Pearson Correlation | -0.085 | 0.532 | -0.338 | 0.202 | -0.532 | 0.117 | -0.374 | -0.048 | 0.156 | 0.463 |
| | Sig. (2-tailed) | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.058 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Typrnd | Pearson Correlation | 0.663 | 0.531 | -0.760 | -0.446 | -0.525 | 0.036 | 0.416 | 0.346 | 0.486 | 0.284 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.153 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Typsemd | Pearson Correlation | 0.539 | 0.693 | -0.786 | -0.328 | -0.724 | 0.107 | 0.270 | 0.347 | 0.436 | 0.350 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Typdetch | Pearson Correlation | 0.528 | 0.768 | -0.718 | -0.199 | -0.787 | 0.040 | 0.082 | 0.165 | 0.495 | 0.395 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.111 | 0.001 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Typcondo | Pearson Correlation | 0.506 | 0.283 | -0.666 | -0.058 | -0.209 | -0.038 | 0.233 | 0.671 | 0.303 | 0.297 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.021 | 0.000 | 0.139 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| CBD | Pearson Correlation | 1 | 0.218 | -0.284 | -0.262 | -0.276 | -0.031 | 0.074 | -0.013 | 0.822 | 0.497 |
| | Sig. (2-tailed) | | 0.000 | 0.000 | 0.000 | 0.000 | 0.216 | 0.003 | 0.592 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Primarysch | Pearson Correlation | 0.218 | 1 | -0.414 | 0.020 | -0.761 | 0.300 | -0.095 | -0.061 | 0.344 | 0.430 |
| | Sig. (2-tailed) | 0.000 | | 0.000 | 0.423 | 0.000 | 0.000 | 0.000 | 0.016 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Secondarysch | Pearson Correlation | -0.284 | -0.414 | 1 | 0.429 | 0.434 | -0.029 | -0.400 | -0.554 | -0.242 | -0.253 |
| | Sig. (2-tailed) | 0.000 | 0.000 | | 0.000 | 0.000 | 0.251 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Hospitals | Pearson Correlation | -0.262 | 0.020 | 0.429 | 1 | -0.040 | -0.134 | -0.829 | -0.348 | -0.106 | 0.031 |
| | Sig. (2-tailed) | 0.000 | 0.422 | 0.000 | | 0.113 | 0.000 | 0.000 | 0.000 | 0.000 | 0.223 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Commercial | Pearson Correlation | -0.276 | -0.761 | 0.434 | -0.040 | 1 | -0.329 | [illegible] | 0.115 | -0.234 | -0.521 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.113 | | 0.000 | [illegible] | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Lakes | Pearson Correlation | -0.031 | 0.300 | -0.029 | -0.134 | -0.329 | 1 | 0.271 | -0.160 | -0.286 | 0.560 |
| | Sig. (2-tailed) | 0.216 | 0.000 | 0.251 | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Industry | Pearson Correlation | 0.074 | -0.095 | -0.400 | -0.829 | [illegible] | 0.271 | 1 | 0.444 | -0.290 | -0.106 |
| | Sig. (2-tailed) | 0.003 | 0.000 | 0.000 | 0.000 | [illegible] | 0.000 | | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Recreation | Pearson Correlation | -0.013 | -0.061 | -0.554 | -0.348 | 0.115 | -0.160 | 0.444 | 1 | -0.174 | -0.023 |
| | Sig. (2-tailed) | 0.592 | 0.016 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 | 0.389 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Malev | Pearson Correlation | 0.822 | 0.344 | -0.242 | -0.106 | -0.234 | -0.286 | -0.290 | -0.174 | 1 | 0.380 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Timesavings | Pearson Correlation | 0.497 | 0.430 | -0.253 | 0.031 | -0.521 | 0.560 | -0.106 | -0.023 | 0.380 | 1 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.223 | 0.000 | 0.000 | 0.000 | 0.389 | 0.000 | |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

## Scatter Plots of Detecting Potential Collinearity among Local Parameter Estimates in Model 8.1-Model 8.2

The potential multicollinearity of local parameter estimates were detected by using scatter plots that can be performed within SPSS environment. The results of scatter plots analysis are shown below:

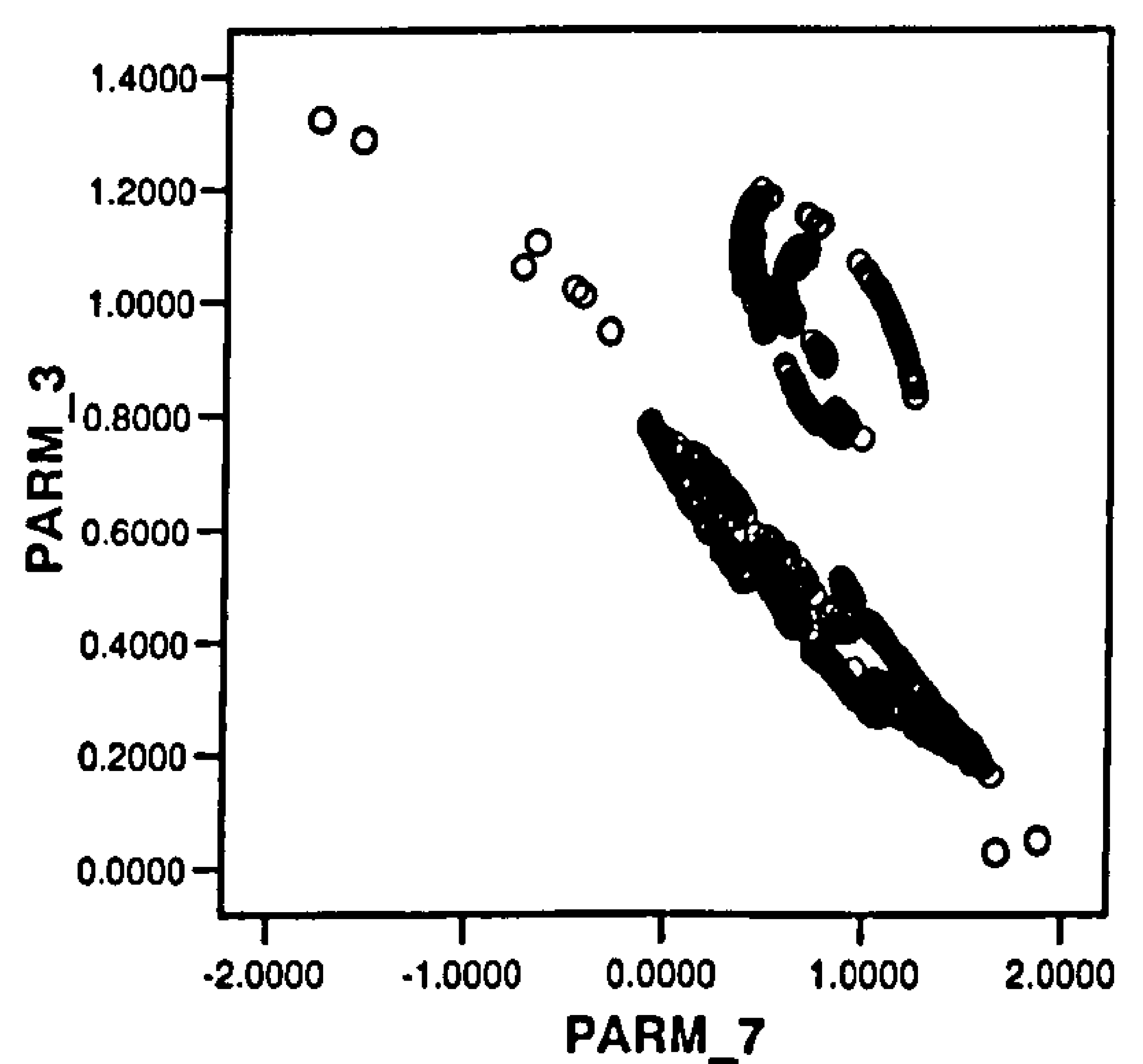



**Figure II.1**: Scatter plot of FLRAREA and TYPDETCH variables

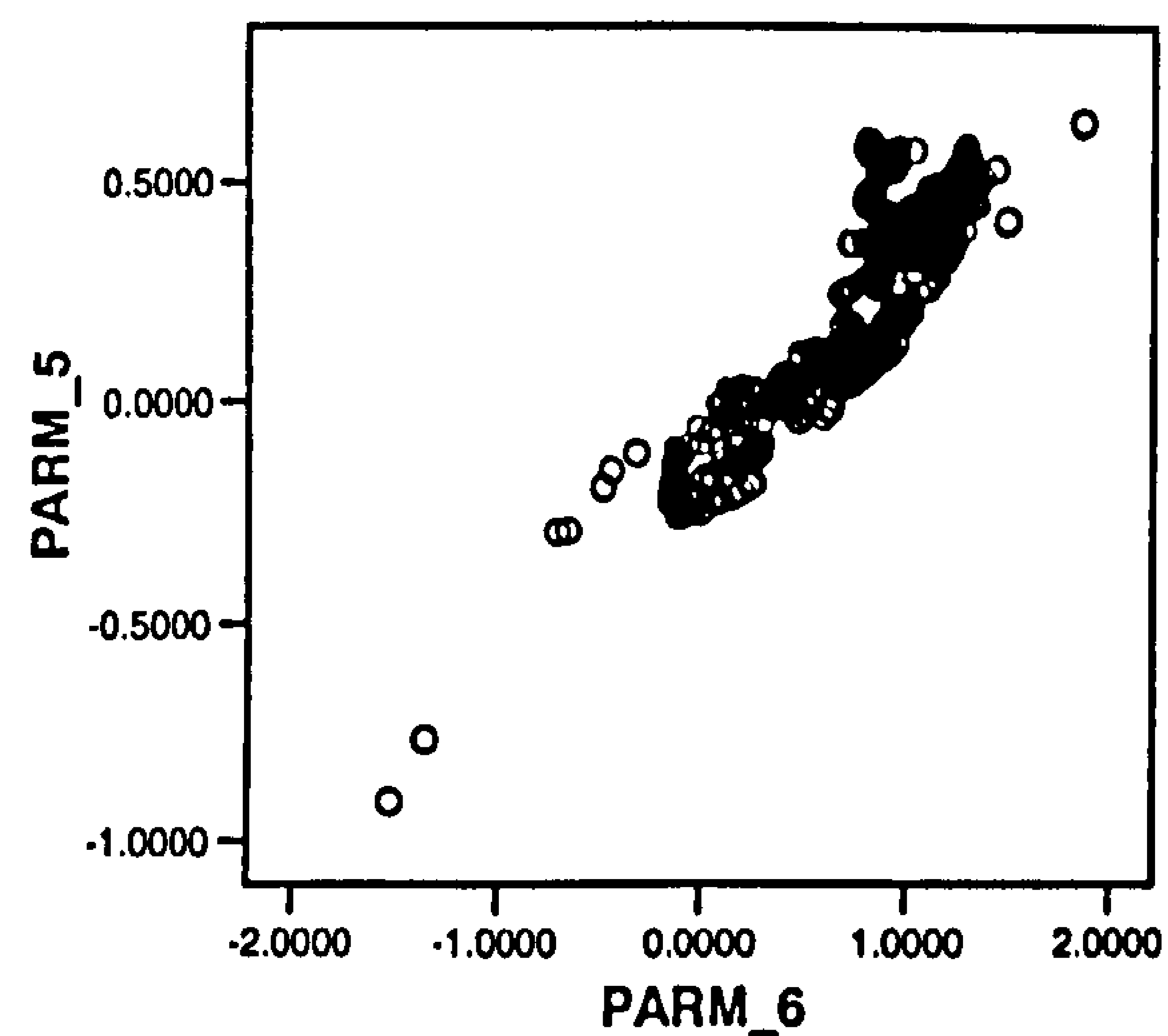



**Figure II.2**: Scatter plot of TYPTRRD and TYPSEMID variables

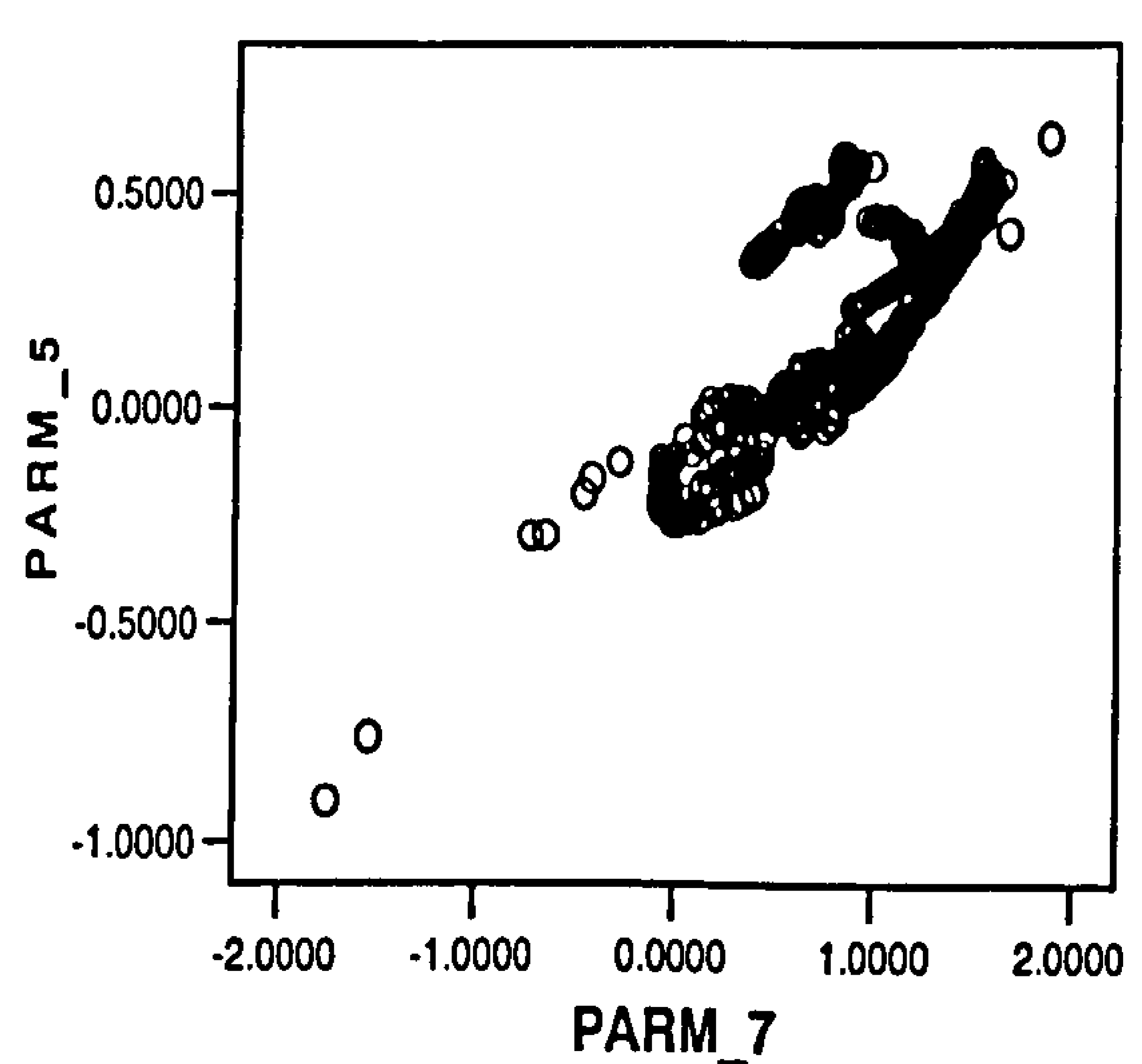



**Figure II.3**: Scatter plot of TYPTRRD and TYPDETCH variables

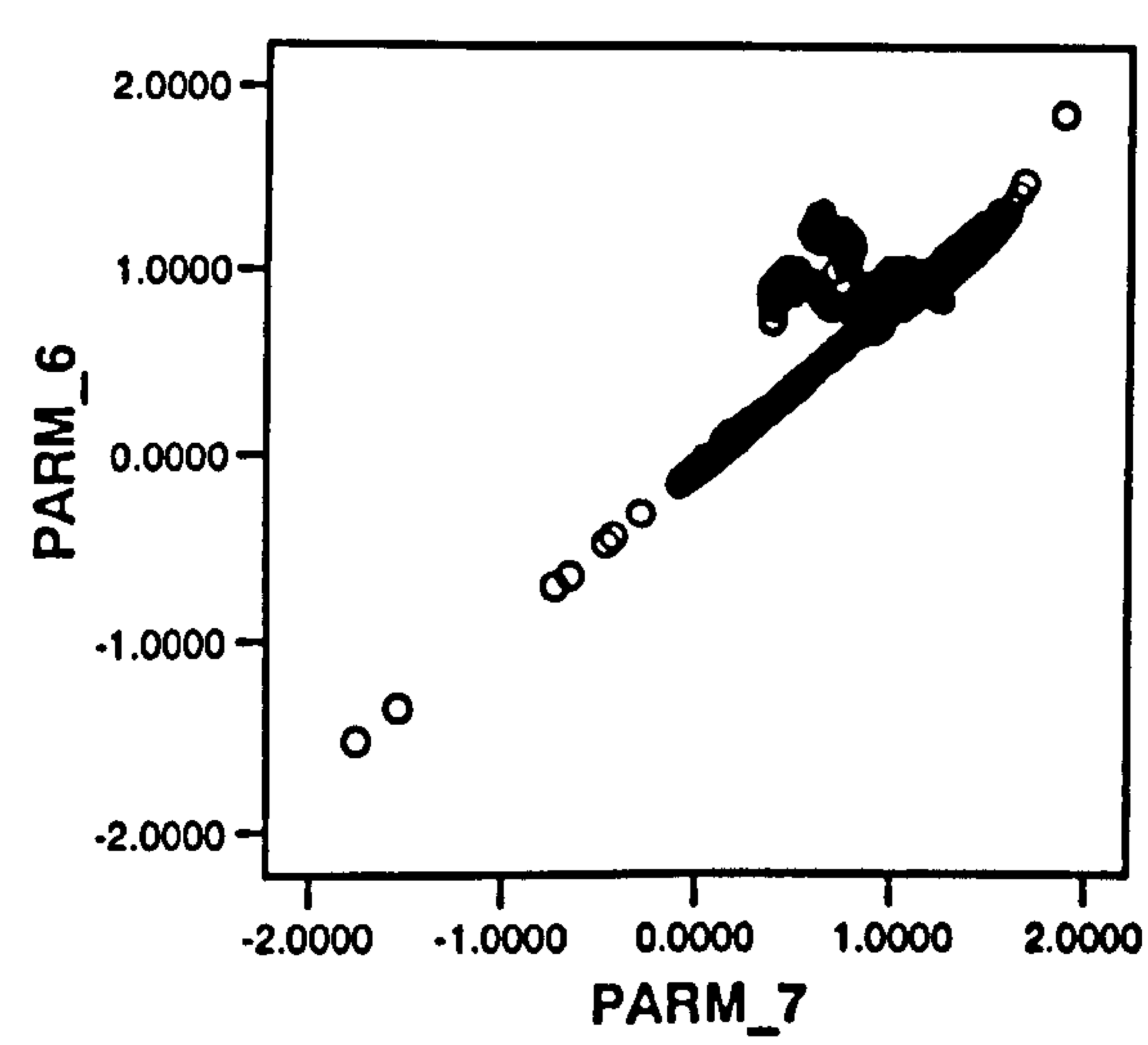



**Figure II.4**: Scatter plot of TYPSEMID and TYPDETCH variables

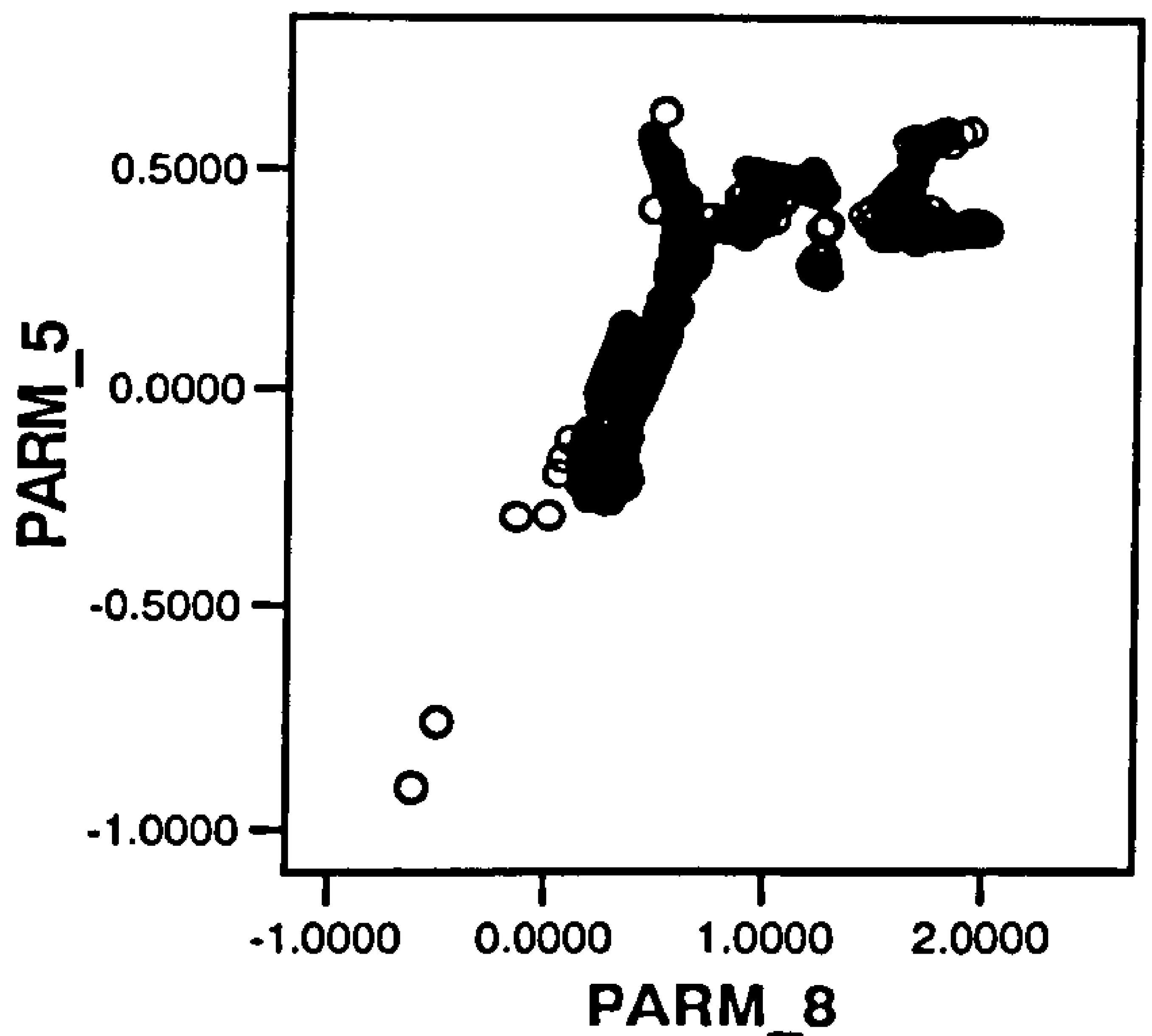



**Figure II.5**: Scatter plot of TYPCONDO and TYPTRRD variables

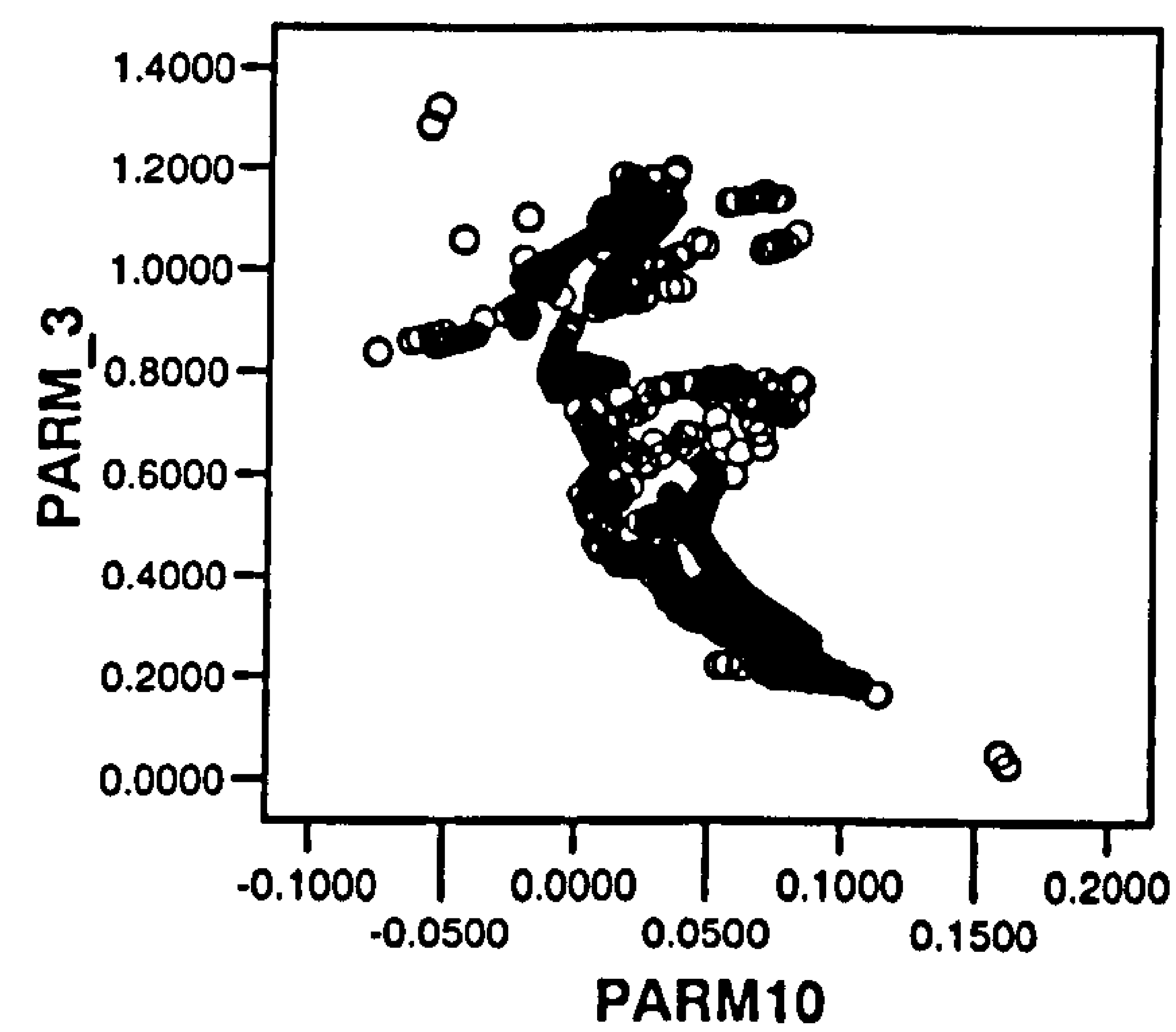



**Figure II.6**: Scatter plot of FLRAREA and PRIMARYSCH variables

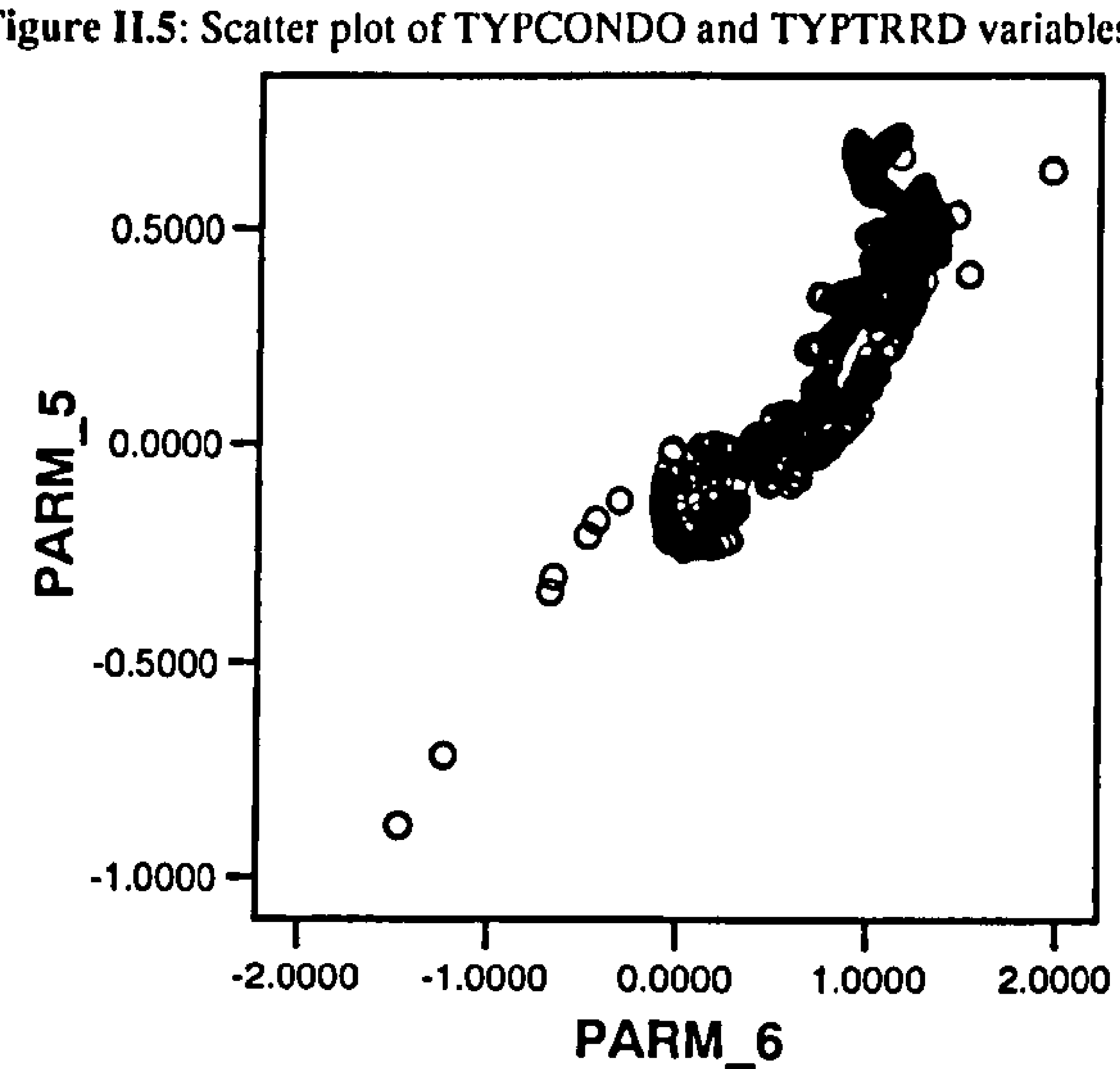



**Figure II.7**: Scatter plot of TYPTRRD and TYPSEMID variables

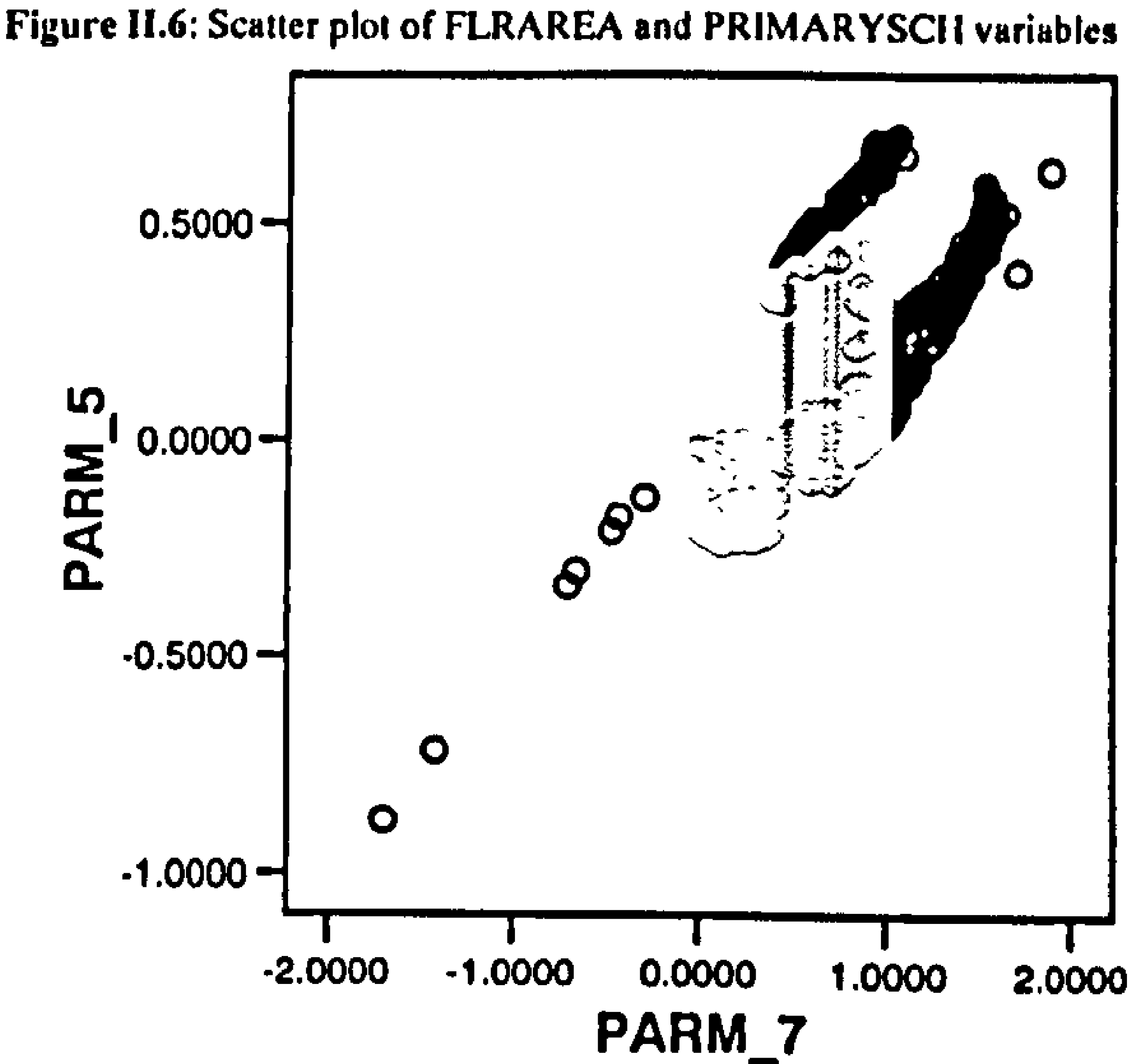



**Figure II.8**: Scatter plot of TYPTRRD and TYPDETCH variables

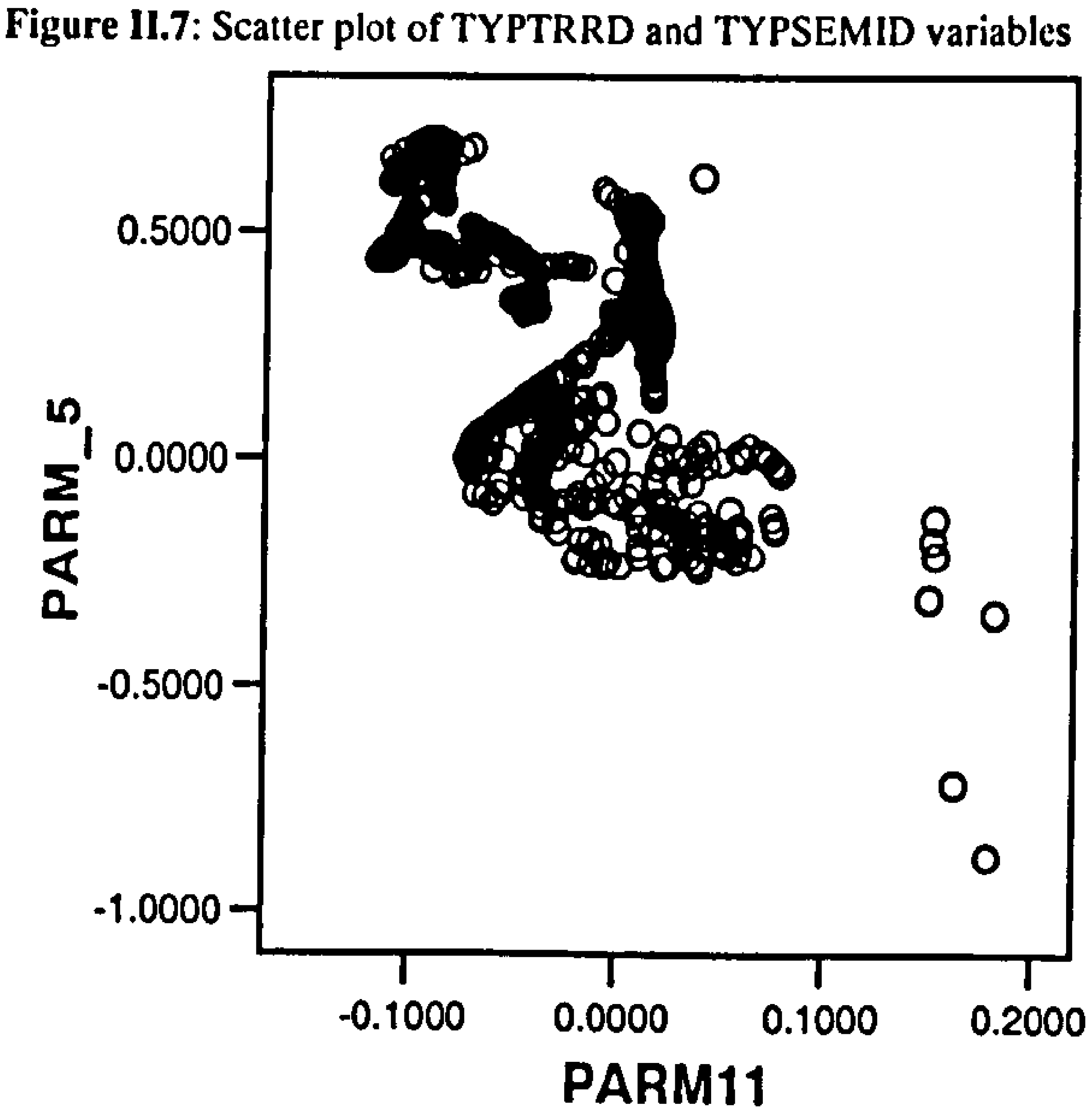



**Figure II.9**: Scatter plot of TYPTRRD and SECONDARYSCH variables

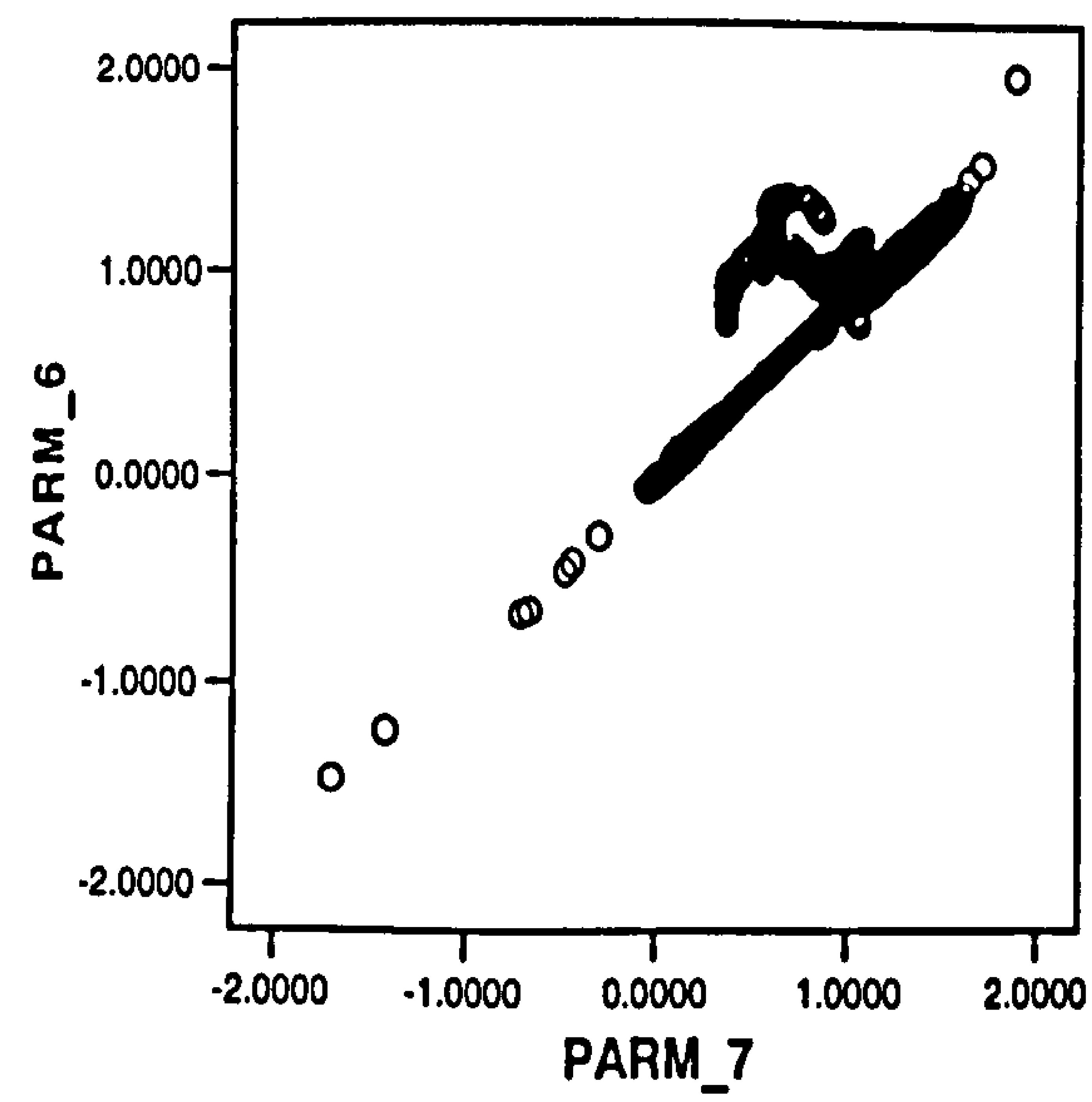



**Figure II.10**: Scatter plot of TYPSEMID and TYPDETCH variables

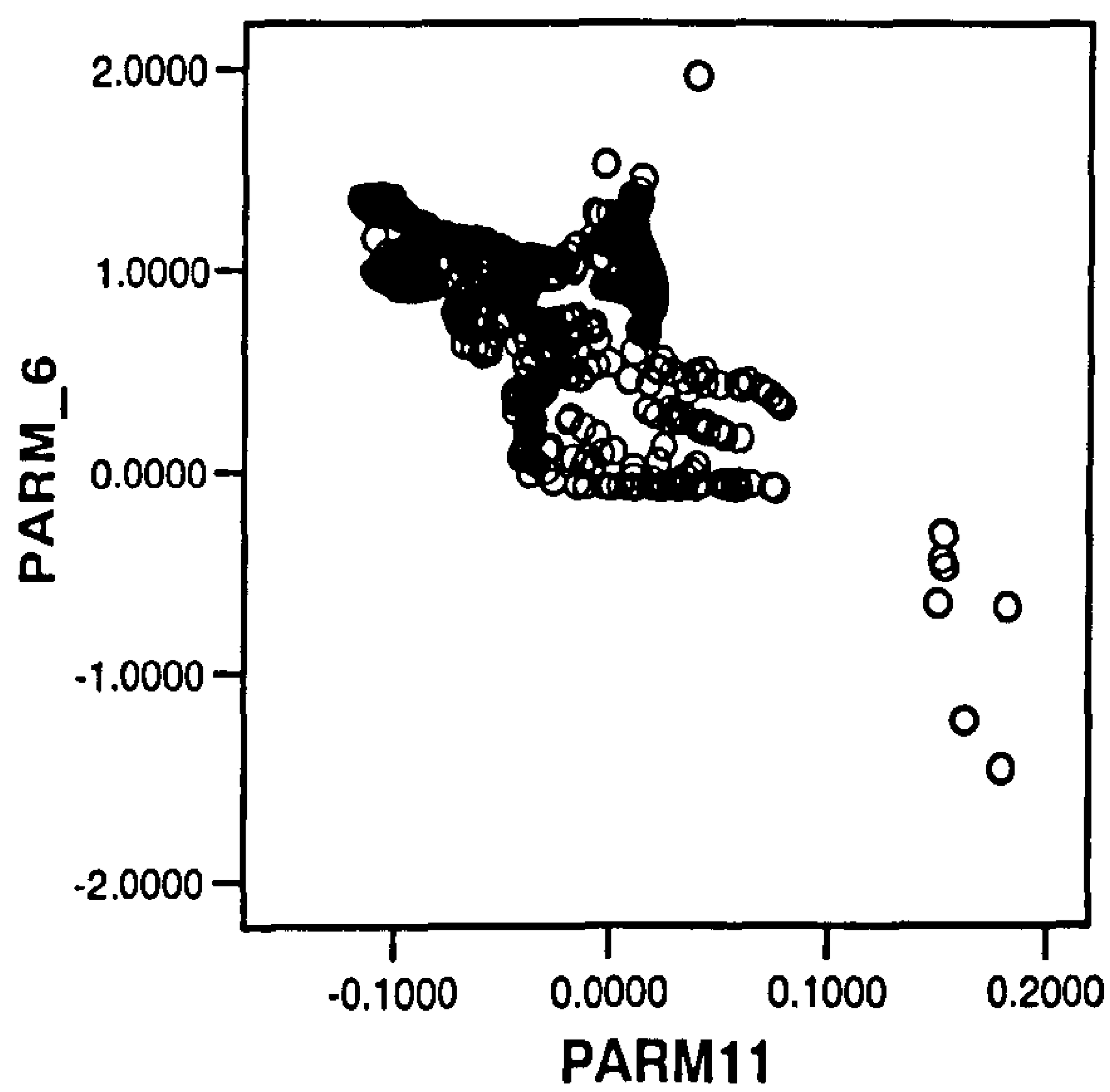



Figure H.11: Scatter plot of TYPSEMID and SECONDARYSCH variables

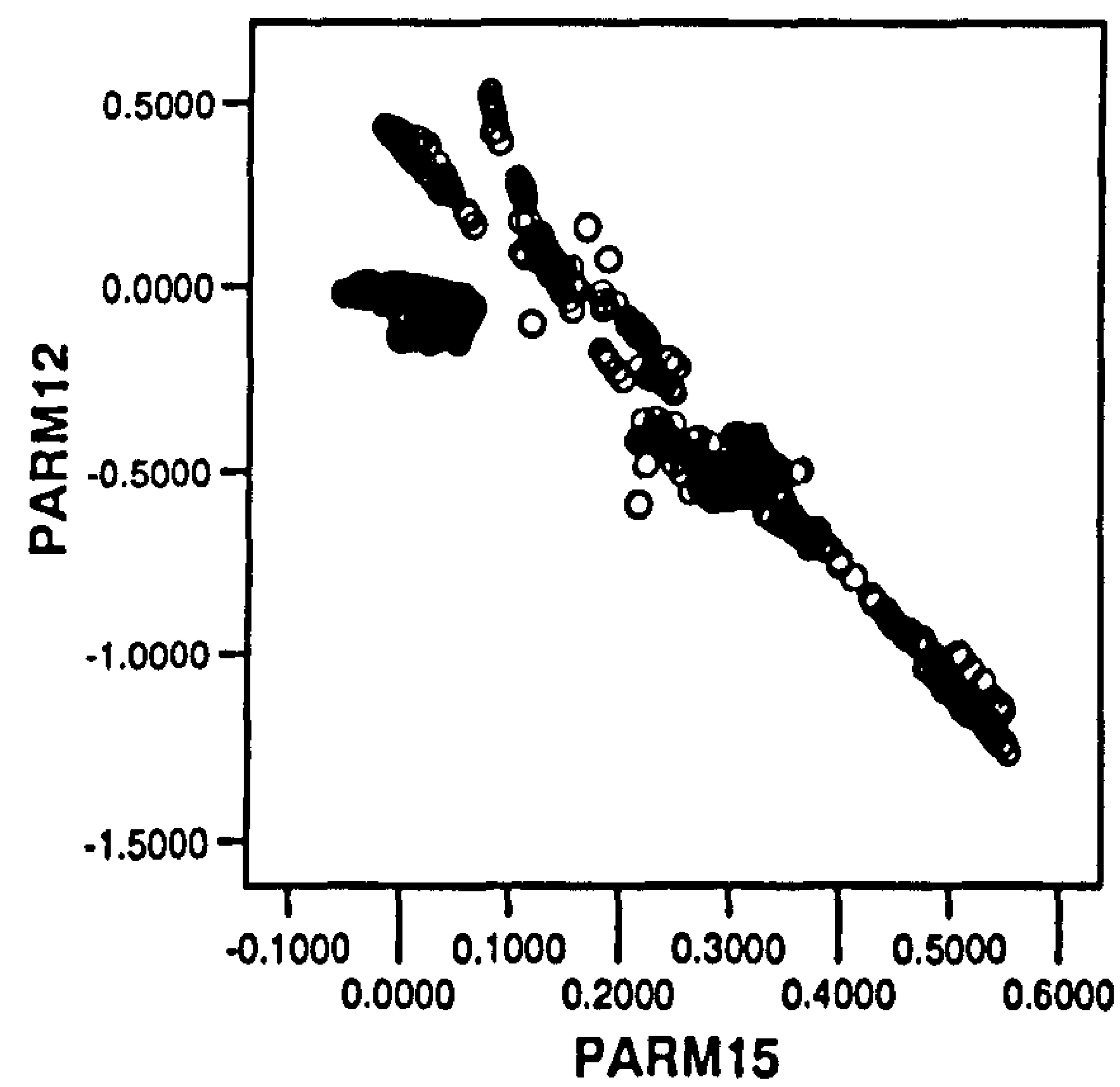



Figure H.12: Scatter plot of HOSPITALS and INDUSTRY variables

## Scatter Plots of Detecting Potential Collinearity among Local Parameter Estimates in Model 8.4-Model 8.5

The potential multicollinearity of local parameter estimates were detected by using scatter plots that can be performed within SPSS environment. The results of scatter plots analysis are shown below:

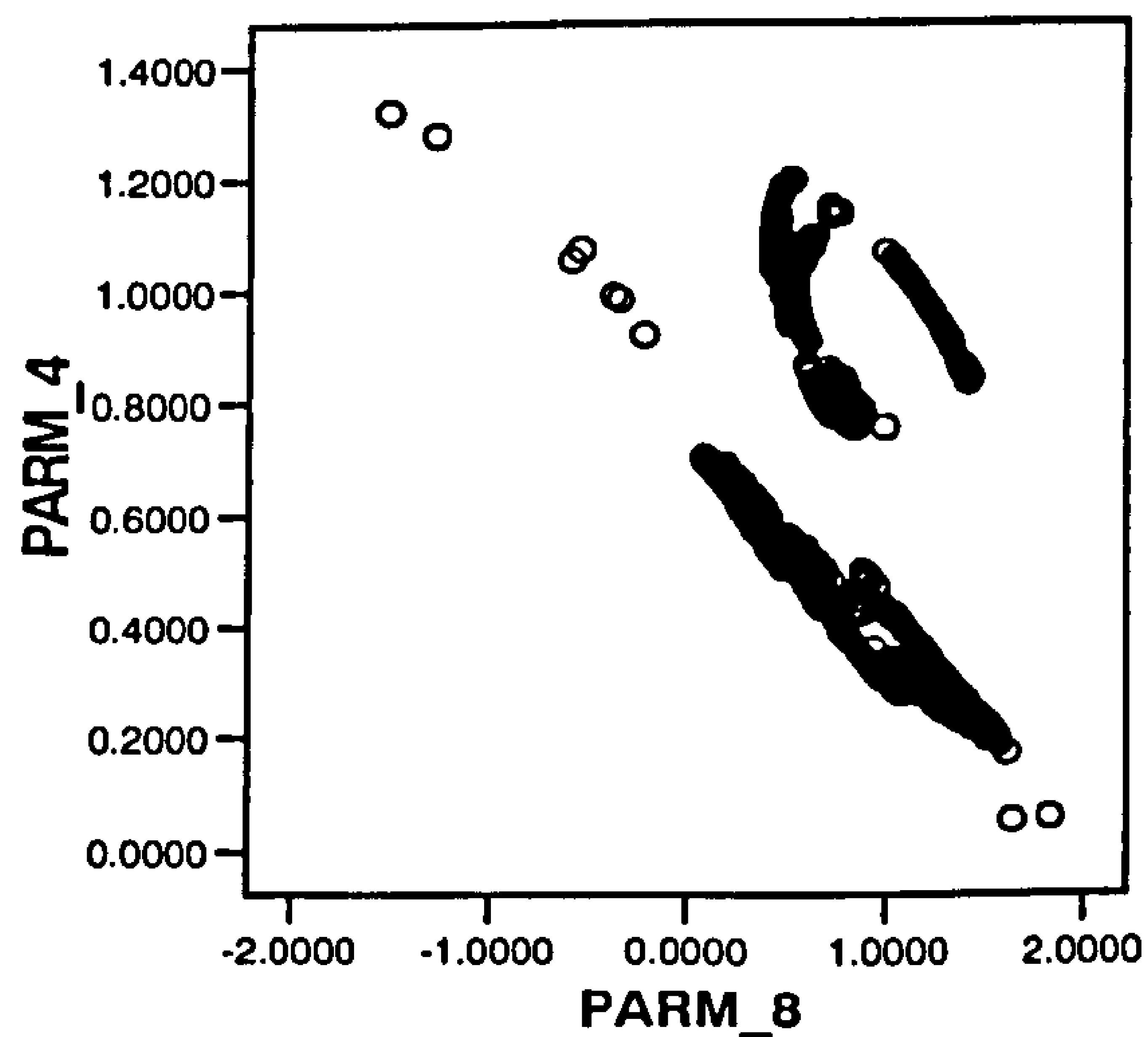



**Figure I.1**: Scatter plot of FLRAREA and TYPDETCH variables

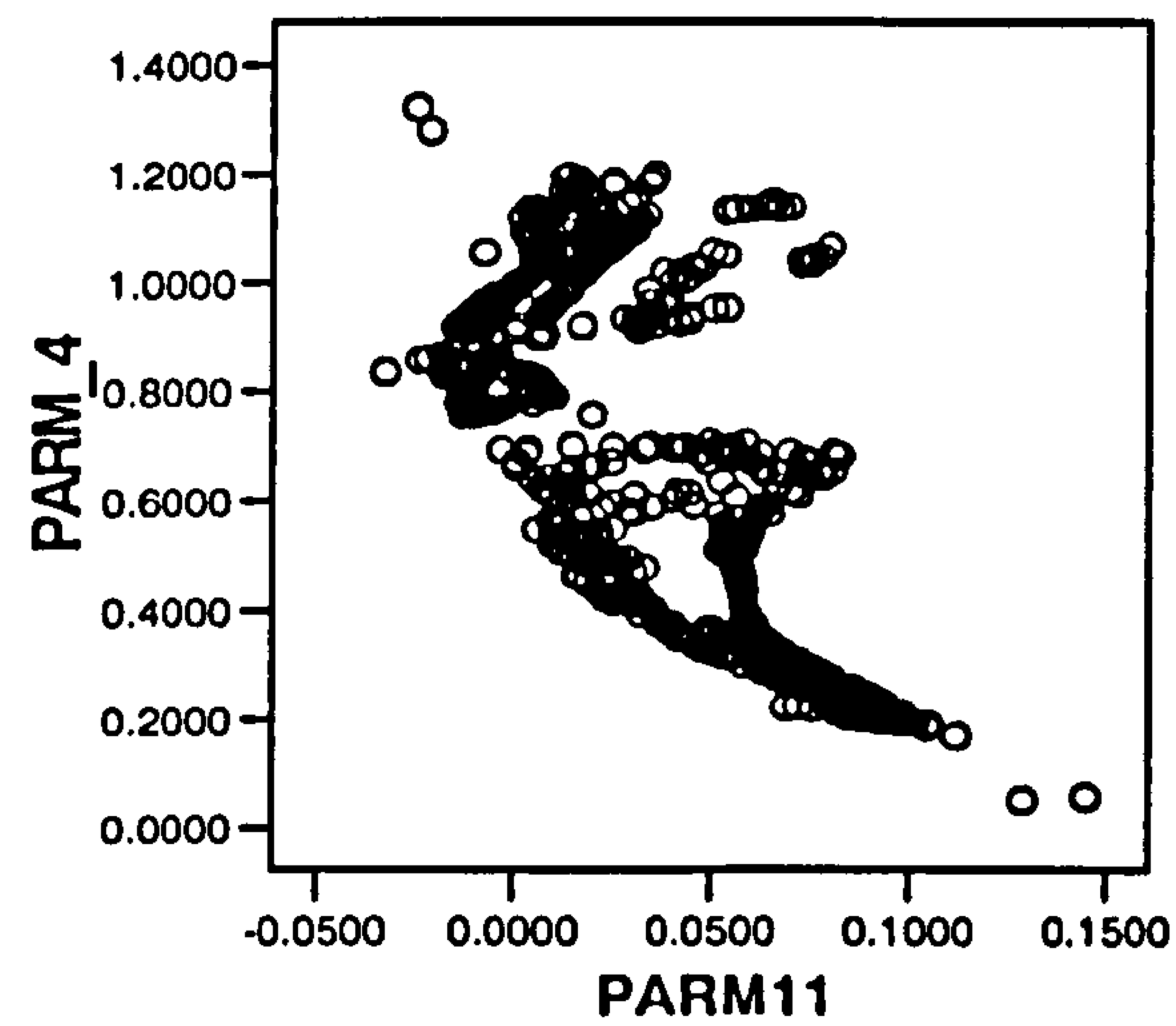



**Figure I.2**: Scatter plot of FLRAREA and PRIMARYSCH variables

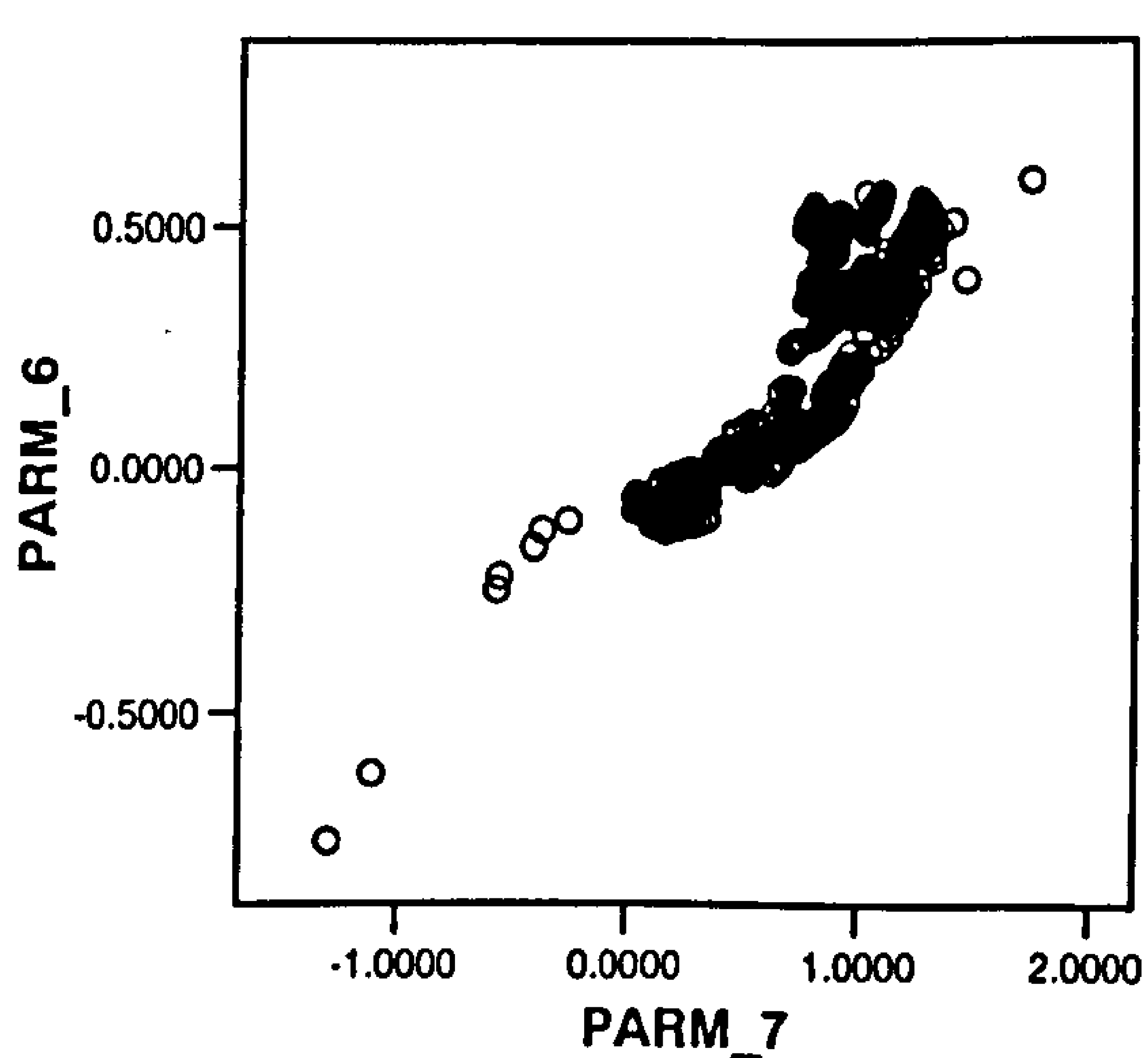



**Figure I.3**: Scatter plot of TYPTRRD and TYPSEMID variables

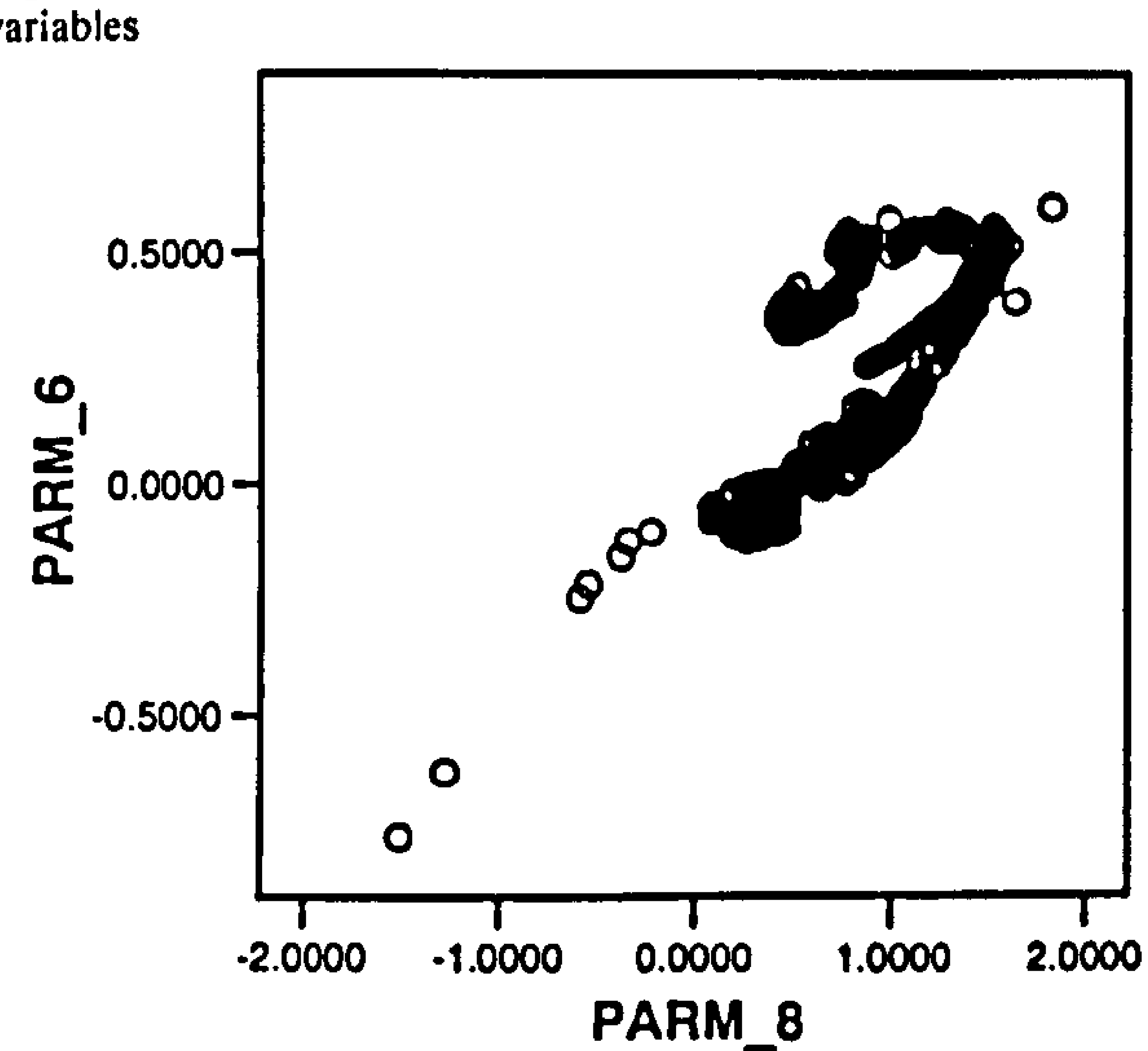



**Figure I.4**: Scatter plot of TYPTRRD and TYPDETCH variables

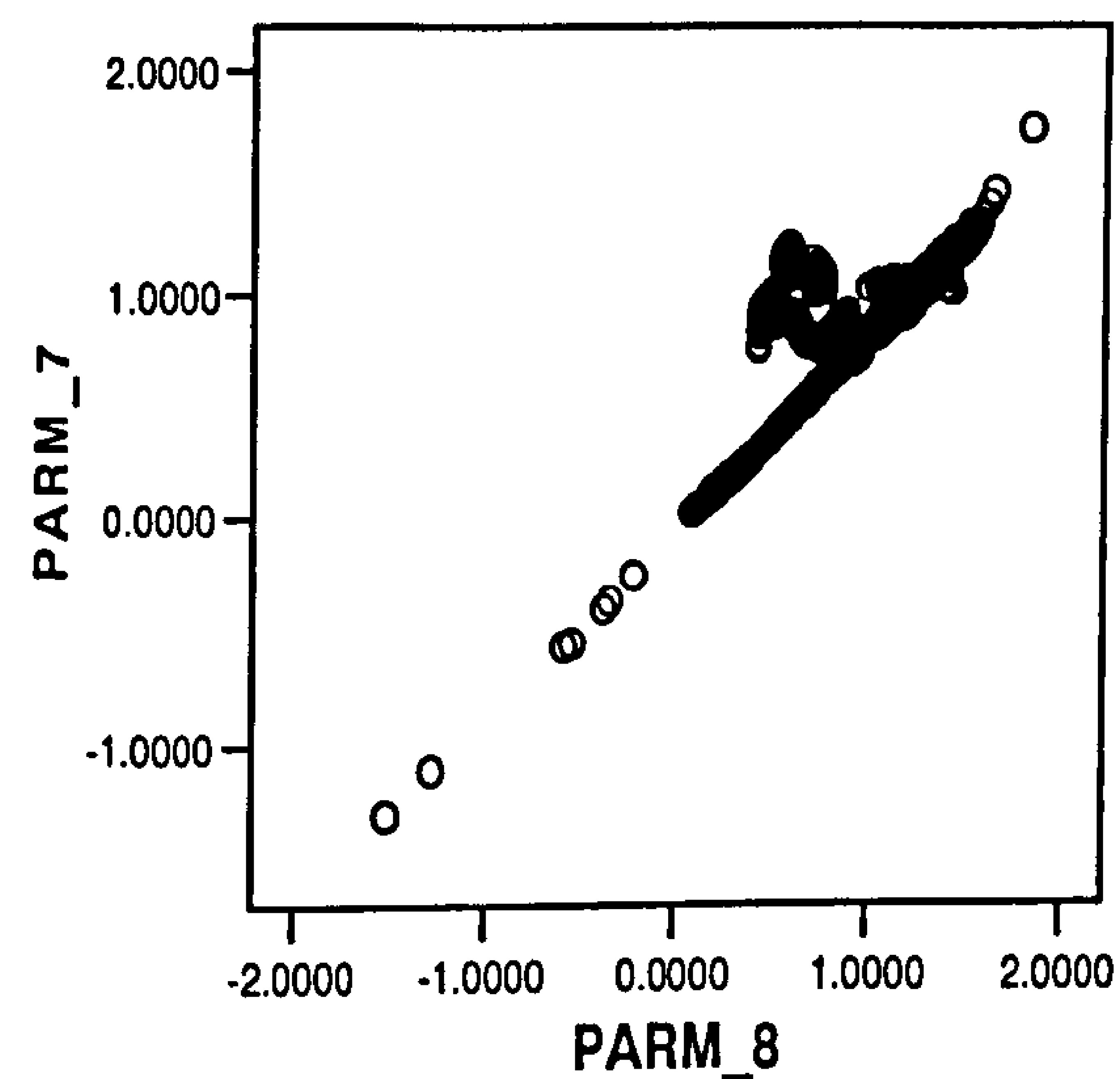



**Figure I.5**: Scatter plot of TYPSEMID and TYPDETCH variables

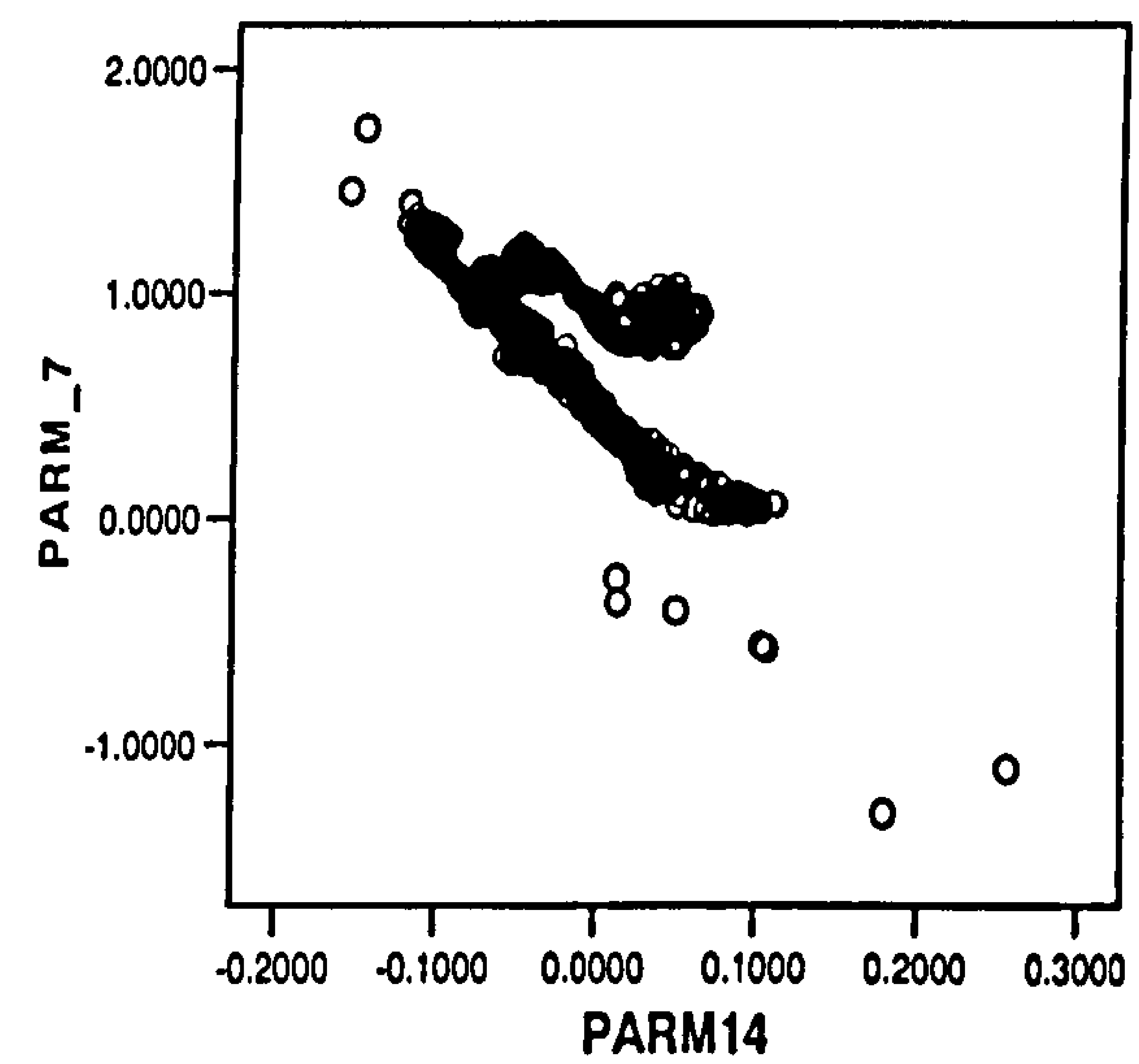



**Figure I.6**: Scatter plot of TYPSEMID and COMMERCIAL variables

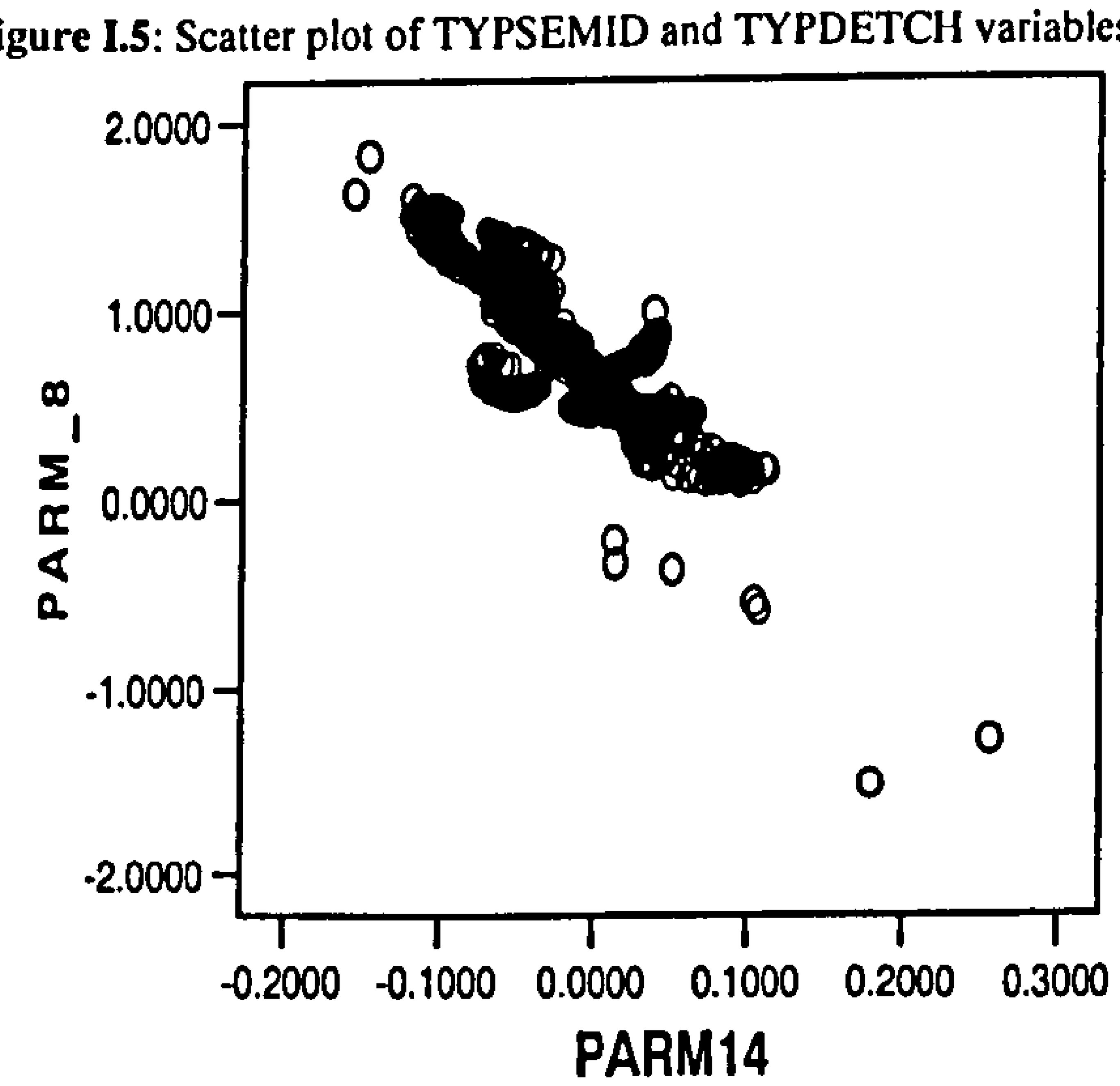



**Figure I.7**: Scatter plot of TYPDETCH and COMMERCIAL variables

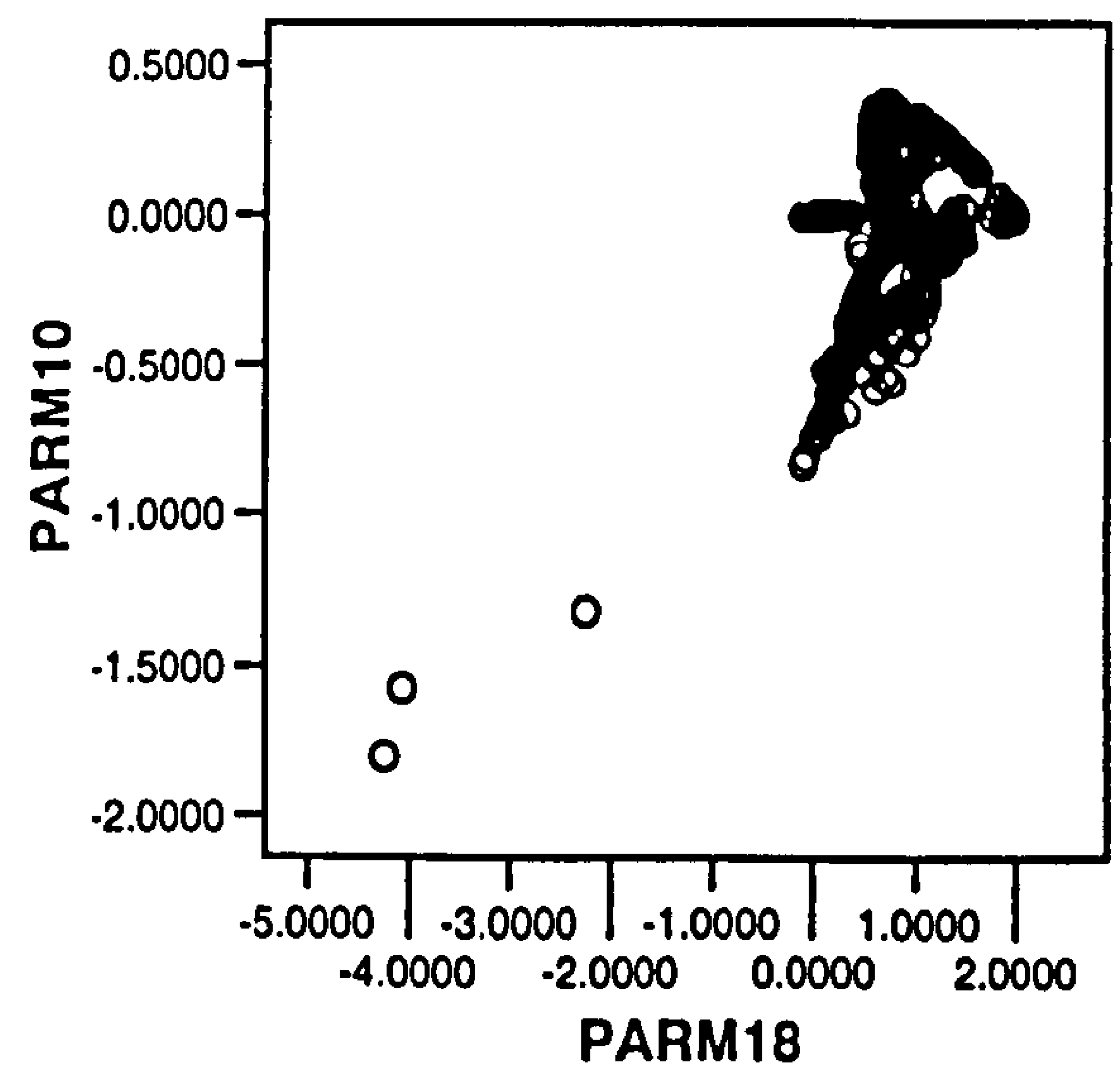



**Figure I.8**: Scatter plot of CBD and MALAY variables

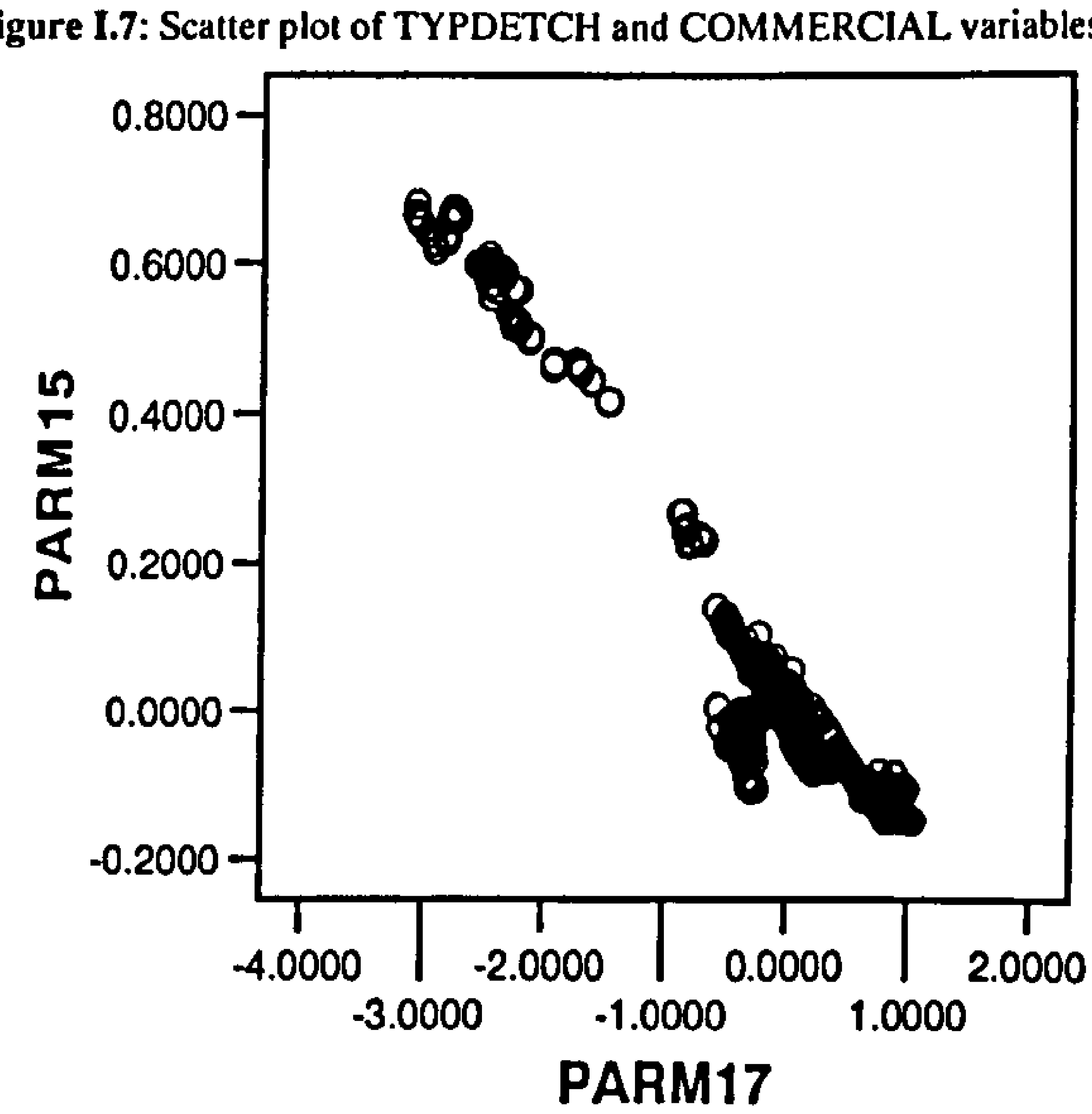



**Figure I.9**: Scatter plot of RECREATION and LAKES variables

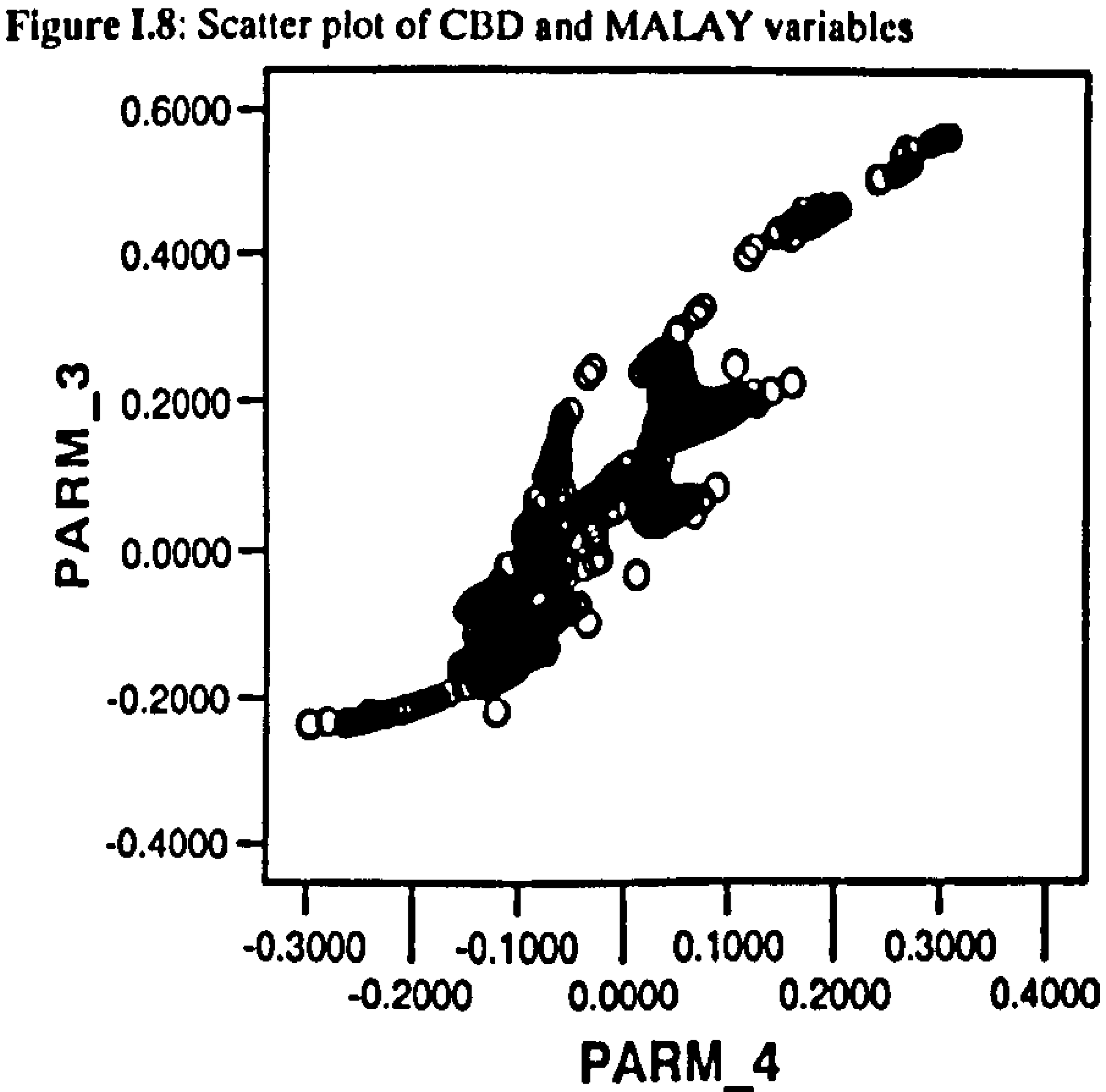



**Figure I.10**: Scatter plot of NETSTN2 and NETSTN3 variables

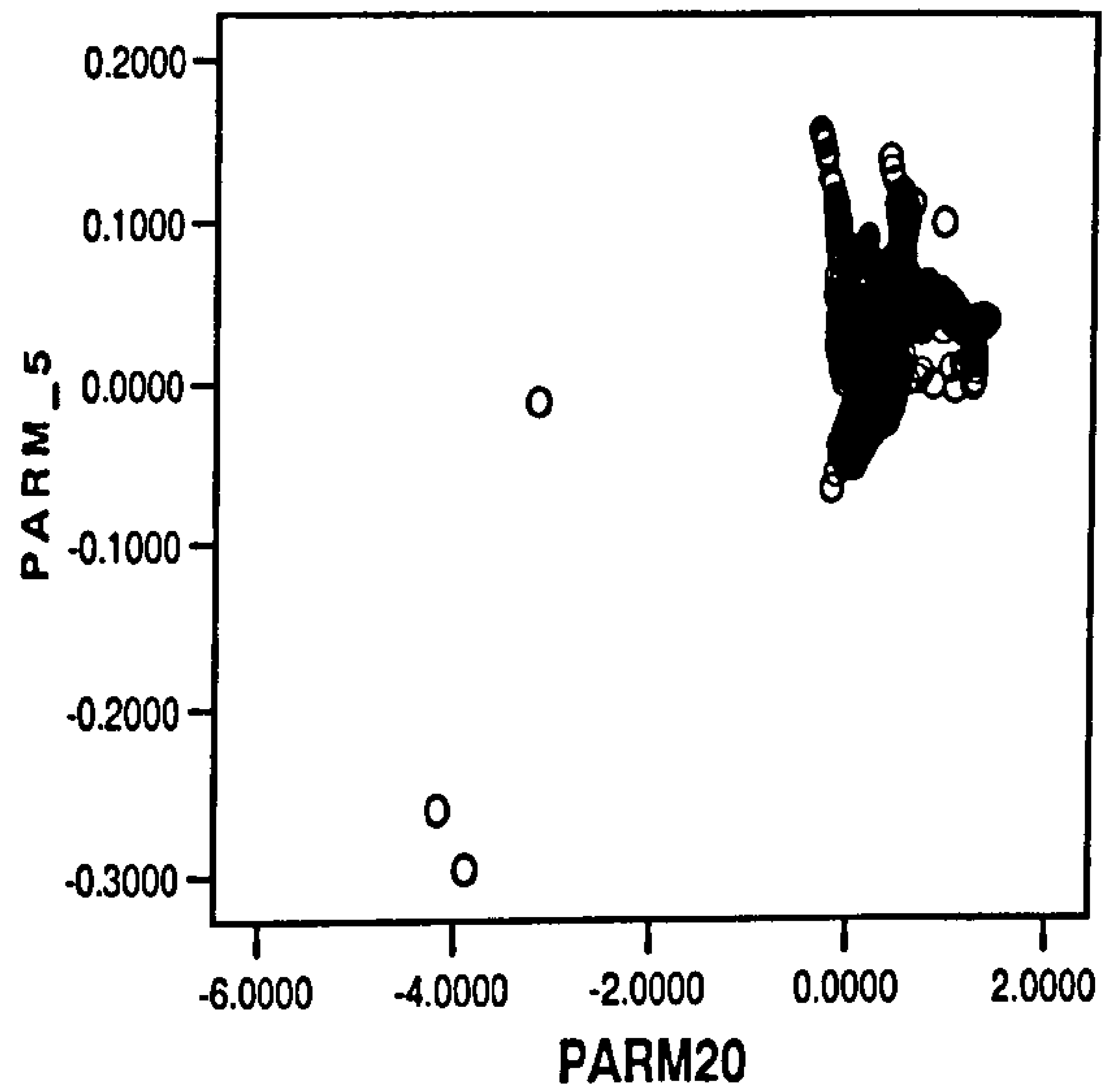



**Figure I.11**: Scatter plot of NETSTN4 and MALAY variables

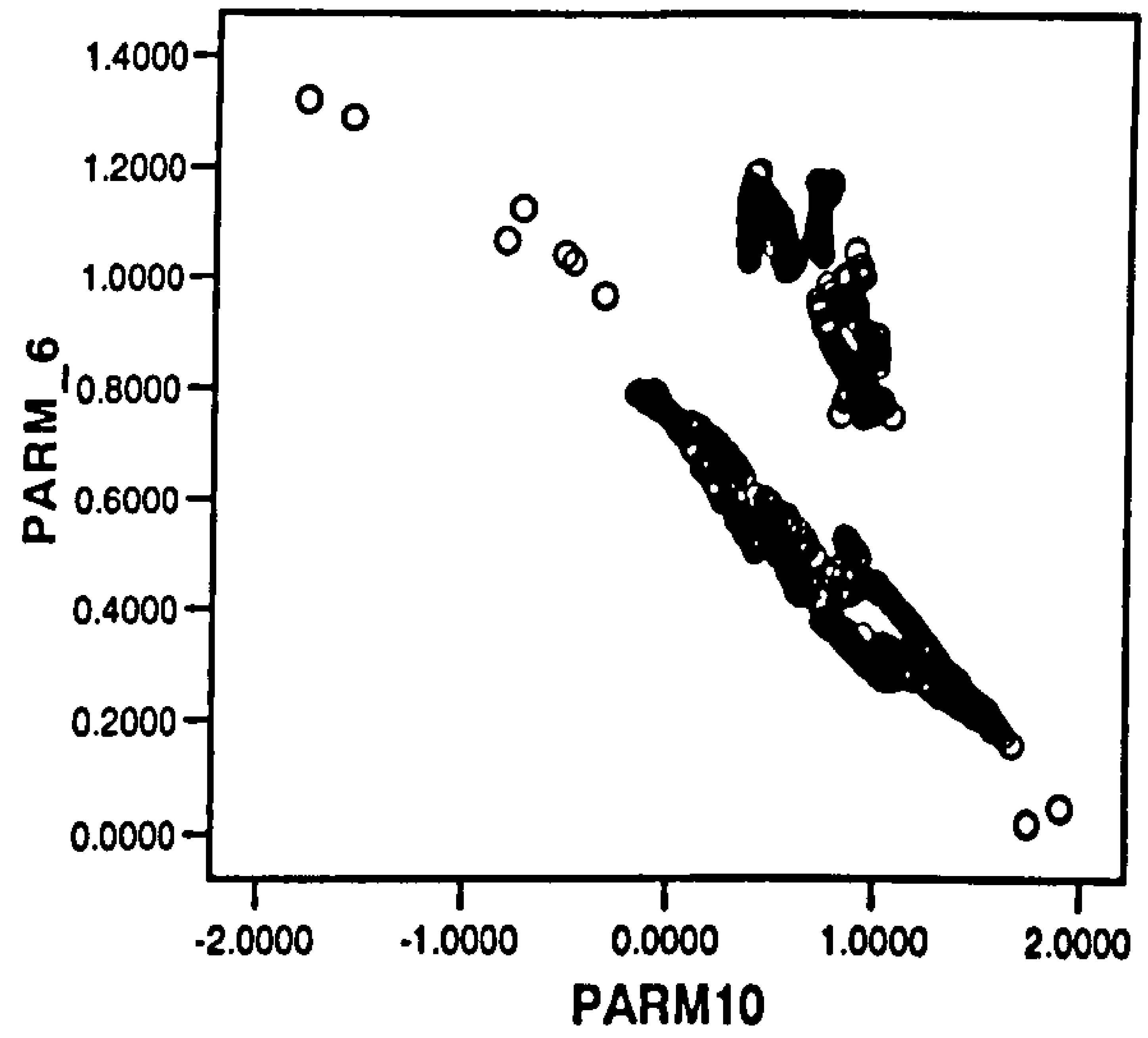



**Figure I.12**: Scatter plot of FLRAREA and TYPDETCH variables

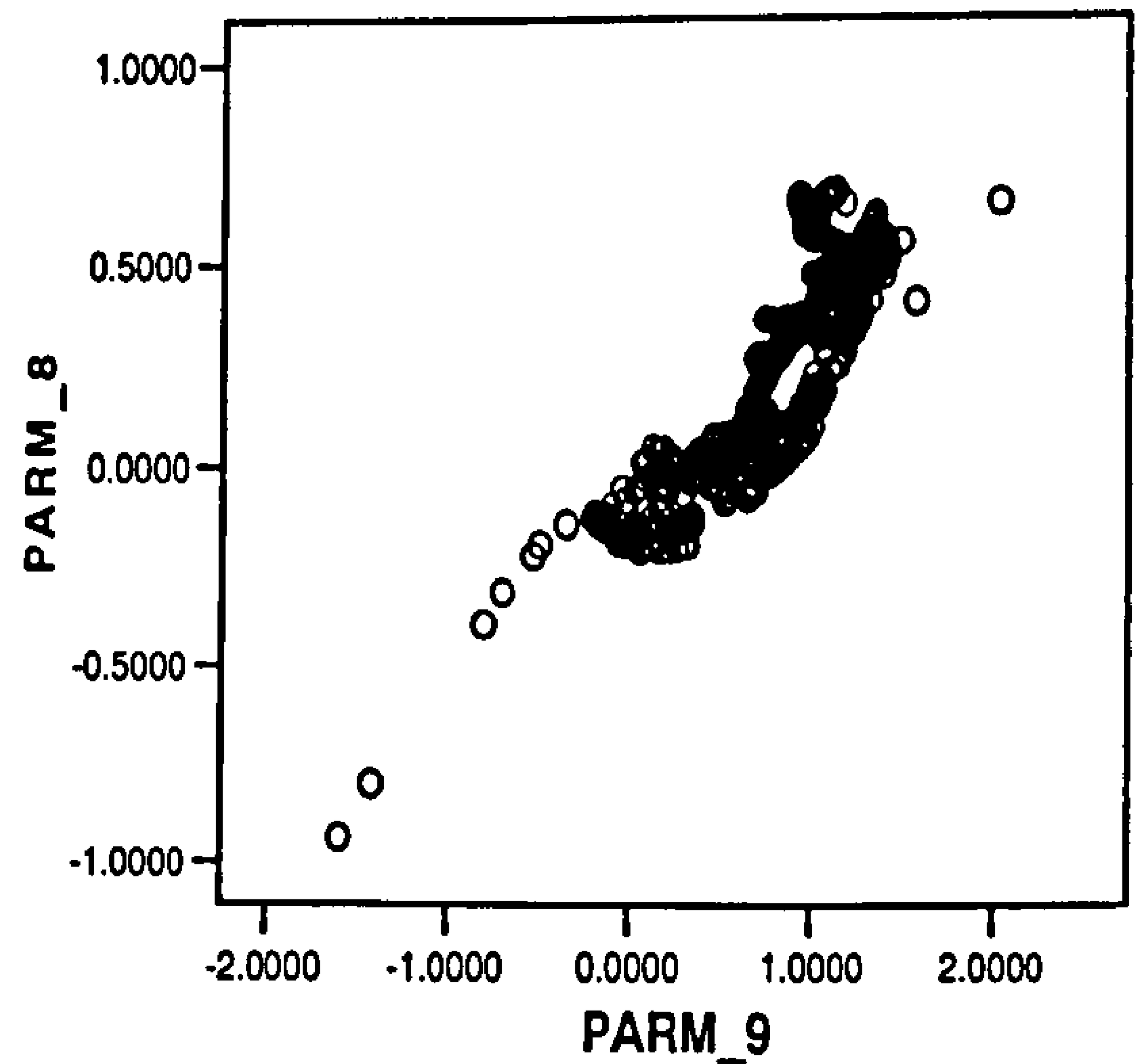



**Figure I.13**: Scatter plot of TYPTRRD and TYPSEMID variables

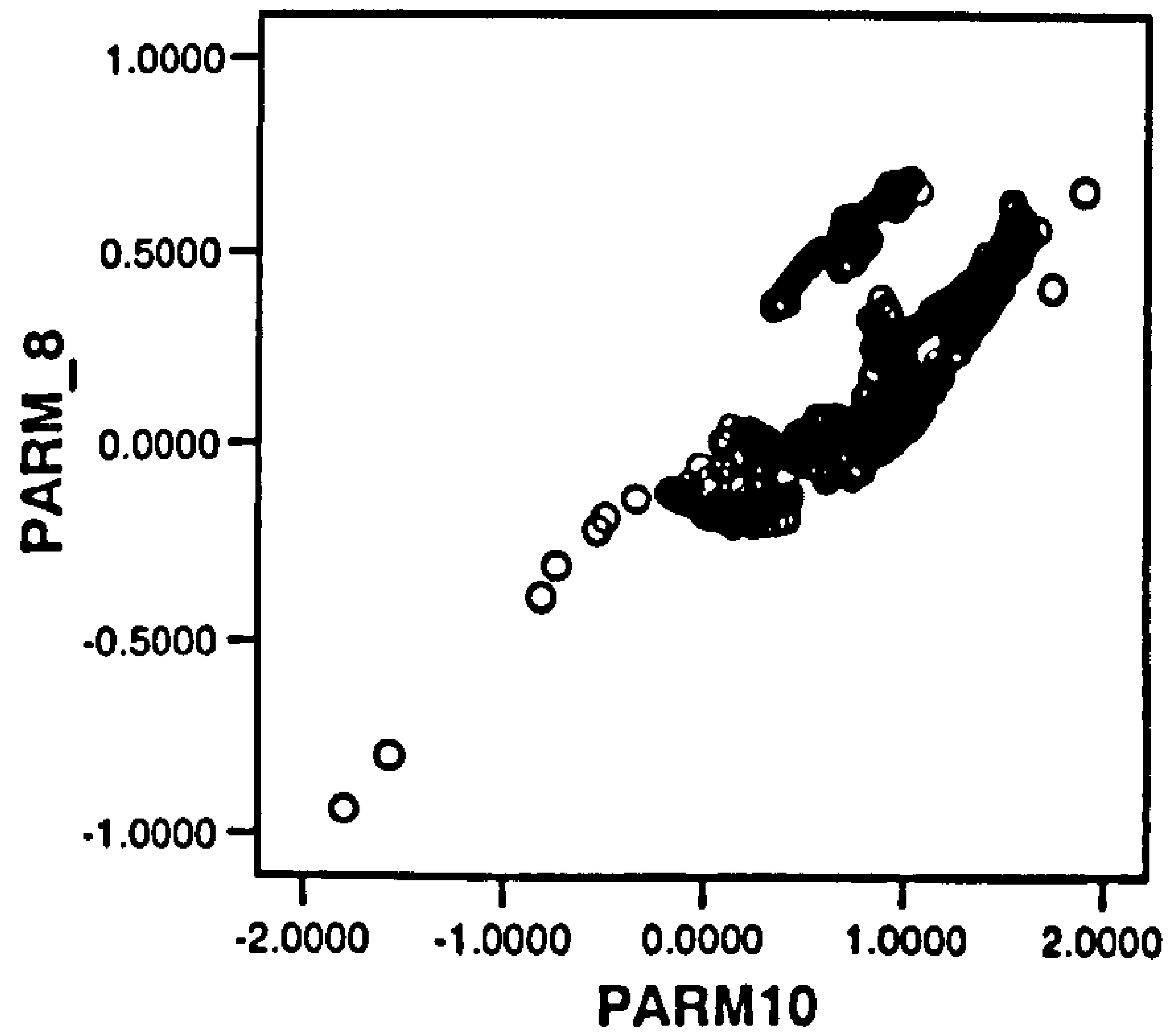



**Figure I.14**: Scatter plot of TYPTRRD and TYPDETCH variables

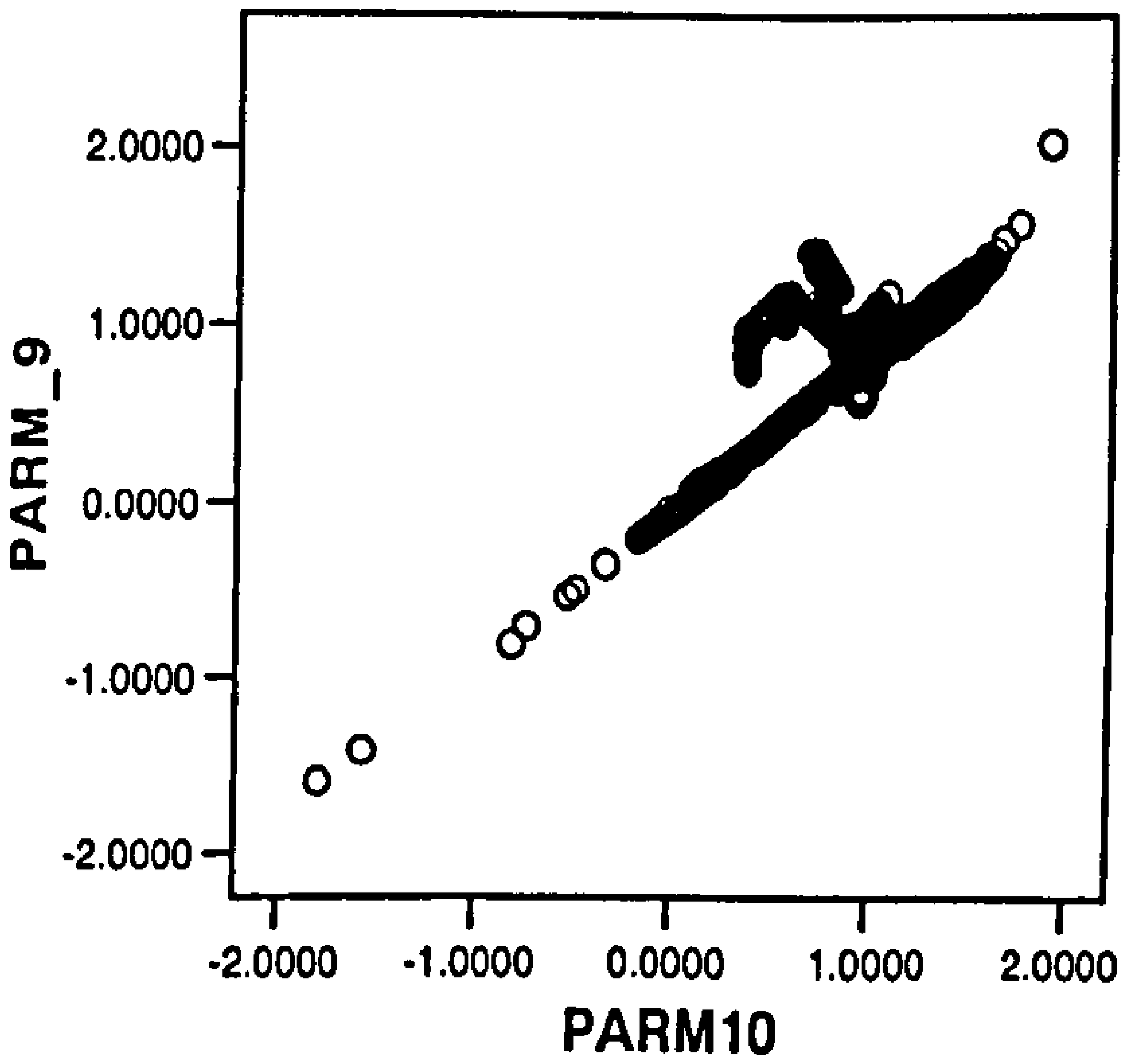



**Figure I.15**: Scatter plot of TYPSEMID and TYPDETCH variables

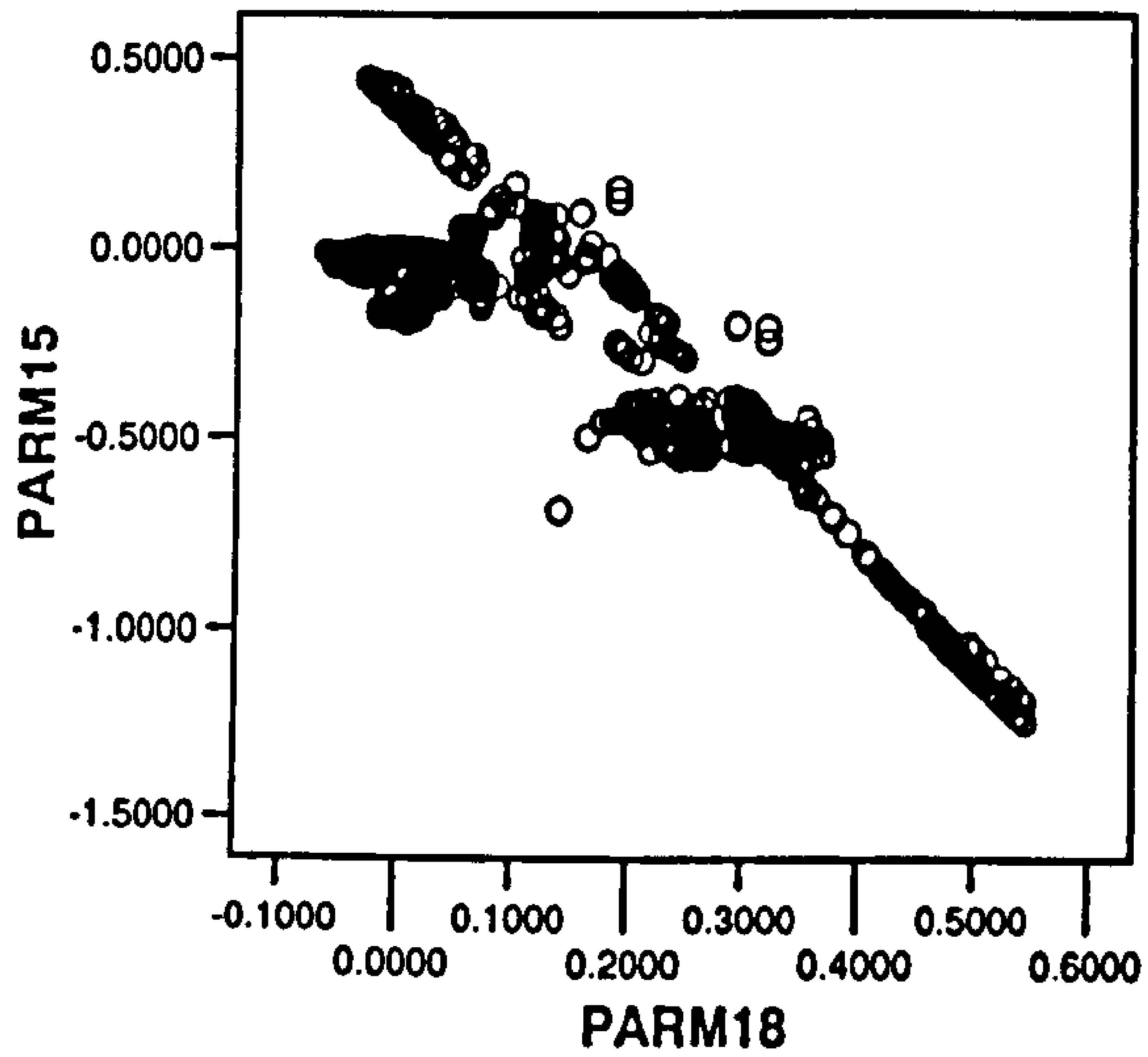



**Figure I.16**: Scatter plot of HOSPITALS and INDUSTRY variables

**Table A8.6:** The results of a high correlation between local parameter estimates

| | | Intercept | Strdist | Flrarea | Beds | Secondarysch | Hospital | Industry |
|---|---|---|---|---|---|---|---|---|
| Intercept | Pearson Correlation | 1 | 0.380 | -0.657 | 0.066 | -0.158 | -0.668 | 0.534 |
| | Sig. (2-tailed) | . | 0.000 | 0.000 | 0.008 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Strdist | Pearson Correlation | 0.380 | 1 | -0.232 | -0.049 | -0.209 | -0.702 | 0.730 |
| | Sig. (2-tailed) | 0.000 | . | 0.000 | 0.051 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Flrarea | Pearson Correlation | -0.657 | -0.232 | 1 | -0.331 | 0.035 | 0.453 | -0.299 |
| | Sig. (2-tailed) | 0.000 | 0.000 | . | 0.000 | 0.167 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Beds | Pearson Correlation | 0.066 | -0.049 | -0.331 | 1 | -0.464 | 0.070 | -0.064 |
| | Sig. (2-tailed) | 0.008 | 0.051 | 0.000 | . | 0.000 | 0.006 | 0.011 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Secondarysch | Pearson Correlation | -0.158 | -0.209 | 0.035 | -0.464 | 1 | 0.047 | -0.160 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.167 | 0.000 | . | 0.061 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Hospital | Pearson Correlation | -0.668 | -0.702 | 0.453 | 0.070 | 0.047 | 1 | -0.799 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.006 | 0.061 | . | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Industry | Pearson Correlation | 0.534 | 0.730 | -0.299 | -0.064 | -0.160 | -0.799 | 1 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.011 | 0.000 | 0.000 | . |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

**Table A8.7:** The results of a high correlation between local parameter estimates

| | | Intercept | Netdist | Flrarea | Beds | Secondarysch | Hospital | Industry |
|---|---|---|---|---|---|---|---|---|
| Intercept | Pearson Correlation | 1 | 0.160 | -0.721 | 0.086 | -0.113 | -0.716 | 0.516 |
| | Sig. (2-tailed) | . | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Netdist | Pearson Correlation | 0.160 | 1 | -0.394 | -0.011 | -0.299 | -0.286 | 0.371 |
| | Sig. (2-tailed) | 0.000 | . | 0.000 | 0.667 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Flrarea | Pearson Correlation | -0.721 | -0.394 | 1 | -0.251 | 0.176 | 0.604 | -0.481 |
| | Sig. (2-tailed) | 0.000 | 0.000 | . | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Beds | Pearson Correlation | 0.086 | -0.011 | -0.251 | 1 | -0.494 | -0.003 | 0.114 |
| | Sig. (2-tailed) | 0.001 | 0.667 | 0.000 | . | 0.000 | 0.911 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Secondarysch | Pearson Correlation | -0.113 | -0.299 | 0.176 | -0.494 | 1 | -0.068 | -0.130 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | . | 0.007 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Hospital | Pearson Correlation | -0.716 | -0.286 | 0.604 | -0.003 | -0.068 | 1 | -0.703 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.911 | 0.007 | . | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Industry | Pearson Correlation | 0.516 | 0.371 | -0.481 | 0.114 | -0.130 | -0.703 | 1 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | . |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |

**. Correlation is significant at the 0.01 level (2-tailed).

**Table A8.8**: The results of a high correlation between local parameter estimates

| | | Intercept | Strstn1 | Strstn2 | Flrarea | Beds | Secondarysch | Hospital | Industry |
|---|---|---|---|---|---|---|---|---|---|
| Intercept | Pearson Correlation | 1 | -0.402 | -0.405 | -0.791 | 0.050 | -0.153 | -0.695 | 0.535 |
| | Sig. (2-tailed) | . | 0.000 | 0.000 | 0.000 | 0.049 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Strstn1 | Pearson Correlation | -0.402 | 1 | 0.837 | 0.480 | 0.012 | 0.377 | 0.346 | -0.551 |
| | Sig. (2-tailed) | 0.000 | . | 0.000 | 0.000 | 0.634 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Strstn2 | Pearson Correlation | -0.405 | 0.837 | 1 | 0.515 | -0.395 | 0.571 | 0.315 | -0.526 |
| | Sig. (2-tailed) | 0.000 | 0.000 | . | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Flrarea | Pearson Correlation | -0.791 | 0.480 | 0.515 | 1 | -0.168 | 0.155 | 0.685 | -0.558 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | . | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Beds | Pearson Correlation | 0.050 | 0.012 | -0.395 | -0.168 | 1 | -0.425 | -0.026 | 0.185 |
| | Sig. (2-tailed) | 0.049 | 0.634 | 0.000 | 0.000 | . | 0.000 | 0.293 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Secondarysch | Pearson Correlation | -0.153 | 0.377 | 0.571 | 0.155 | -0.425 | 1 | -0.031 | -0.354 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | . | 0.214 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Hospital | Pearson Correlation | -0.654 | 0.346 | 0.315 | 0.685 | -0.026 | -0.031 | 1 | -0.586 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.293 | 0.214 | . | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Industry | Pearson Correlation | 0.535 | -0.551 | -0.526 | -0.558 | 0.185 | -0.354 | -0.586 | 1 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | . |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix K

**Table A8.9**: The results of a high correlation between local parameter estimates

| | | Intercept | Netstn1 | Netstn2 | Flrarea | Beds | Secondarysch | Hospital | Industry |
|---|---|---|---|---|---|---|---|---|---|
| Intercept | Pearson Correlation | 1 | -0.404 | -0.495 | -0.664 | 0.007 | -0.201 | -0.627 | 0.588 |
| | Sig. (2-tailed) | . | 0.000 | 0.000 | 0.000 | 0.777 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Netstn1 | Pearson Correlation | -0.404 | 1 | 0.647 | 0.109 | 0.092 | 0.146 | 0.571 | -0.801 |
| | Sig. (2-tailed) | 0.000 | . | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Netstn2 | Pearson Correlation | -0.495 | 0.647 | 1 | 0.416 | -0.055 | 0.633 | 0.445 | -0.749 |
| | Sig. (2-tailed) | 0.000 | 0.000 | . | 0.000 | 0.030 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Flrarea | Pearson Correlation | -0.664 | 0.109 | 0.416 | 1 | -0.278 | 0.112 | 0.443 | -0.247 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | . | 0.000 | 0.000 | 0.000 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Beds | Pearson Correlation | 0.007 | 0.092 | -0.055 | -0.278 | 1 | -0.314 | 0.097 | -0.085 |
| | Sig. (2-tailed) | 0.777 | 0.000 | 0.030 | 0.000 | . | 0.000 | 0.000 | 0.001 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Secondarysch | Pearson Correlation | -0.201 | 0.146 | 0.633 | 0.112 | -0.314 | 1 | 0.031 | -0.362 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | . | 0.219 | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Hospital | Pearson Correlation | -0.627 | 0.571 | 0.445 | 0.443 | 0.097 | 0.031 | 1 | -0.717 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.219 | . | 0.000 |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |
| Industry | Pearson Correlation | 0.588 | -0.801 | -0.749 | -0.247 | -0.085 | -0.362 | -0.717 | 1 |
| | Sig. (2-tailed) | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | 0.000 | 0.000 | . |
| | N | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 | 1,580 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).