How to improve the sustainability of logistics on the Coherent Campus at Newcastle University?

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Abstract

The aim of this thesis was to improve the sustainability of logistics on the Coherent Campus at Newcastle University.

The wider problems of unsustainable nature of urban freight logistics, at an international, national and local level, were emergent in the academic peer reviewed literature, with 77% of all articles reviewed published after 2011. The literature revealed challenges to all three pillars of sustainability: economic, social and environmental. As part of the scoping, a semi-systematic literature review was combined with a socio-technical theoretical framing and four research questions were identified:

RQ1: How to improve the sustainability of logistics on the Coherent Campus at Newcastle University?

RQ2: To what extent can sustainable HEI logistics only be achieved through sustainable procurement practices?

RQ3: How effective were participatory research approaches in facilitating this improvement?

RQ4: What novel approaches for policy and practice locally, nationally and at an EU level could be developed from this work?

A research philosophy grounded in the social sciences, pragmatism, abduction, constructionism and pluralist ontology was chosen; methodologically, a systems approach of Action Research was selected. Within that, the Design and Monitoring Framework, the Business Model CANVAS, archival procurement data, and empirical traffic surveys were all deployed. A pilot demonstration of a receiver-led inbound consolidation centre service was trialled.

RQ1 confirmed the utility of the approach adopted, and the intervention demonstrated, potentially yielding a circa 16% reduction in freight vehicles coming to campus. RQ2 was answered in the negative, but assessed the successful action taken. The effectiveness of the participatory research approaches taken was confirmed in answer to RQ3. Policy recommendations were developed and detailed in answer to RQ4. A novel contribution to theoretical knowledge was made, in the development and presentation of practical knowing, in the form of a socio-technical framing.

Dedication

I dedicate this work to my wife Ann
and my children: Leesa, Michael and Matthew.

Acknowledgements

I acknowledge that co-funding was received from the European Commission's Seventh Framework Programme (FP7/2007-2013), as part of the Smartfusion project, under Grant Agreement No. 285195. Smartfusion was funded under the European Green Car Initiative and was far wider than the scope of this thesis, covering 3 EU city-regions, research into electric vehicle technology, urban freight routing, different urban freight interventions and a (different) impact assessment approach. I, Thomas H Zunder, was the proposer, co-ordinator and principal investigator of this project; funding was received for part of my salary and also part-paid for Research Assistant Bruce Carnaby, who assisted in the wider project work as well as helping in Newcastle upon Tyne. Budgets for traffic surveys, electric vehicles and travel were also part funded. The PhD fees were funded by Newcastle University.

All of the research work in this thesis was performed by me. All data collection was specified, supervised and analysed by me, as were all collaborative activities which formed a key part of the action research.

Other research work was carried out in parallel, either by myself alone, with others, or by others alone. Some of this work shared the same raw data and may have formed some of the preliminary findings or deliverables to the Commission, but all research work in this thesis is entirely the author's own work, often replacing, nuancing or complementing earlier enquiries, analyses, and findings. All such relevant work is referenced and attributed throughout.

I wish to thank Dr. Shirley Coleman, Dr. Simon Kometa, Dr. Paul Goodman, Dr. Fabio Galatioto, Dr. Dewan Islam, and Dr. Paulus Aditjandra for their support and help with mastering some methodological skills, pointing out or providing data, or simply knowing when best to support my getting on with it alone. I wish to thank Neil Addison and Lyn Edis - from the University Purchasing and Estates departments, respectively - for their support and for allowing me to embark on and support change to policy and procedure, as well as providing access and data in abundance. I thank my three supervisors: Prof. Mark Robinson, for sticking with me month by month, calmly smiling and supporting; Prof. John Mangan; and, once more, Dr Paul Goodman, for stepping up and for his insightful critique.

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Introduction

For 15 years I worked as a supply chain manager, managing purchasing, production control, distribution and overall supply chain, in manufacturing industry. I qualified as a Member of the Chartered Institute of Purchasing and Supply (MCIPS) and I am a Fellow of the Chartered Institute of Logistics and Transport (FCILT). Now in the 18th year of my academic career, and currently a Principal Research Associate, I manage activities in the Future Mobility Group at Newcastle University, produce deliverables and dissemination in European Union (EU) research projects, and pursue academic and applied research.

My three decades of experience in purchasing and supply chain management have involved the analysing and implementing of innovative solutions in road, rail and sea freight. Having previously worked in the steel, automotive, transport, and machine tools industries I have, since 2002, been able to take my hands-on experience into academic research within the field of freight and logistics, combining practical experience with field research into the relationships between all actors in the freight and logistics arena.

This thesis details one key strand of research into sustainable logistics, in which I have been engaged since 2002. It describes and reports on the identification of problems with freight goods deliveries at Newcastle University main campus, the development of a research philosophy and methodology to address these problems, the work completed and its outcomes, and finishes with policy and practice guidelines.

The thesis is written in the active voice and with personal pronouns - partly in line with my research philosophy, and partly to allow clarity between “I” and “we”. The use of “we” clearly states a team effort, and “I” clearly denotes work where I was the sole researcher. This clarity is important in this action research, since some elements of the work were purposefully collaborative.

Chapter 1. Purpose and Rationale

This Chapter introduces the research undertaken, and the research context in which it sits, in terms of both the practical operational benefits to Newcastle University and the contribution to wider knowledge. The Chapter clearly identifies the local, national and international *rationale* for the research, the *contracts* in place to proceed with the work, and the *access* gained in order to carry out the work effectively.

The rationale for the operational research was based upon international, national and local needs of The European Union, the United Kingdom (UK), and Newcastle University; this was the action part of the research. The theoretical rationale for the thesis was developed from the literature review in Chapter 2 and the framing in Chapter 3. The research philosophy was then planned in the epistemological Chapter 4 and the methods and techniques in Chapter 5. The context and observations from 2011 were reported in Chapter 6. The core action was reported in Chapters 7, 8 and 9; Stakeholder Engagement, Business Model Generation and Pilot; respectively. The Outcomes were evaluated in Chapter 10. Chapter 11 concentrated on reflections and meta learning, and Conclusions and Answers to Research Questions constituted Chapter 10.

1.1. International problem

The increased demand for distribution of goods and services in cities (usually 'urban freight logistics') and solutions to the dis-benefits generated (usually 'city logistics') was forecast to continue its growth through the 21st century due to increasing urbanisation, income growth, and fragmentation of supply chains. Urbanisation was rising globally, with Europe the most urbanised continent. In the EU28[1], 73% of citizens lived in cities and generated 85% of its GDP; this level of urbanisation was expected to rise to 82% by 2050 (European Commission, 2013). Future urbanisation in Asia and Africa was predicted to rise from circa 50% to 66% by 2050 (United Nations, 2014) as a result of natural growth and rural-urban migration. Income growth, leading to greater demand for goods and services in cities, was rising most in Asia-Pacific, where India, China and Indonesia had recently been growing at rates at or above 7% per annum (World Bank, 2015). At the same time, a fragmentation of logistics at the last mile delivery was evident, both globally and locally, as smaller vehicles delivered smaller

[1] *28-member state European Union*

consignments of lower value, higher density goods (Browne, Allen, Nemoto, *et al.*, 2010). The causes of this fragmentation were extremely complex and yet to be fully understood, but probably included (not exhaustively): rising home deliveries; a boom in on-line shopping; continued independent retailers in urban cores; city regulations on time, vehicle size or type; reduction of shop storage; adoption of just-in-time principles; and replacement of working capital with transport response (Jackson, Islam, *et al.*, 2013; Macharis and Kin, 2016).

This generated challenges to all three pillars of sustainability: economic, social and environmental - also known as 'people, planet and profit', or the 'triple bottom line' (Brundtland, 1987; Elkington, 2004; Kleindorfer, Singhal and Wassenhove, 2005). In the field of transport, exactly which resources are relevant when the term 'sustainable' is used is always in contention; different groups may have different resources in mind. Larger policy goals interplay alongside resource depletion in transport policy and practice, such as job creation, economic growth, social inclusion, land use, and are redistributive of quality of life and wealth on a class or geographical basis. As Goldman and Gorham have said: "These powerful but often unstated agendas mean that approaching sustainable transport simply as an exercise in resource optimization is somewhat naïve" (2006).

Within the UK, as a member state of the EU, subsidiary legislation, regulation and policy align with the EU top level, not least since the UK has been a key driver of EU policy in this area - as evidenced by the UK definition of sustainable transport development adopted by the UK Round Table in 1996 which defined:

- economic impacts as (i) congestion, (ii) inefficiency and (iii) resource wastage;
- environmental impact as (i) pollutant emissions including the primary greenhouse gas carbon dioxide, (ii) the use of non- renewable fossil–fuels, land and aggregates, (iii) waste products such as tyres, oil and other materials, and (iv) the loss of wildlife habitats and associated threats to wildlife species;

social impacts as (i) the physical consequences of pollutant emissions on public health, (ii) the injuries and death resulting from traffic accidents, (iii) noise, (iv) visual intrusion, (v) the difficulty of making essential journeys without a car or suitable public transport, and (vi) other quality of life issues (including the loss of green field sites and open spaces in urban areas as a result of transport infrastructure developments) (Parliamentary Office Of Science And Technology, 1997; Mao, 2010).

For this work I have aligned to the definition of sustainable transport agreed by the Council of Transport Ministers of the European Union, in April 2001, and therefore as enacted in EU legislation, directives and regulation. The definition:

- allows the basic access and development needs of individuals, companies and societies to be met safely and in a manner consistent with human and ecosystem health, and promotes equity within and between successive generations;
- is affordable, operates fairly and efficiently, offers choice of transport mode, and supports a competitive economy, as well as balanced regional development;
- limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of generation, and, uses non-renewable resources at or below the rates of development of renewable substitutes while minimising the impact on the use of land and the generation of noise (European Commission, 2001a).

Inefficient use of resources impacts on economic viability, since the cost of last mile deliveries could contribute anywhere between 13% and 75% of the total logistics costs, with research suggesting a norm of 40-50% for parcel deliveries (Onghena, 2008; Gevaers, Van de Voorde and Vanelslander, 2014). Costs could be generated by the low load utilisation of urban freight vehicles, partially due to market demand, restrictive regulation, and lack of co-operation in a free market (MDS Transmodal and Centro di recerca per il Trasporto e la logistica (CTL), 2012; Verlinde, Macharis and Witlox, 2012). The social effects of urban distribution were potentially lower than expected; delivery vehicles made up between 10% and 18% (Woudsma, 2001; European Commission, 2006b) of urban road traffic and in general tended to avoid peak times. There were few noticeable social equity issues, although some recent research into US metropolitan areas had suggested traffic congestion growth negatively affected growth in income and employment (Jin and Rafferty, 2017). Freight traffic was, however, highly unpopular with the public in the UK, who considered it of the lowest priority in terms of road use (SYITA, 2001) and saw a growing issue of safety conflict between cyclists and trucks (Steer Davies Gleave, 2014). The most noticeable issue was that of ‘intrusion’ - vehicles displacing or making pedestrians feel uncomfortable - and this was clearly the issue in historic city centres, and on localised campuses *such as* Newcastle University. The environmental impact of freight distribution in cities was disproportionate to the number of vehicles: 20-30% of road-based emissions were related to freight and, with regard to air quality, freight could account for up to 50% of pollutants. Diesel was the predominant freight fuel and therefore the major contributor to nitrogen oxide pollutants (NO_x) and particulate matter (PM) - the main causes of poor air quality.

The EU identified a need to address the impact of logistics activities in urban areas and set an ambitious target in the 2011 Transport White Paper to "achieve essentially CO_2-free city logistics in major urban centres by 2030" (European Commission, 2011). These tasks were then detailed further as sub tasks in integrated urban mobility planning:

- Produce best practice guidelines to better monitor and manage urban freight flows (e.g. consolidation centres; size of vehicles in historical centres; regulatory limitations; delivery windows; unused potential of transport by river).
- Define a strategy for moving towards 'zero-emission urban logistics', bringing together aspects of land planning, rail and river access, business practices and information, and charging and vehicle technology standards.
- Promote joint public procurement for low emission vehicles in commercial fleets (delivery vans, taxis, buses …) (European Commission, 2011).

As detailed in the literature review and in the framing (detailed in the next two chapters) these ambitious tasks raised problems with how to convert the flows - to and from major urban freight generators, using primarily diesel propulsion - in a liberal economy of free competition between suppliers, operators and public procurement policies that had not integrated sustainable logistics as a goal. Explored later in greater detail, these were best summarised in 2007 as "difficult to organize, difficult to modernize" (Dablanc, 2007).

The Urban Freight Research Roadmap 2014, developed by two European Technology Platforms (ETP)[2], noted: "Therefore, a holistic approach should be followed to understand what can be done upstream to the supply chain to optimise urban logistics. But the peculiarities of cities and the differences [...] also call for a focus on the urban logistics itself. Different business models, new processes and technologies should be researched and implemented." (ALICE and ERTRAC, 2014).

While most academic research dated from 2010 onwards (Macharis and Kin, 2016), in the UK interventions in the field dated back to the 1970s (Schuster, 1978), with a surge in

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[2]*ERTRAC, the European Road Transport Research Advisory Council, and ALICE, Alliance for Logistics*

Germany in the 1980s, and emergent EU policy from the 2001 White Paper onwards (Zunder and Ibanez, 2004). This focus on intervention, driven by EU aspirations for both the use of renewables to counter climate change and the shift to clean propulsion systems to improve air quality, led to successive calls within the EU Framework Programmes to address these issues through a mix of research and practical intervention. Horizon 2020 (H2020), then the current instrument, was impact oriented. During the period of this research I had been successful, as a co-ordinator and principal investigator, in bidding for funding in the field of clean urban logistics, providing it with a pan-continental *rationale* within EU urban transport policy. I had two funding *contracts*, and *access* to a consortium of experts, researchers, cities, logistics operators, and vehicle manufacturers.

1.2. National problem

At the outset of the research the UK had no substantive policy for urban freight: "Of the 162 pages in the UK government's Integrated Transport White Paper of 1998, only around six were specifically related to freight transport, raising concerns about the extent to which freight would be 'integrated' into its new policy framework" (McKinnon, 2003).

The daughter document "Sustainable Distribution: A Strategy" (DETR, 1999) attached much greater importance to the environment than had previous UK government statements; it emphasised integration across modes and a welcome integration between freight transport and land use and across different policy areas. The document was the first to adopt a broader logistical / supply chain perspective on freight transport, by championing funding of intermodal facilities, using a Freight Facilities Grant (FFG) scheme, and by the facilitation of change through Freight Quality Partnerships (FQP) and best practice research. Most of these initiatives were abolished after the change of government in 2010. The document had little to say on urban logistics, but did encourage the short flourishing of FQPs, if in name only. Some cities and regions paid more than lip service to FQPs - the North East of England being one such region.

1.3. Key local problem

Newcastle University is a prestigious University in the North East of England, a member of the Russell Group, with strong expertise in medical research and teaching, engineering and the humanities. At the time of research commencement, the University had over 144 schools, departments or institutes, more than 80 buildings, and around 5000 staff and 20000 students - making the University the second largest employer in the city, behind the NHS. The

Newcastle University campus lies next to that of Northumbria University, a Higher Education Institution (HEI) of similar size and population.

The main campus was integral to (but separated from) the main city, with other campus Sites situated elsewhere in the city (e.g. Institute of Genetic Medicine at the International Centre for Life – 1 mile south of main campus, near Newcastle Central Station; Campus for Aging and Vitality – 2 miles west of main campus, by the General Hospital). The main campus was quite well defined relative to the city, was a distinct geospatial area that could be isolated by a cordon, and is shown in Figure 1 as an aerial photograph from 2009.

The main campus also housed autonomous or semi-autonomous organisations – e.g. the Students' Union and the Northern Stage theatre. The University was also a medical teaching and research hospital, with two medical goods locations on the main campus: a shared goods entrance for the Royal Victoria Infirmary (RVI), and a sole-use delivery point for the medical teaching and research facilities. Both were included in the study, since their traffic was noted as important and their potential differences were likely to reveal insights. As an initial scoping, the work was to cover this main campus, which formed a distinct geospatial area isolated by a cordon but with a recognition of the 'fuzzy edges' and outlying secondary campuses.

Figure 1: Main Campus of Newcastle University in 2009, Source: Airfotos

Newcastle University launched a Coherent Campus initiative in July 2008, following a 'Think Tank' workshop hosted by the Vice-Chancellor (Newcastle University, 2008).

The aim was to improve the spaces between buildings, to create a sense of place that was friendly and welcoming, with well-designed, well-linked social spaces. The campus aimed to be: permeable; pedestrian and cyclist friendly; safe; clean and tidy; visually recognisable; clearly defined; and environmentally sustainable. This led to: road closures on campus; parking space reduction; new buildings; new-build living accommodation; and pedestrianisation. There was no brief to address freight, nor did the advising consultants address freight issues. The first transport focus was on sustainable travel planning, part of the 'Smarter Choices' programme introduced by the UK Department for Transport (DfT) as soft policy measures, largely well known for promoting a reduction in carbon-based travel to school and workplace via a personalised travel plan. This programme was carried out working closely with the local city council.

Within the University, the presence of freight delivery vehicles generated a steady flow of complaints from senior management, generating pressure on the Estates Service and the Purchasing function. Subjective impressions suggested a high proportion of freight on campus, with frequent complaints from senior management to Purchasing and Estates staff with regard to vehicle intrusion (Zunder, Aditjandra and Carnaby, 2012).

Conversations with Newcastle City Council about traffic around and on the campus had always been cordial and constructive and the Third Local Transport Plan (LTP3) for Tyne and Wear (Tyne and Wear Integrated Transport Authority, 2011b) had developed and stated three clear and pertinent policy actions for freight in the city and city-region:

- The continuance of the successful Tyne and Wear Freight Partnership (established 2005)[3];
- The development of Low Emission Zone(s) (LEZ); and
- An Urban Consolidation Centre (UCC) for freight, using electric vehicles.

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[3] *By 2017 this had expanded to the "North East Freight Partnership", http://northeastfreightpartnership.info.*

Meetings between the University's Estates Service, its Purchasing function, and the University Registrar, led to an agreement to address how to manage freight, increase logistics sustainability, and prevent subsidiary impacts on the city - on a campus with reducing vehicle access and increasing staff and student numbers. The University was operating a highly decentralised Purchasing organisation. The core department was small, with circa 4 full-time equivalent employees, and focused on the high spend, high turnover contracts. The system was a mix of minimal central control and widespread decentralised autonomy. Discussions had revealed, before deeper analysis, that the contractual role of a buyer could vary greatly between Faculties, Schools, Departments, Centres and Functions.

The local problem at Newcastle University then, was how to manage inbound deliveries, in a sustainable fashion, according to the *rationale* and aims of the Coherent Campus initiative. It was agreed that Thomas Zunder had both a non-monetary *contract* to help solve these problems and *access* to the necessary data and people.

The timing of key events is detailed in Table 1 below.

Year	Event
2011	Smartfusion consortium formed by author and proposal submitted to EU
2012	Smartfusion project funded and commenced
2012	First traffic survey of campus
2014	PhD proposal accepted by Newcastle University and backdated to 2011
2014	Pilot of consolidation centre scheme commenced
2015	Smartfusion project ended
2016	Pilot of consolidation centre scheme paused
2018	PhD thesis submitted
2019	Thesis second submission

Table 1: Key dates and events

1.4. Key impacts and externalities of urban freight

Key to the quantitative understanding of the impacts of urban freight was a clear definition of the key emissions, noise and safety effects of the activity. Depending on the interest and mandate of the stakeholders in any study or intervention, these were accorded different priorities.

1.4.1. Carbon dioxide equivalent (CO_2e)

'Carbon dioxide equivalent' (CO_2e) is a term for describing different greenhouse gases (GHG) in a common unit. For any quantity and type of greenhouse gas, CO_2e signifies the amount of CO_2 which would have the equivalent global warming impact. A GHG can be expressed as CO_2e by multiplying the amount of the specific gas by its Global Warming Potential (GWP) as shown in Table 2. For example, an emission of 1kg of methane can be expressed as 25kg of CO_2e (1kg CH4 * 25 = 25kg CO_2e).

The term CO_2e is useful: it allows 'bundles' of greenhouse gases to be expressed as a single number, and the total global warming impact of different bundles easily compared.

	GHG	GWP
1.	Carbon dioxide (CO_2)	GWP 1
2.	Methane (CH4)	GWP 25
3.	Nitrous Oxide (NO_2)	GWP 298
4.	Hydrofluorocarbons (HFCs)	GWP 124-14800
5.	Perfluorocarbons (PFCs)	GWP 7390-12200
6.	Sulphur Hexafluoride (SF6)	GWP 22800
7.	Nitrogen Trifluoride (NF3)	GWP 17200

Table 2: Kyoto's Greenhouse Gases, Source: (Parry *et al.*, 2007)

As can be seen in Table 3 below, transport had grown from emitting 22.3% of GHG in 2011, to 26.9% in 2016. This trend was likely to continue, if a 'business as usual' approach were adopted in the UK, as detailed in the 2017 Freight Carbon Review (Department for Transport, 2017a).

Of note for freight is the rising proportion of heavy goods vehicles (HGVs) and light vans (LGVs) as contributors to GHG emissions. It is pertinent to note that LGVs have grown proportionally greater than HGVs, a trend in alignment with the growth of LGV usage in the UK over recent decades, representing 15% of all motor vehicle traffic in 2018 compared to 10% in 1998 (Linton, Fuller and Bray, 2018). Both HGVs and LGVs have improved in fuel efficiency, but absolute miles, and a move to larger LGVs, have offset this trend in absolute emissions. In particular, this is reflective of the increase in home deliveries - typically undertaken by vans. The step-change to increased internet shopping and home deliveries coincided with manufacturers offering businesses more attractive finance packages for new vehicles. As a consequence, the light commercial vehicle (LCV) 'parc' (total number of vehicles in use) rose by more than 50% since 2000 to 4.18 million units in 2016. The LCV market doubled in size from the low of 2009 and 2016, and, while it slipped by 3.6% in 2017 to 362,149 units, it remained 94% above the 2009 level. The rise followed a sharp uplift in the distance such vehicles are travelling, up by more than 50% since 2000 (SMMT, 2018).

Greenhouse gas emissions by transport mode, United Kingdom: 2003 to 2016		Million tonnes of carbon dioxide equivalent
Percentage of domestic emissions	*in 2011*	*in 2016*
Cars and taxis	12.7%	15.0%
Heavy goods vehicles	3.3%	*4.3%*
Light vans	2.9%	*4.1%*
Buses and coaches	0.7%	*0.7%*
Motorcycles and mopeds	0.1%	*0.1%*
Other road transport emissions	0.1%	*0.1%*
Total	19.8%	*24.4%*
Rail	0.4%	*0.4%*
Domestic aviation	0.3%	*0.3%*
Domestic shipping	1.2%	*1.3%*
Other	0.6%	*0.5%*
Total	2.4%	*2.5%*
Total domestic transport as % of net domestic emissions all sources	22.3%	*26.9%*

Table 3: : GHG emissions by Transport mode, 2011 versus 2016, compiled from DfT statistics (Department for Transport (DfT), 2018a)

Urban delivery activity represented 21% of freight vehicles on UK roads in 2014, contributing 10-12% of all GHG emissions attributable to such vehicles. A further 10% of traffic and 4% of GHG were generated by 'municipal utility', such as refuse collection - a form of freight (Department for Transport, 2017a, p. 18). This makes such activity a significant part of traffic volume, but not the main source of GHG emissions from overall freight traffic.

1.4.2. Nitrogen Oxides (NOx)

NOx is the generic term in atmospheric chemistry for the nitrogen oxides most relevant to air pollution: Nitric Oxide (NO) and Nitrogen Dioxide (NO_2). In areas of high motor vehicle traffic, such as large cities, they can be a significant source of air pollution. These gases contribute to the formation of acid rain and smog, as well as tropospheric ozone, and are usually produced from the reaction between nitrogen and oxygen, during combustion in air of fuels (e.g. hydrocarbons) - especially at high temperatures (e.g. car engines). NO_x and volatile organic compounds (VOCs) react in the presence of sunlight to form photochemical smog - a significant form of air pollution. People who work or exercise outside, and people with lung diseases such as asthma, are particularly susceptible to adverse effects, such as lung tissue damage and reduction in lung function. The UK Government provided conversion factors for NO_2 reporting by companies; it is thus the emission utilised in this thesis.

In Figure 2 the growing absolute tonnage of NO_2 emitted by diesel LGVs is evidenced, alongside the falling absolute tonnage emitted by petrol LGVs (a minority vehicle type), and rigid and articulated HGVs. This is further illustrated in Figure 3, showing the changing dominance between LGVs and HGVs as sources of NO_2 in all driving conditions and locations.

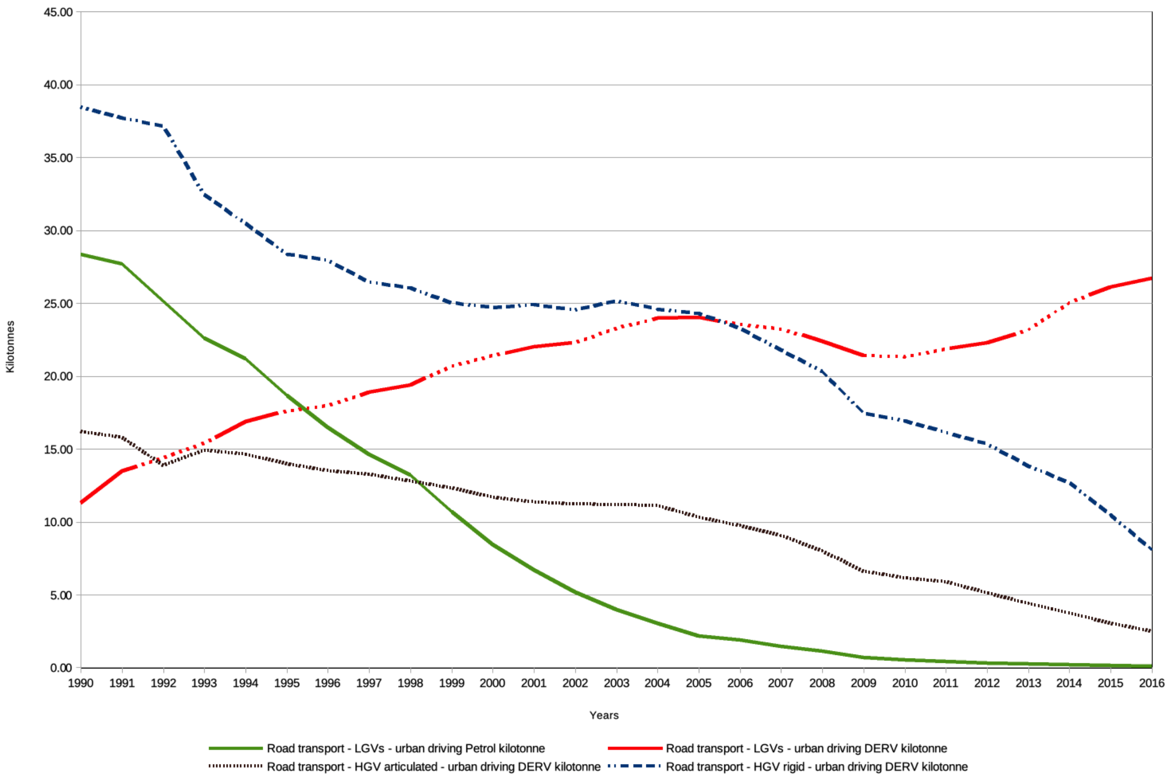

Figure 2: Nitrogen oxides emitted by Urban Freight 1990-2016, compiled from NAEI data[4]

[4] http://naei.beis.gov.uk/data/data-selector-results?q=114346

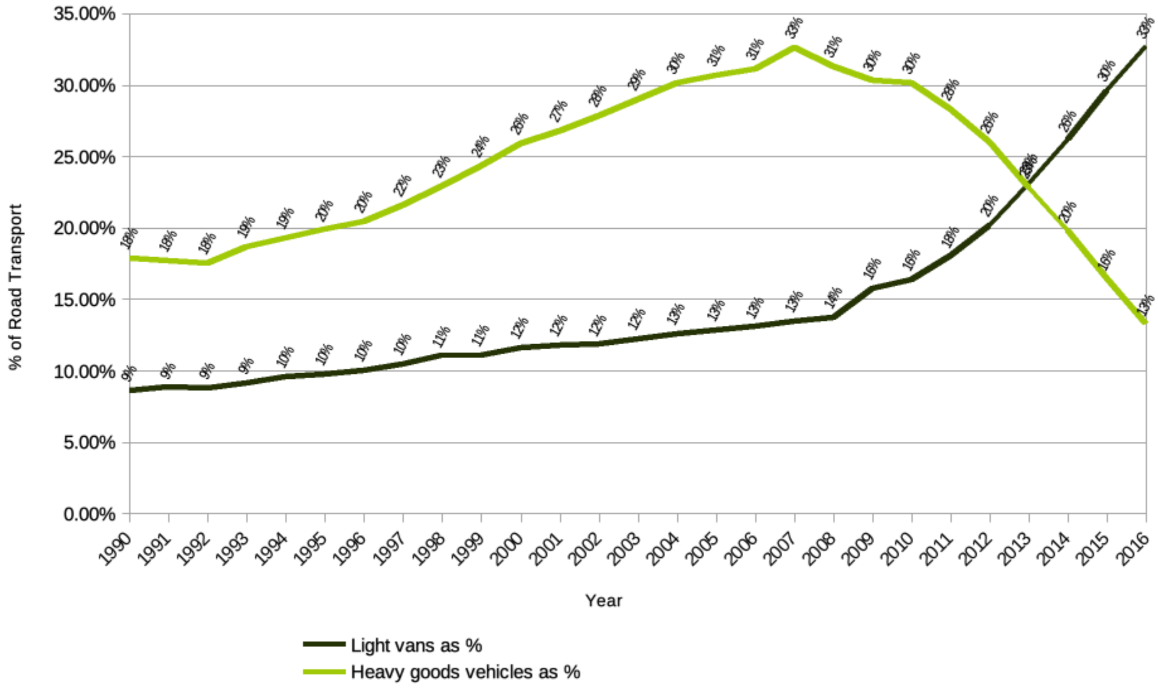

Figure 3: NOx Air pollutant emissions LGVs versus HGVs 1990-2016, compiled from DfT statistics (Department for Transport (DfT), 2018b)

1.4.3. Particulate Matter

Particulate matter (PM), also known as particle pollution, is a complex mixture of extremely small particles and liquid droplets escaping to air. PM_{10} is particulate matter 10 micrometres or less in diameter; $PM_{2.5}$ is particulate matter 2.5 micrometres or less in diameter. $PM_{2.5}$ is generally described as fine particles. Once inhaled, these particles can affect the heart and lungs and cause serious health effects (US EPA, 2017).

In 2014, about 16 % of the EU28 urban population was exposed to PM_{10} above the EU daily limit value (i.e. 50μg/m^3 not to be exceeded on more than 35 days per calendar year, for short-term exposure). The extent of exposure above this EU daily limit value fluctuated between 16 % and 42 % from 2000–2014, and between 16 % and 21 % from 2012 to 2014. Furthermore, up to 50 % of the same urban population was exposed to concentrations exceeding the stricter WHO AQG value for PM_{10} (20 μg/m^3 annual mean, for long term exposure) in 2014 (Guerreiro *et al.*, 2016, p. 55).

In Figure 4, the declining emissions of PM_{10} from different modes of transport can be noted. Traffic has been rising, however, and it is worth noting this was reflected in Figure 4 as a rising trend in emissions of particulates from tyre and brake wear, as well as road abrasion.

These sources are not related to the engine, or fuel, and are emitted by all vehicles, including cleaner (e.g. electric) vehicles.

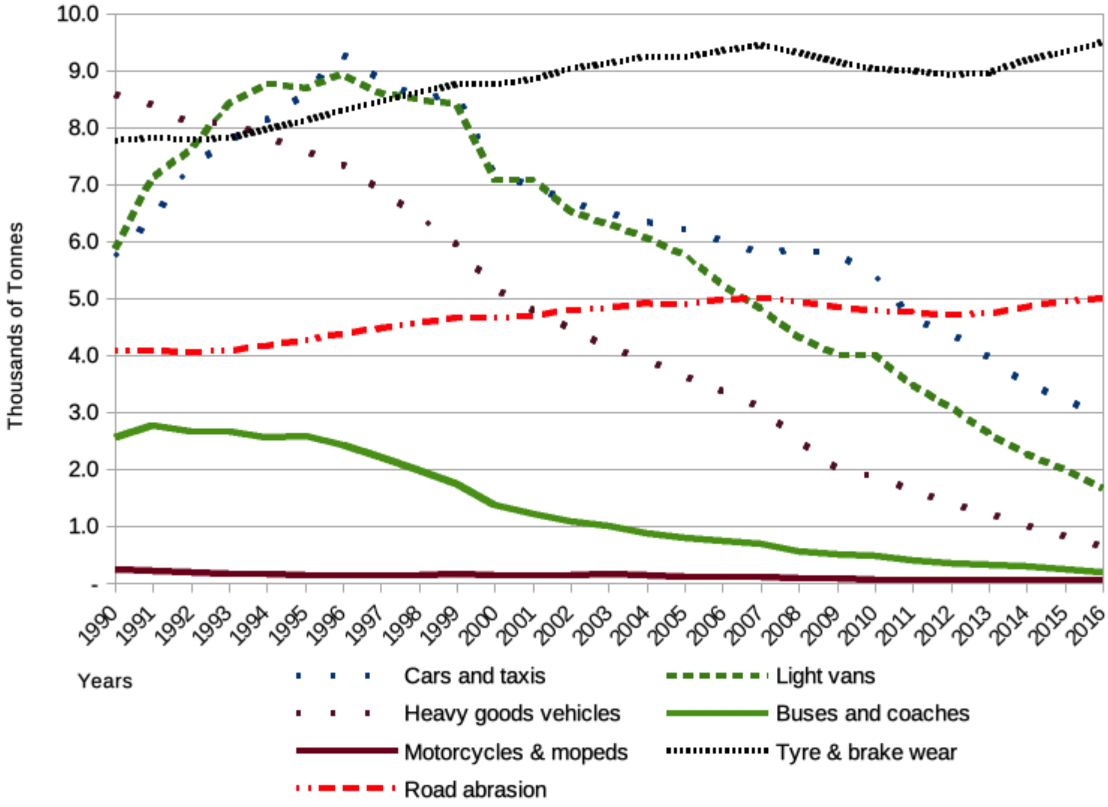

Figure 4: PM10 Air pollutant emissions by road transport mode 1990-2016, compiled from DfT statistics (Department for Transport (DfT), 2018b)

In Figure 5 the emissions inventory data for the UK 1990-2006 showed that PM_{10} fell in absolute tonnage from vehicles over this period, but again it was noted that this does not evidence the particulates from tyre, brake and road abrasion.

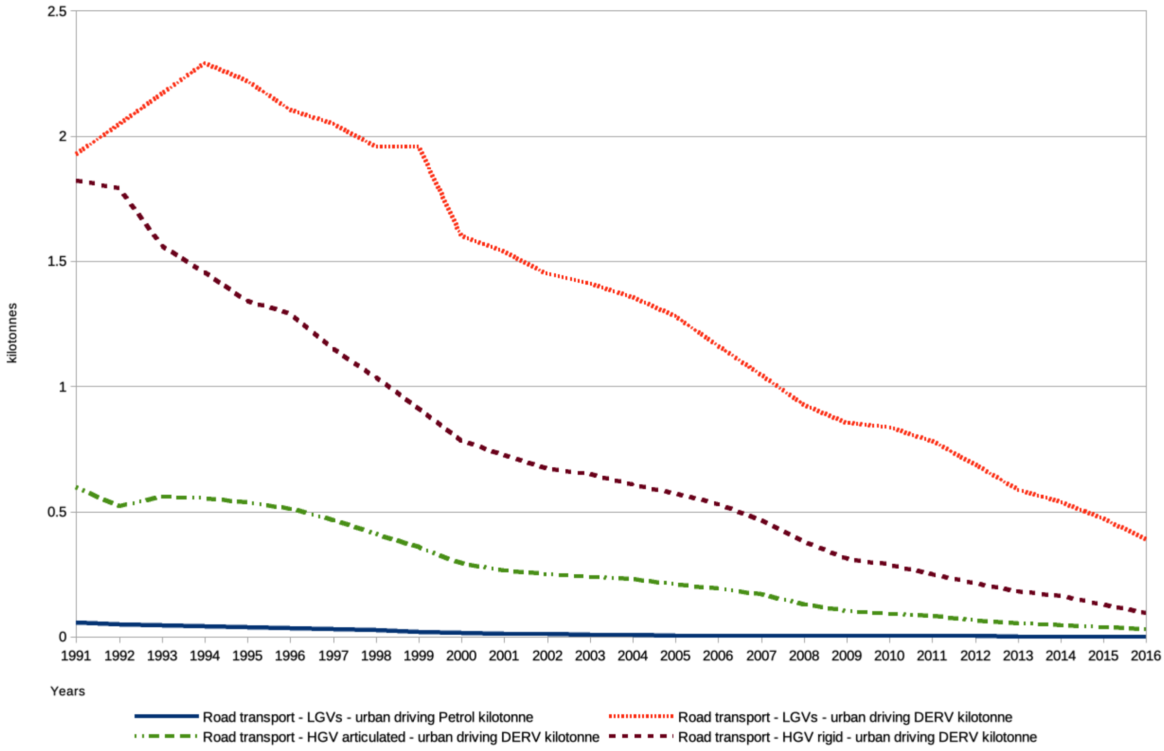

Figure 5: PM10 emitted by Urban Freight 1990-2016, compiled from National Atmospheric Emissions Inventory data[5]

The changing balance between LGVs and HGVs as the sources of emissions in cities, as noted for NO_2 and GHG, is again evidenced in Figure 6 as the share shifted to LGV dominance, in the early 90s.

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[5] *http://naei.beis.gov.uk/data/data-selector-results?q=115295*

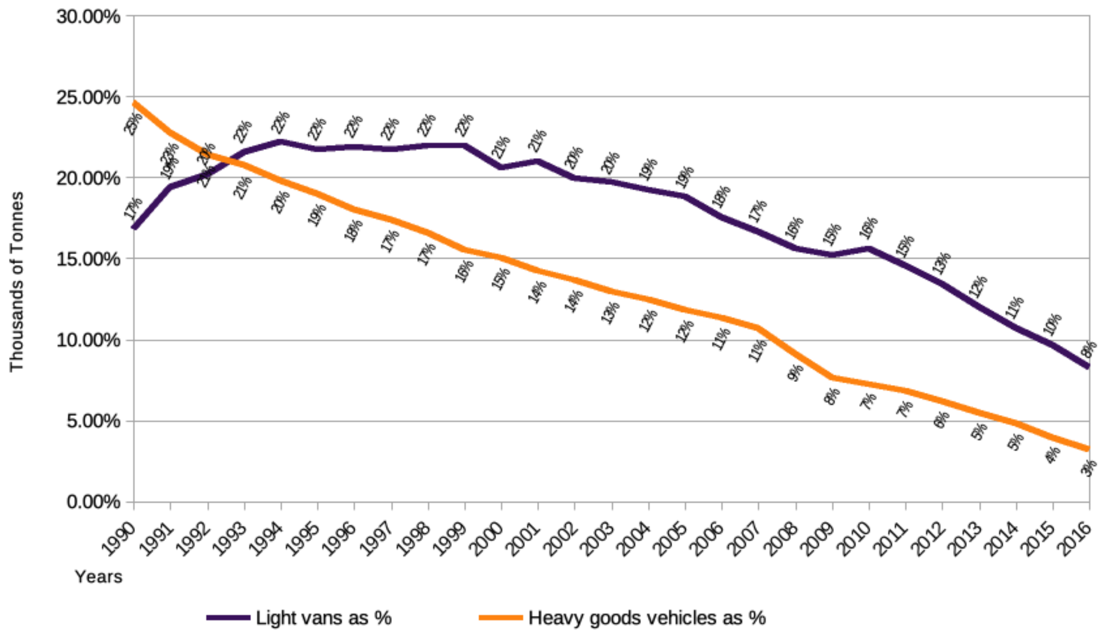

Figure 6: Air pollutant emissions LGVs versus HGVs 1990-2016, compiled from DfT statistics (Department for Transport (DfT), 2018b)

The changes in emissions of NO_2 and PM_{10} over this period were all related to the positive impact of increasingly tight emissions standards in the manufacture of vehicles in the European Union, known as the EURO standards: 1-6 for cars and I-VI for trucks. These standards formed the basis of evaluation and assessment of impact in Chapter 10 and are detailed further there.

1.4.4. Noise

Noise as an external dis-benefit from freight activities was a well recorded problem, especially in the evening and at night. The EU Environmental Noise Directive of 2002 was the main EU instrument to identify noise pollution levels and to trigger the necessary action, both at Member State and at EU level, with a key emphasis on quiet area preservation and loud area amelioration (EUR-LEX, 2002).

The application of mechanical engineering and operational practices could reduce the noise impact of freight substantially and had been developed as a workable programme in the Netherlands under the PIEK[6] initiative (Browne *et al.*, 2012). This programme, championed

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[6] *PIEK is not an acronym but the Dutch for 'peak', as in peak noise limit*

in the UK by the Noise Abatement Society[7], was used extensively by Transport for London (TfL) as part of the retiming of deliveries for the 2012 London Olympics (King's College London, 2012; Transport for London, 2017). To achieve the standard, each product was acoustically measured and had to function emitting under a peak 60dB at 7.5 metres from the sound source. It was then deemed suitable for out-of-hours delivery that would not cause noise disturbance to local residents. I decided to check the degree to which standardised noise impact evaluations would be required or possible in this research.

1.4.5. Safety

The safety implications of freight traffic, cars, cyclists and pedestrians on an increasingly pedestrianised campus were of interest to the University. Generally, statistics and analysis displayed in Figure 7 showed that freight drivers were safe drivers, rarely causing or being involved in road traffic collisions (RTCs) but that when they were, there was a higher likelihood of these involving a fatality (Allen, Piecyk and Piotrowska, 2016; Pokorny *et al.*, 2017)

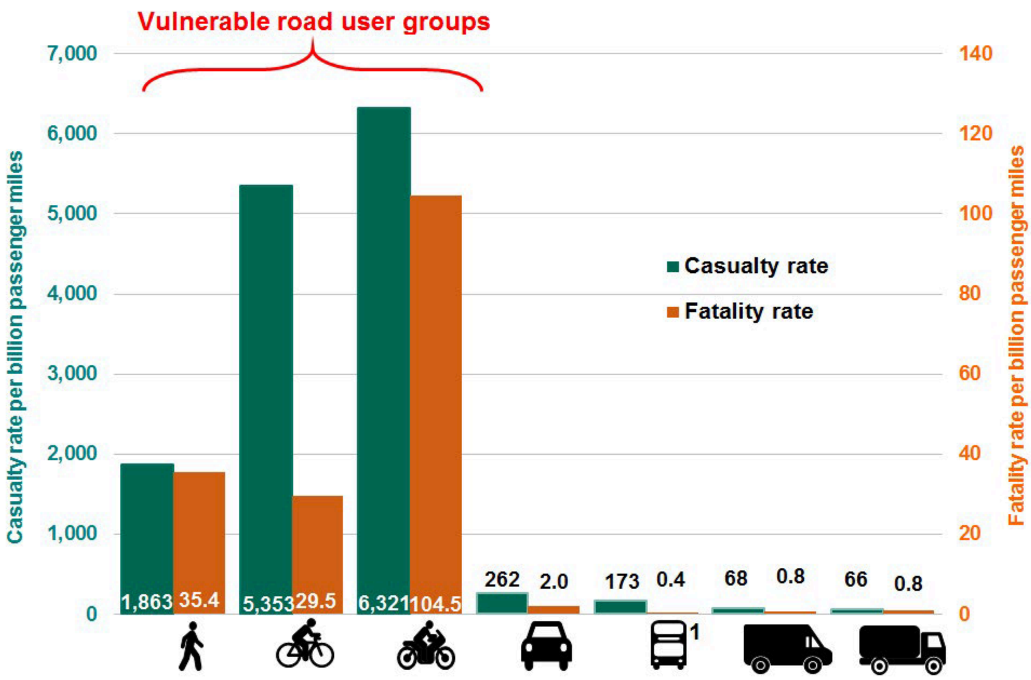

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Figure 7: Casualty and fatality rates per billion passenger/driver miles by road user type: GB, 2016: Source (Department for Transport, 2017b)

Caution was given to this analysis by those who believed it was due to the fact that goods vehicles were only involved in a certain class of accident: "that there is a different pattern of

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[7] *http://noiseabatementsociety.com/campaigns/nas-piek/*

accidents which involve HGVs, and simple claims that they are “safer” than other vehicles are not supported by this analysis” (MTRU, 2013).

The Urban Transport Group, in their ‘White Van Cities’ (Linton, Fuller and Bray, 2018) reported that 88.5% of vans checked in 2013 were overloaded, 63% were noted as having serious mechanical defects in 2017, and 50% failed the MOT Test in that year.

Initial queries with the University’s on-campus Security department showed no reported accidents between vehicles and pedestrians since records were started. However, I decided to consider the degree to which standardised safety impact evaluations would be required or possible in this research.

1.5. Subsidiary Problems

Having considered these externalities I now moved to considering problems that traversed the local/national/international core problems and began to form questions that would need to be answered.

1.5.1. Demand

The University demanded goods and services that led to vehicle activity. This simple statement had many subsidiary levels of complexity, for example: were all demands expressed through a purchase order and created and authorised through a standardised requisition, tendering, authorisation and release process? Were some demands perhaps expressed through other official processes, such as purchasing cards (a form of corporate credit card)? Did simply ringing a supplier, having goods delivered, and then following the official process after the event, perhaps create ‘unofficial’ demand? With its multiplicity of schools, departments, support services, catering outlets, and residences, was the University truly a single institution, or did it actually have divergent processes and practices, both official and unofficial, spread across the 144 entities contained within 80 buildings?

Another interesting question would have been to address the number of vehicles attending nearby or co-located areas in the city centre, such as the NHS hospitals, the Civic Centre, or nearby Northumbria University. This would suggest whether the activity seen on the main campus was part of a longer, efficient transport chain through the city, or consisted of single incursions into the main urban area.

How consciously aware was the end user about the requirements they expressed? Why did they require next day delivery of goods: because they held no stocks and needed urgent replacement, or because the data entry screens simply defaulted to ‘next day’ and very few people saw any need or had a role in changing it? Did people deliberately differentiate between one supplier and another? To what extent was the quantity or frequency of ordering based on a specific approach, need, or policy?

What did the University demand? Was it an educational institution, ordering paper and pencils or, as an engineering University, was it a buyer of bulk gases, steel and electrical components or, as a medical research and teaching body, did it order medical supplies, biological agents, and live or radioactive samples?

The problem of how demand was expressed was intertwined with the issue of how data were created within the demand generation processes and practices. In some ways, the official systems may have generated sound data and the unofficial systems less so but, in practice, both could be problematic. Was the University procurement system designed to manage logistics, or financial transactions? For example, a system like SAP[8] could be configured in many ways and the implementation at the University could have been primarily focused on financial processes and audits. This might have led to a paucity of data, or even misleading data, in such fields as requested delivery dates, dates received, and even the actual date of the stated demand - as opposed to the recorded date of the documentation. Some records may not even have shown the goods ordered: sales and purchasing professionals might frequently exchange paperwork with such uninformative text as “see below”, “as soon as possible”, or “for reference purposes only”. As Puschmann and Alt said: “Companies also have to realize that a non-standardized e-procurement solution exists and that important success factors are ‘non-technical’ in nature” (2005).

Investigation showed clear problems with the creation, processing, expression, and recording of demand from the University to its suppliers and, consequently, potential research gaps and questions could be identified:

- How, by whom and why was demand for goods and services generated by the various elements of the University?

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[8] *A full enterprise resource planning software suite used widely and at Newcastle University: originally “Systeme, Anwendungen, Produkte in der Datenverarbeitung”; or later: Systems, Applications and Products in Data Processing.*

- How, and how accurately, for logistics analysis purposes, were data on the demand activities of the University recorded?

1.5.2. Supply

It was also appropriate to examine the issues associated with the supply-side of the provision of goods and services to the University. Which suppliers did the University use? Where were they based: was the despatch location(s) known, as distinct from their registered office, manufacturing base, sales office, or accounts receivable department? Was there clarity about who was supplying what from where?

What methods did the suppliers use to deliver? Did they utilise their own fleet of vehicles, or outsource to third party logistics providers (3PLs)? How frequently did they use open carrier networks, such as Royal Mail, UPS or TNT, and to what extent did they actively or passively control their logistics flows? Of great interest was how suppliers managed the differing urgencies and scales of demand from the University. For example, if the supplier had a policy of holding significant stocks of goods at a distance, which required special transport runs to achieve a next day delivery, did they use a different logistics method - perhaps a less efficient one - to meet a next day demand, when a longer lead time (say 2-3 days) would have enabled a slower and yet more efficient routing that was perfectly acceptable to the purchaser?

How important was the University to the suppliers? Most ERP and other purchasing systems had management reports offering customer pareto analyses as standard, with splits varying from organisation to organisation and from time period to time period. (Salespeople applied similar metrics to their customers, although these could differ, with profitability per customer, sales turnover and/or marketing strategy sometimes afforded different importance.)

It was clear that, in commerce, not all suppliers and customers were equal, and the degree of attention focused on one or the other varied between organisations and over time.

Did such pareto metrics for managing focus and relative importance help when looking at freight activity generation? Did a supplier with whom the University spent a great deal of money, and who deserved a great deal of attention commercially, already deliver goods efficiently in a manner consistent with sustainable development, as detailed in section 1.1 above, or might they have had the resources to utilise a logistics chain so efficient as to make little impact on the number of vehicles on campus? Did a supplier with whom the University spent little, on a sporadic demand pattern, deliver inefficiently – or did it perhaps use a large carrier network which had already achieved critical mass and sustainability, and might a combination of many such small cases contribute more significantly to overall freight flows, for good or ill? Other scenarios could be imagined, that could mitigate or exacerbate the traffic impact of suppliers in different groups. So, how important were different characteristics and metrics in segmenting the supplier base and then correlating their behaviour and our relative interest in focusing on their logistics activities?

There were clear problems in understanding the physical nature of suppliers, their logistics processes, relative importance to the University, how important they considered the University to be, and the degree to which these factors influenced final delivery activity. Consequently, the following potential gaps and questions were identified:

- Who supplied the University and what were their organisational structures with regard to deliveries?
- How important were the suppliers to the University - and vice versa - and how did this influence logistics chain?
- Which logistics methods could/did suppliers deploy to meet demand and why?
- How best to categorise and segment the supplier base, to better understand it?
- How do procurement practices lead to unsustainable logistics activity?

1.5.3. Activity

The interplay of demand and supply generated much activity on the campus. Although the University had a travel planning policy, and active intervention for personal travel, it did not record vehicle movements on the campus, nor did the City Council do so. Several key parts of the campus were public highways, whilst others were private roads of the University, where access to the public had been granted. Many areas lay outside the direct planning and monitoring of the city.

At the beginning of the research there was no traffic analysis, nor any understanding of freight flows, freight volumes, or the nature of vehicle types. All comments on such activity were subjective, usually expressed by senior management, and supplemented by a noted volume of vans and trucks parked, often illegally, outside the perimeter of the recently pedestrianised campus.

Figure 8: Freight Vehicle Intrusion on Newcastle University Campus

The need for good traffic count data, broken down by location, time, and vehicle type, was therefore a key research gap.

Freight generated dis-benefits that were wider than simple intrusion, including generation of greenhouse gases (GHG) - primarily Carbon Dioxide (CO_2) – and the emission of sulphur oxides (SO_X), nitrogen oxides (NO_X) and particulate matter (PM). Although these were not expressed directly in the Coherent Campus initiative, they affected the University mission statements with regard to carbon footprint and, for SO_X, NO_X and PM, directly affected the quality of air on campus - a key metric for all cities across Europe and part of the safe and attractive campus aspect of the Coherent Campus initiative.

It was not adequate to simply know volumes and types of freight activity; the nature of delivery chains and their flow across the campus's wide range of delivery locations had also to be understood. One useful metric would be how many vehicles were making multiple drops across multiple locations.

I had now identified further problems with freight activity: it generated intrusion; it was unmonitored and largely un-scoped; its environmental impacts were not measured; and the trip chaining and nature of freight trips were not fully understood. This in turn generated further subsidiary questions:

- How many vehicles of what kind were on campus?

- How did vehicles on site carry out their activities - in long chains of multiple drops (on campus, or in other areas of the city centre), or as single drops?
- What were the key outputs of freight activity in terms of GHG, SOx, NOx and PM emissions?
- To what extent could the University campus be seen as part of the wider set of similar campuses nearby?

1.6. Change

How would or could the current state change? To what extent were the drivers and dynamics of the interrelated activities of goods and service supply to the University understood? Was there an understanding of how change might happen, or could be made to happen in the future, and what would be its positive or negative outcomes? What was the likelihood that interventions to bring about change would either take effect or affect outcomes? Were appropriate changes or interventions to solve the problem understood, and was there certainty that the problem was itself fully described and understood by the researcher, by the actors, and by the wider interested parties?

To these ends, key questions about change were possibly the key questions of the research to be answered in this thesis.

- How could the activities that were associated with the problem(s) be understood in terms of drivers, causes, effects, and interdependencies?
- How could interventions and potential changes be identified?
- How could understanding be reached of the likelihood that activities would change and the potential outcomes of such change?
- What advice would be suitable to give those with the ability to act, to solve the perceived problems?

1.7. Research Questions

Based on the rationale detailed in sections 1.3, 1.2, locally and internationally, the literature review in Chapter 2, and the subsequent framing in Chapter 3, the research questions for this work were considered, reconsidered, refined and decided upon. They are listed here in Chapter 1 and the process of generating and refining generic research questions worthy of further investigation is detailed in the next two chapters.

Since the work was both a practical intervention with benefits to the University, and of subsequent value in international demonstration, one potential question to be asked was 'How to improve the sustainability of urban freight at a University campus?' However, this was too broad a definition, so others were considered. Other potential questions were: 'How to facilitate change in an academic institution to achieve sustainable city logistics'; and 'Was method X effective in achieving change for sustainable city logistics in a large institution?' The key research question had to be local sustainability, then a second question to advance knowledge about research itself, and finally one to draw out a sustainable enduring legacy of the work, with value to others in the field.

> *RQ1: How to improve the sustainability of logistics on the Coherent Campus at Newcastle University?*
>
> *RQ2: To what extent can sustainable HEI logistics only be achieved through sustainable procurement practices?*
>
> *RQ3: How effective were participatory research approaches in facilitating this improvement?*
>
> *RQ4: What novel approaches for policy and practice locally, nationally and at an EU level could be developed from this work?*

The RQs are listed here for the use of the reader, and were developed as part of the processes reported later in Chapter 2 and Chapter 3 below.

1.8. Summary

In this Chapter I have laid out the practical rationale for the work undertaken and the local, national and EU context in which it lay. I have shown how the policy *rationale* at local and EU levels led to *contracts* for the work, and *access* to allow it to proceed effectively. The importance of rationale, contract, and access in Action Research is detailed further in Chapter 5 below.

The key quantitative impacts of urban freight have been detailed. Greenhouse gases that affect climate change were usually subsumed into a Carbon Dioxide equivalent. The emissions that affect air quality and health were NOx and particulate matter (PM). Noise was an emission that particularly affected people in the evening and at night. Safety had been a driving force in UK transport planning and freight had different characteristics to other road user types.

I have discussed how the subsidiary problems of the supply and demand of goods and services raised a series of potential operational gaps and questions. The activity that this commerce generated led to further questions, as did the very real question of how to enact change - one of the key issues of modern-day study in operations management.

This chapter sets the scene, at international, national and local levels, and I have summarised the organisational gaps and questions raised at each. In the following two chapters the process of reviewing the literature, identifying research gaps, and framing them in the literature as research questions, is reported.

Chapter 2. Literature Review

This chapter details the literature used from commencement of the research in 2011 to final submission in 2019. This literature review places the case study within the context of the wider research area. It covers the literature, both peer-reviewed and otherwise, to position the work in the area of knowledge concerning more efficient management of procurement and the resulting delivery and service flows to ‘large municipal organisations’ emanating from it. The literature - a body of 219 works - was reviewed using a mix of peer-reviewed and grey literature, and a combination of online scholarly databases: the NOVELOG toolkit database, a CASP checklist, and textual-graphical analysis using word clouds. Key concepts were identified and grouped as recurring, or with noticeable gaps.

Literature reviews are utilised by researchers to help build knowledge, identify gaps, and begin the process of drawing out the concepts to develop a theoretical framework against which to benchmark the research outcomes of the work - not the practical outcomes of actions taken. This is a key part of the planning of the thesis research and should address these key questions: “What is the level of existing knowledge of the topic; what is the role of existing theory; and what contribution to knowledge is the academic/thesis project expected to make?” (Coughlan and Coghlan, 2016). The intent is to build a conceptual framework that guides the data gathering and analysis, as well as framework(s) that are embedded in the practical research. The former is guided by the literature review and the latter by the rationale and needs of the work in praxis.

There are multiple ways in which a literature review can be viewed. For this work I adopted the concept of a ‘report’, with a focus on “framing a written discourse about the literature which may be established as a component part of a thesis or other research” (Bruce, 1994).

Most literature reviews in social sciences are ‘narrative’ reviews, which means they develop an overview of a field through a reasonably comprehensive assessment and critical reading of the literature. An alternative approach, more common in medicine and the traditional sciences, is that of a ‘systematic’ review. A systematic review applies a transparent, replicable and often quantitative methodology to the process of literature identification and review. In some highly quantitative fields, a researcher may adopt a meta-analysis, extrapolating and synthesizing results from multiple papers. A systematic approach to qualitative research has also been developed and named meta-ethnography (Bryman, 2012, pp. 98–112). It has been suggested that meta-analysis is not appropriate for transport-based literature reviews, due to the "fact that many variables influence an independent variable (e.g. travel behaviour) in a complex way, resulting in complex causal relationships, and a multitude of data analysis methods and interpretations" (van Wee *et al.*, 2016).

It has been noted that a weakness of literature reviews in the field of transport has been the lack of explicit methodology (van Wee *et al.*, 2016); to mitigate this tendency I adopted a narrative review, but one guided by a core systematic review in terms of literature survey and selection (Bryman, 2012, pp. 98–112). This allowed an emphasis on such features as transparency about how searches were done, and the potential for comprehensiveness in the literature found. These systematic review practices were evidenced in the use of the explicit thesis research questions to guide the review, and the specification of replicable research search procedures.

2.1. Scope of the Review

Based upon the problems identified and listed in Chapter 1, the literature review covered the following:

- Enquiry into and about the movement of freight goods and derived vehicle demand in cities. Initial reading and personal insight revealed that this has been variously defined as 'urban logistics', 'city logistics', and also 'urban freight'.
- The impacts large municipal organisations have on cities in terms of wealth creation, jobs, person and freight related trip making.
- The operational models associated with goods and service supply to large municipal organisations (centralised and decentralised service provision).
- The ways in which procurement systems operate across municipal organisations with large numbers of departments and potentially "power buyers".
- The ways in which supply chains serving large municipals have been made more sustainable, including collaborative logistics techniques (to include consolidation) as well as smart procurement.
- The potential for typologies or taxonomies in the field that would inform the development of the framing of the work in the field.

Methodology was excluded from the literature review, since considerations of epistemology and methods are discussed in Chapter 4 and Chapter 5 below.

2.2. Review Protocol

First, the literature review utilised the WEB OF SCIENCE [WOS][9] Google Scholar [GS] and the EU Transport Research and Innovation Monitoring and Information System [TRIMIS[10]] databases, using explicit searches and to report the overall scoping of literature in this top-level field. A large proportion of non-peer reviewed literature existed in this field, often from research projects, in the form of reports and other deliverables. Bryman calls this 'grey' literature and it is of great value in many fields of research into people and systems. To enable a systematic review of such materials, I utilised research outputs carried out with my colleague Paulus Aditjandra and others (Aditjandra and Zunder, 2018), available as part of the NOVELOG toolkit[11].

The top-level scoping was then followed by keywords and search terms developed from the core research questions and the top-level scoping. This subset of the literature was then examined against an inclusion list, checking that none of the works met any exclusion criteria. These more focused searches formed the body of work for the next step.

Secondly, the key literature was reviewed narratively, which allowed for an emergent view of the literature and theory, as a result of this narrative, throughout the whole period of the work.

2.3. Top-Level Scoping Review

The field in which the review was carried out, and renewed many times, lay in the enquiry into and about the movement of freight goods and derived vehicle demand in cities. Initial reading and personal insight revealed that this had been variously defined as 'urban logistics', 'city logistics', and also 'urban freight'.

Searching for ("urban freight" or "urban logistics" or "city logistics") in the Web of Science reported 1,248 records as at 30/11/2018[12]. The papers were published in fields largely related

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[9] *apps.webofknowledge.com*

[10] *https://trimis.ec.europa.eu*

[11] *http://www.uct.imet.gr/Novelog-Tools/Toolkit*

[12] *Search from 1970 to 2018, search terms applied to all fields.*

to transport, management, urban studies and environmental studies, as evidenced in Figure 9 below.

Figure 9: Top level visualisation of urban/city freight/logistics by field, all publications, 1970-2018 Source: Web of Science 30-11-18

It was apparent that this field was novel and, over the last year, the number of publication and citations had risen sharply, as shown in Figure 10; this was suggestive of a field of research emergent in academic research.

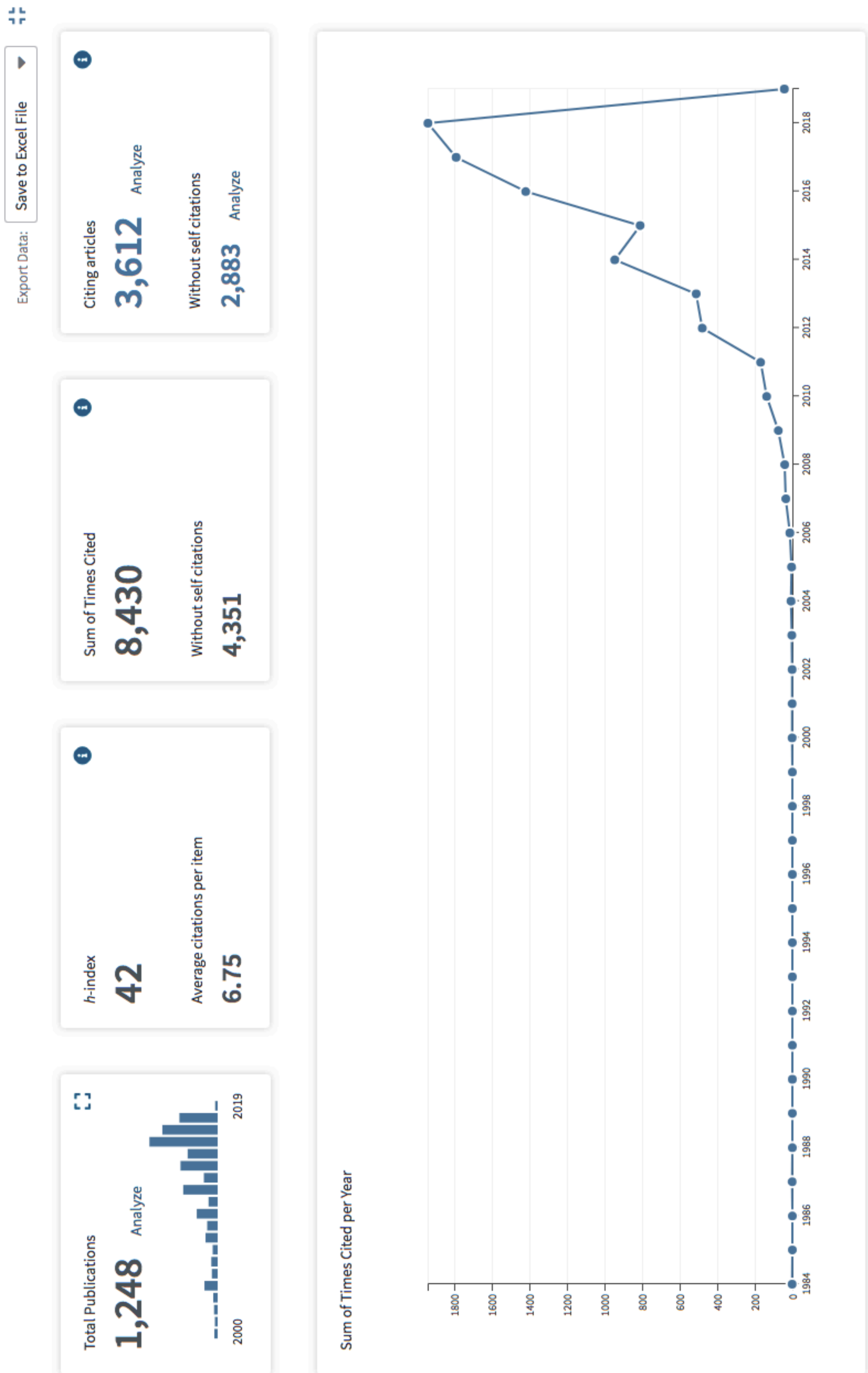

Figure 10: Citations metrics urban/city freight/logistics, all publications, 1970-2018 Source: Web of Science 30-11-18

The authors with the highest output were as detailed in Table 4. Whilst highest volume may not usually indicate quality/relevance, it is helpful for setting context and identifying key authors.

Author	No publications	% of total
TANIGUCHI E	38	3.05%
COMI A	28	2.24%
BROWNE M	27	2.16%
HOLGUIN-VERAS J	25	2.00%
IWAN S	25	2.00%
KIJEWSKA K	20	1.60%
MARCUCCI E	20	1.60%
MUNUZURI J	20	1.60%
CRAINIC TG	19	1.52%
GONZALEZ-FELIU J	19	1.52%
MACHARIS C	19	1.52%
THOMPSON RG	19	1.52%
GATTA V	17	1.36%
YAMADA T	17	1.36%
PERBOLI G	16	1.28%
DABLANC L	15	1.20%
NUZZOLO A	15	1.20%
ALLEN J	14	1.12%
CORTES P	13	1.04%
VAN DUIN JHR	13	1.04%
QUAK H	12	0.96%
QURESHI AG	12	0.96%
ROUTHIER JL	12	0.96%
DE OLIVEIRA LK	11	0.88%
MALECKI K	11	0.88%

Table 4: Top Authors by publication count urban/city freight/logistics Source: Web of Science 30-11-18

In terms of citations, the top ten publications ranked by citation were as detailed in Table 5:

Title	Authors	Source Title	Date
Goods transport in large European cities: Difficult to organize, difficult to modernize	Dablanc, Laetitia	Transportation Research Part A - Policy And Practice	Mar 2007
Models for Evaluating and Planning City Logistics Systems	Crainic, Teodor Gabriel; Ricciardi, Nicoletta; Storchi, Giovanni	Transportation Science	Nov 2009

Title	Authors	Source Title	Date
Advanced freight transportation systems for congested urban areas	Crainic, TG; Ricciardi, N; Storchi, G	Transportation Research Part C-Emerging Technologies	Apr 2004
Solutions applicable by local administrations for urban logistics improvement	Munuzuri, J; Larraneta, J; Onieva, L; Cortes, P	Cities	Feb 2005
An adaptive large neighborhood search heuristic for Two-Echelon Vehicle Routing Problems arising in city logistics	Hemmelmayr, Vera C.; Cordeau, Jean-Francois; Crainic, Teodor Gabriel	Computers & Operations Research	Dec 2012
Intelligent freight-transportation systems: Assessment and the contribution of operations research	Crainic, Teodor Gabriel; Gendreau, Michel; Potvin, Jean-Yves	Transportation Research Part C-Emerging Technologies	Dec 2009
Intelligent transportation system based dynamic vehicle routing and scheduling with variable travel times	Taniguchi, E; Shimamoto, H	Transportation Research Part C-Emerging Technologies	Jun-Aug 2004
The Two-Echelon Capacitated Vehicle Routing Problem: Models and Math-Based Heuristics	Perboli, Guido; Tadei, Roberto; Vigo, Daniele	Transportation Science	Aug 2011
Travel time reliability in vehicle routing and scheduling with time windows	Ando, Naoki; Taniguchi, Eiichi	Networks & Spatial Economics	Sep 2006
An evaluation methodology for city logistics	Taniguchi, E; van der Heijden, RECM	Transport Reviews	Jan-Mar 2000

Table 5: Top ten publications ranked by citation

The publication dates offered evidence that this was a newly emergent area of publication, with 77% of all articles published after 2011, the start of this research work. 59% of the publications were conference proceedings, and 41% were peer reviewed articles. This top-level survey suggested a recent expansion of publication in the previous decade, and a high proportion of conference proceedings. The first pass suggested key authors in this field, a range of topics, and areas of research. These were followed up and then a refined, more focused series of searches were carried out, as detailed in section 2.5 below.

2.4. NOVELOG Toolkit Database

NOVELOG 2015-2018 was an EU project, funded by the H2020 Programme, to advance understanding of freight distribution and service trips by providing guidance for implementing effective and sustainable policies and measures. The project involved experts from all UFT stakeholder categories (city authorities, academia and industry) and established multi-stakeholder platforms in each project city, for a higher impact. The project developed four tools to help cities understand urban freight transport (UFT), facilitate stakeholder collaboration, and to transfer best governance (measures and policies) and business cooperation models. Dr Aditjandra and I developed a comprehensive database of urban freight research programmes and initiatives as the 'NOVELOG Toolkit', which could be interactively queried online (Aditjandra and Zunder, 2018). Since research and innovation projects and interventions had preceded academic publication in this field, this database provided a comprehensive parallel inventory for the literature review process.

The NOVELOG Toolkit database had 280 records of interventions and projects dating backing to the 1970s. It had patchy levels of quantitative data, making a metric-based analysis difficult. Instead I adopted a textual word cloud technique to adapt the raw text into a ‘cloud’ with the relative occurrence of the top 100 words denoted by relative size; this is illustrated in Figure 11 below.

From this word cloud analysis, the relative frequency of words that would be helpful in adopting concepts was visualised as larger font words, and thus further informed the more focused narrative review to follow. Terms such as ‘city’, ‘stakeholders’, ‘operations’, ‘planning’, ‘supply’ and so on were all of relevance, as were the others in the top 100.

Figure 11: Top 100 Word Cloud of Textual Occurrence of KEYWORDS in NOVELOG Toolkit database Tool used: tagcrowd.com

2.5. Focused searches

Following the top-level searches, I began a series of more focused searches covering the timespan 1970-2018. This approach was applied to each of the topics identified above, as shown in Table 6:

Review topic	Explicit search terms	WOS Results[13]	TRIMIS[14] Results	GS
The impacts large municipal organisations have on cities in terms of wealth creation, jobs, person and freight related trip making.	("urban freight" or "urban logistics" or "city logistics") AND (“municipal”)	22	31	466
The operational models associated with goods and service supply to large municipal organisations are (centralised and decentralised service provision)	("urban freight" or "urban logistics" or "city logistics") AND (“operational model”)	63	79	37
The ways in which procurement systems operate across municipal organisations with large numbers of departments and potentially power buyers	("procurement" or "purchasing") AND (“systems) *AND* ("municipal")	74	44	>35k[15]
Power buyers and freight generation	(“power buyers”) AND (“freight”)	0	0	121[16]
The ways in which supply chains serving large municipals have been made more sustainable, including collaborative logistics techniques (to include consolidation) as well as smart procurement.	("collaborative logistics") *AND* ("procurement")	28	0	533

[13] *WOS searches were always TOPIC searches*

[14] *EU funded research projects*

[15] *Too high a response and excluded*

[16] *All related to utility buying or non-relevant and excluded*

Review topic	Explicit search terms	WOS Results[13]	TRIMIS[14] Results	GS
The utilisation of delivery service planning for receivers[17]	"urban freight" or "urban logistics" or "city logistics" and "delivery service"	16	0	8
The potential for typologies, taxonomies or conceptualisation in the field that would inform the development of the framing of the work in the field.	("urban freight" or "urban logistics" or "city logistics") AND ("taxonomy" or "typology" or "concept")	117	51	23

Table 6: Topic search terms

2.6. Grey Literature

The grey literature focused review was based on the relative occurrence of projects in the NOVELOG database. These were then further investigated, primarily on Google Scholar, which was more suited to finding non peer-reviewed reports, handbooks, and other grey literature.

[17] *Added later as a conscious cross check after earlier iterations of the review cycle*

Figure 12: Top 100 Word Cloud of Textual Occurrence of Project ACRONYMS in NOVELOG Toolkit database Tool used: tagcrowd.com

Again, the relative frequency of words in the top 100 that would be helpful in adopting concepts was visualised as larger font words. From this word cloud, attention could be drawn to certain projects, as they proved of import in the conceptualisation of the framing in Chapter 3 below.

2.6.1. Co-gistics 2014-2017

This project developed a model-based Decision Support System (DSS), offering different services and aiming to integrate logistics management and decision support for multimodal transportation systems. The proposed DSS was devoted to managing logistics networks in order to synchronize different transportation means, by using the modern Information and Communications (Fanti, Iacobellis and Ukovich, 2015; Salanova Grau *et al.*, 2016).

2.6.2. *CIVITAS urban freight initiatives 2002-present*

These were multiple EU projects and initiatives developing city logistics in the European Union. Urban freight logistics was one of eight CIVITAS groups that aimed to improve sustainability in member cities. During the previous decade, the CIVITAS initiative had resulted in 53 innovative urban freight logistics measures that had been implemented and evaluated in European cities (van Rooijen and Quak, 2014).

2.6.3. *The Smartfusion 2012-205 and STRAIGHTSOL 2011-2014 projects*

These ran in parallel. Smartfusion was a co-funding project for this work. Both projects developed and applied evaluation frameworks to assess innovative urban and interurban freight transport solutions; the frameworks were to be generic and applicable to any measure within the urban-interurban context and across regions in Europe. To reach that goal, the two projects worked together on improvements (Balm *et al.*, 2014; Macharis, Milan and Verlinde, 2014).

2.6.4. *SUGAR 2009-2011, BESTUFS 2003-2008, BESTFACT 2012-2016 etc*

These were projects focused on urban freight solutions, inventories and best practice guides and databases. They adopted a largely empirical observational approach, with some emergent commentary (Huschebeck and Allen, 2005; Allen, Thorne and Browne, 2007; Dablanc *et al.*, 2011).

2.6.5. *NOVELOG 2015-2018*

The NOVELOG project focused on the enabling of knowledge and understanding of freight distribution and service trips by providing guidance for implementing effective and sustainable policies and measures. This guidance supported the choice of the most optimal and applicable solutions for urban freight transport and facilitated stakeholder collaboration and the development, field testing and transfer of best governance and business models. In delivering evaluation and guidance toolkits, the project developed the earlier work of many EU projects into a categorised and searchable database - used in this literature review (Aditjandra, Zunder, Islam, *et al.*, 2016).

2.6.6. *TURBLOG 2013-2014*

This project was aimed at extending, expanding and transferring existing knowledge to other countries and thus effectively contributed to the overall objective of extending the research and knowledge dissemination between EU and Latin America. In that sense it was not remarkable, save for the important development of an Urban Logistics variant of the CANVAS Business Framework[18], key to the potential unlocking of financial viability for urban logistics interventions.

2.6.7. Trailblazer 2010-2013

Funded by Intelligent Energy Europe, this was an important project for this review, in that it was the first to systematically develop and trial delivery and service planning, and hence a receiver – and establishment - led approach to the *demand* for goods, rather than *supply* (Wagdahl, 2010).

2.7. Inclusion/Exclusion Process

The resulting articles and grey literature were imported into the Mendeley reference manager software, merged, duplicates removed, and then filtered through the inclusion/exclusion protocol. A source had to receive 'YES' in all boxes of the CASP, as detailed in Figure 13. Of the original 289 items found, and after consideration of the wider field and certain key items of grey literature from UK and EU projects, additional works were added - primarily reflecting the top authorship in the field and personal expert knowledge, leaving a final review bibliography of 313 articles, reports and documents.

A modified version of the Critical Appraisal Skills Program (CASP) checklist was used to perform this inclusion/exclusion protocol (Campbell *et al.*, 2003; Wang and Notteboom, 2014).

CASP inclusion/exclusion protocol for literature review		Yes	No	Can't tell
A: Screening question: Does this work address a clear question?				
1	Does this work address a clearly focused issue?			
a	A clear statement of the aims of the research?			
b	Have an appropriate study design?			
2	Is the work relevant to the research questions and the purposes of the literature review?			
B: Are the results of the study valid?				
3	Does the work clearly explain it's research methods?			
4	Does the work clearly explain it's data collection?			
5	Does the work elaborate concepts or theory in a meaningful fashion?			
C: How are the results?				
6	Are the results of the work explicit and easy to understand?			
7	Is the work and the conclusions sufficiently presented to support descriptive findings?			
8	Does the work add to the knowledge or theory in the field?			
9	Are the results important in practice?			

Figure 13: Modified CASP list for inclusion/exclusion

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[18] *The CANVAS Business Framework is fully detailed later in section 5.11 and implementation in Chapter 8.*

The core purpose of the literature review was to explore existing theory and knowledge to create a first framing of the contribution the thesis was expected to make. These would be used to generate generic research questions worthy of further investigation. To that end, works that explored theoretical and conceptual matters were given greater weighting in question A2 (in Figure 13 above), which I viewed as the first critical inclusion/exclusion criteria. Works which were largely empirical were likely to be excluded at A2, or at question C8 (also in Figure 13), with minimal contribution to knowledge and theory.

After application of the CASP, the number of works was reduced from 313 to 219, forming the final body of work from which I drew out the concepts to frame a theoretical framework; these are shown graphically, as a flowchart, in Figure 14 below.

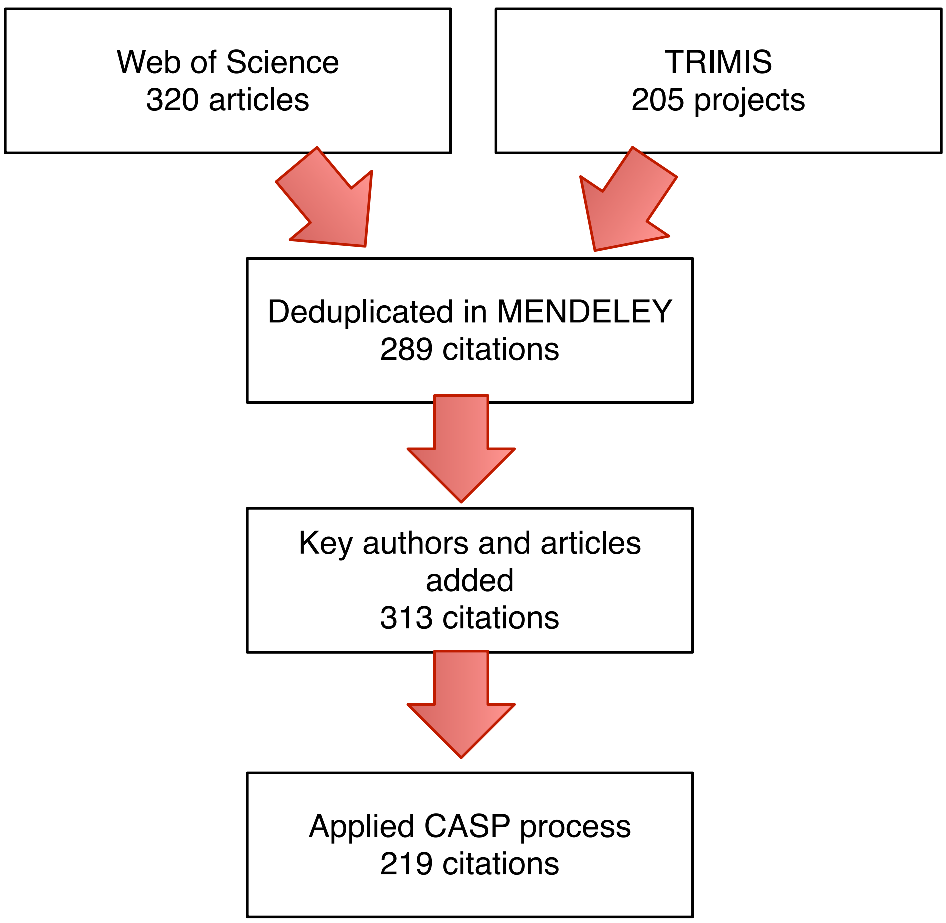

Figure 14: Systematic review as a flowchart

2.8. Concepts

The concepts I identified in the review were then organised into two categories: those that those that were recurring and relevant; and those that showed significant gaps in the review. Whilst there had been recurrent theming, grouping, typologies, taxonomies and classification in the grey literature (BESTUFS Consortium, 2008; Dablanc *et al.*, 2011; Huschebeck, 2013; Balm *et al.*, 2014), as well as in certain key peer-reviewed literature review articles (Wolpert and Reuter, 2012; Aljohani and Thompson, 2016), it was key to the process of framing that the conceptual process be reviewed for this thesis, rather than adopting a previously suggested generic typology or taxonomy.

Both categories were relevant to the task of framing a theory against which to benchmark the research outcomes of the work - as opposed to the outcomes of actions taken, which followed.

2.8.1. Concepts recurring and relevant

There was a significant body of work researching, analysing and modelling the <u>use of rail, light rail, or trams, for freight delivery</u> in urban areas. This work had been led by colleagues at Newcastle University and elsewhere, and explored technical, operational and timetabling issues. The potential for such modal shift of freight to urban rail systems had divided opinion, would require existing rail infrastructure and, although valid for research, would need significant infrastructure investment. Examples of interventions included the Dresden cargo tram, the Zurich recycling tram, and the short-lived Amsterdam cargo tram. The Dresden example was probably best viewed as an extended dedicated 'conveyor belt' between separated assembly lines at Volkswagen; the Zurich recycling tram was a novel use of infrastructure for regular but non time-critical collection of large items for recycling; and the Amsterdam example failed due to the lack of a viable business model (Robinson and Mortimer, 2004; Liu *et al.*, 2008; Motraghi and Marinov, 2012; Arvidsson and Browne, 2013; Browne *et al.*, 2014; Singhania and Marinov, 2017; Behiri, Belmokhtar-Berraf and Chu, 2018; Ozturk and Patrick, 2018).

Co-operative Intelligent Transport Systems (<u>C-ITS</u>) is the utilisation of Intelligent Transport Systems (ITS) and new ICT apps and infrastructures to leverage vehicle to vehicle, vehicle to infrastructure, and vehicle to human communications (Salanova Grau *et al.*, 2016). The theme of optimisation of urban freight through C-ITS was emergent in the literature, but immature compared to the literature on C-ITS integration for private and public transport.

The literature had a lot of research outputs on timed delivery-window modelling, from Japan, associated primarily with the research team around Taniguchi (Taniguchi, Kawakatsu and Tsuji, 2000; Taniguchi and Shimamoto, 2004). That work was associated with the repurposing of traffic and network modelling at a very computational level. Taniguchi was one of the pioneers of city logistics research and was the highest output author in the top-level scoping (see Table 4 above).

Logistics sprawl was seen by researchers as the relocation of logistics facilities away from inner urban areas to suburban areas and had received an increasing level of attention from both academics and policy makers. The potential dis-benefits of extending the ‘last mile’ operation of an urban delivery route was exacerbated by sprawl and was inter-related to how land use planning and zoning of use varied between urban areas. Dablanc was the key foundational researcher in this field, working in both North America and Europe (Dablanc and Rakotonarivo, 2010; Dablanc, Ogilvie and Goodchild, 2014). Her work had then led to a growing body of quantitative and geo-spatial analysis from others (Aljohani and Thompson, 2016; Heitz, Dablanc and Tavasszy, 2017).

The modelling of distribution hub locations, and the balance between too close and too far away, was key to much grey and peer-reviewed literature; this had resulted in work - often led by Leonardi et al. - on the analysis, evaluation and optimisation of the break-point between the initial ‘stem’ delivery leg to a city and the ‘leaf’ delivery leg of routing (LT Consultants Ltd and Buck Consultants International BV, 2002; Leonardi, Browne and Allen, 2012; Allen *et al.*, 2014; Holguín-Veras and Jaller, 2014).

A recurring concept was that a freight landscape was peculiar to each location and time (Allen *et al.*, 2010; Lindholm and Browne, 2013; Lindholm and Blinge, 2014). Rodrigue et al. noted that “Results from New York, Los Angeles, Paris and Seoul reveal substantial variations between metropolitan areas, which are observed across the respective levels of zonal specialization as well as density changes over distance from central areas” (Rodrigue, Dablanc and Giuliano, 2017). Giuliano et al. found that, when trialled in Los Angeles, using proxies to describe the metropolitan freight landscape was of utility (2018).

Land use and zoning establishment surveys were key for North American research reported in the literature. Considered to be highly dependent on the data collected in a nation or city, these tended to yield useful analysis in the USA, but were problematic in the UK and elsewhere in Europe (Holguín-Veras *et al.*, 2011; Holguín-Veras and Jaller, 2014) due to far less stringent zoning and less rich data collection or homogeneity. This was related to freight trip generation and/or attraction, in that the attraction of freight by receivers may have been more relevant to urban logistics than traditional trip generation models (Wagdahl, 2010; Holguín-Veras *et al.*, 2011; Aditjandra *et al.*, 2013).

The multi-stakeholder nature of urban freight, and the concomitant need for co-operation and collaboration, was recurrent: "A key characteristic of it is the heterogeneity of the stakeholders involved. Besides the traditional logistics actors such as shippers, carriers and receivers that share consistent interests (i.e. price and quality), city logistics highly respect the interests of public administrators and citizens that care more about the social welfare. To reach an optimal balance between private and public benefit, it is necessary to understand and in turn forecast the behaviour pattern of different groups" (Anand, Yang, *et al.*, 2012).

This need for co-operation led to the development and deployment of Freight Quality Partnerships in the UK (Collings and Department for Transport, 2003; Allen *et al.*, 2010), and in Sweden (Lindholm and Browne, 2013), and was related to similar co-operation platforms such as "Marchandises en Ville" in France (Dablanc, 1997) and the Dutch "Platform Stedelijke Distributie" (Groothedde, Rustenburg and Uil, 2003). The concept of Freight Quality Partnerships - in which all key stakeholders in freight transport in a city or transport corridor meet collectively to mutually solve problems - although not widely deployed outside of these examples, was emergent across the literature over time (Kijewska and Jedliński, 2016; Kijewska and Jedlinski, 2018).

A clear theme of the literature, focusing again on the degree to which the socio-technical approach of 'why, who, with what, where and when' localised problems and solutions (Zunder and Dellinger, 2005), was that city logistics and urban freight is "difficult to organize, difficult to modernize" (Zunder and Ibanez, 2004; Dablanc, 2007; Munuzuri *et al.*, 2012) due to local peculiarity in both place and time, the disconnect between disbenefits and the paying client, and the disruption of efficient supply chains with the loss of time and increase in costs.

Urban Consolidation Centres (UCC) had been a key theme of research and intervention. An Urban Consolidation Centre had been defined as a logistics facility that was situated in relatively close proximity to the area that it served. Goods destined for this area were dropped off at the UCC and sorted and consolidated onto goods vehicles (sometimes low emission vehicles) for delivery to final destination. This was clearly differentiated from an Urban

Distribution Centre (UDC), which had a wider definition and included all typical commercial logistics hubs in urban locations (Browne *et al.*, 2005; Zunder and Marinov, 2011; Allen *et al.*, 2012).

One of the first explorations of this concept in the literature was Schuster, from Traffic Quarterly (1978). The concept had become highly popular in the 1990s, in Germany, as part of a drive for an integrated 'city logistics' top-down approach to freight traffic management by local government, with over 80 such schemes noted in the trade magazine 'Logistik Heute' in mid-decade. All were eventually cancelled, usually due to financial non-viability (Flaemig, 2003a, 2003b).

The widescale failure of UCCs in Germany had not prevented the concept being promoted at EU level, with multiple schemes (e.g. La Rochelle; Bristol-Broadmead) funded by EU research and development programmes, inter-regional funding etc. (Zunder and Marinov, 2011; Kin *et al.*, 2016). Almost all of these had proved unsuccessful due to three key issues summarised by Martinez et al.: [lack of] <u>Long-term financial viability; Poor selection of location; and Controlled environments</u> (Martinez, Gadsby and Vargas, 2018).

Zunder and Marinov (2011) went further and contended that "most UCC initiatives fail in a liberal economy where free choice and market economics apply". Despite a list of failed schemes, a few pilots - subsidized by EU or local funding – had been held up as beacons to the viability of the UCC (Marinov, Islam and Zunder, 2010; Zunder and Marinov, 2011).

These could be divided into three key types:

- <u>Retail-led UCCs</u> serving whole urban areas, such as Bristol-Broadmead, Bristol-Bath or La Rochelle;
- <u>UCCs serving a controlled geog</u>raphy, with a single landlord or regulatory authority controlling access, operation, and/or permission, such as Monaco, London Heathrow or the Hospital Logistics Centre in London;
- <u>Construction project UCCs</u> such as Hammarsby Sjostad, in Stockholm, Potsdammerplatz in Berlin, or the London Construction Consolidation centres.

There had also been trials and discussions of <u>non-traditional approaches to consolidation</u>, such as mobile consolidation centres (Verlinde *et al.*, 2014), or virtual consolidation centres - where the consolidation was achieved through pre-planned procurement rather than any physical location (Verlinde, Macharis and Witlox, 2012) - or the use of crowd logistics (Buldeo Rai *et al.*, 2017).

At many points in the review I noted repeated complaints about poor 'ex-ante and ex-post' data collection (Gonzalez-Feliu, Toilier and Routhier, 2010; Leonardi, Browne and Allen, 2012; Jacques Leonardi *et al.*, 2015) and the poor quality and homogeneity of data standards across nations and cities (Ambrosini and Routhier, 2004; Allen *et al.*, 2014). It is worth noting that about one third of all UCCs originally identified in 2005 by Browne had left no discernible data for analysis (Browne *et al.*, 2005; Zunder and Marinov, 2011).

The use of bicycles or e-bikes for cargo delivery was well represented in the literature (Gruber, Kihm and Lenz, 2014; Melo and Baptista, 2017). Of note were issues of safely sharing the roads with freight vehicles (Pattinson and Thompson, 2013; Anderluh, Hemmelmayr and Nolz, 2017); health and social insurance issues (Maes and Vanelslander, 2012); scheduling into existing logistics networks (Anderluh, Hemmelmayr and Nolz, 2017); and the opportunity for services such as Gnewt cycles to replace the last mile in London (Allen *et al.*, 2017). This also related to the use of walking as a delivery mode, which had been researched quantitatively in London and shown to constitute circa 62% of inner London delivery rounds for parcel carriers (Allen *et al.*, 2017).

There was an emergent concept of the proposal and development of typologies, taxonomies, and frameworks (Benjelloun, Crainic and Bigras, 2010; Zunder *et al.*, 2013; Dablanc and Rodrigue, 2014; Anand *et al.*, 2015). A significant development was the '4 As' concept of 'Awareness, Avoidance, Act and shift, and Anticipation' of new technologies, by Macharis and Kin (Macharis and Kin, 2016). An alternative approach had been taken by Aditjandra and Zunder, in pragmatically repurposing taxonomies and typologies from research and EU initiatives into a novel, multi-dimensional, poly-parametric typology for city logistics, which had multiple uses in analysing and selecting interventions (Aditjandra and Zunder, 2018).

Recognition of the need for viable business models was evidenced, to allow transition between subsidised pilot trials to standalone viable solutions; a growing interest in the use of different business model frameworks; and the financing of urban logistics from public-private initiatives [PPI] (Macário, Rodrigues and Gama, 2011; Lewis, Fell and Maclean, 2012; Gonzalez-Feliu, Taniguchi and Faivre d'Arcier, 2014; Posthumus *et al.*, 2014; Quak, Balm and Posthumus, 2014; Rytkönen and Nenonen, 2014; Kin *et al.*, 2016; Bjorklund, Abrahamsson and Johansson, 2017).

A key theme of import in the review was the use of delivery and servicing plans (DSP), an establishment-led approach to analysis of receiver-led demand, developed in the Trailblazer project (Wagdahl, 2010), deployed by TfL in their Palestra offices (Transport for London, 2008), and then developed further in the Smartfusion and STRAIGHTSOL projects (Zunder, Aditjandra and Carnaby, 2012; Posthumus *et al.*, 2014; STRAIGHTSOL, 2014). The DSP methodology formed part of the analyses that underlay the Southampton UHS consolidation centre initiatives (Lewis, Fell and Maclean, 2012; Martinez, Gadsby and Vargas, 2018).

The potential to deliver goods 'out of hours' or as 'night delivery' was explored differently in the literature. In Manhattan there had been extensive trials of receiver-led early morning deliveries, offsetting higher labour costs in office staff against reductions in congestion costs (Holguín-Veras *et al.*, 2014). In the Netherlands, the PIEK programme had taken a strongly mechanical engineering-led approach, re-engineering vehicles and handling equipment to prevent 'peak noise'. To comply with the standard, each product was acoustically measured and had to function emitting under 60dB at 7.5 metres from the sound source; it was then deemed suitable for out-of-hours delivery that would not cause noise disturbance to nearby residents.

In the UK the PIEK approach was disseminated by the Noise Abatement Society (Shoemaker, 2005; Goevaers, 2011; Noise Abatement Society, 2018).

2.8.2. Concepts with significant Gaps

The literature held very little on urban freight and procurement activity. There were no references to 'power buyers' or differences between buying choices, save those written in parallel to this thesis. There was a theme of emergent ideas and proposals for mandatory municipal freight consolidation in Swedish cities and the potential power of procurement to change inbound urban freight (Chicksand *et al.*, 2012; Aditjandra, Zunder and Carnaby, 2014; Björklund and Gustafsson, 2015; Balm *et al.*, 2016; Aditjandra and Zunder, 2017; Quak, Nesterova and Kok, 2019). Finally, in 2018, the Transport Catapult had recommended to the UK government that "Government and Local Authorities should ...[adopt]... measures such as retiming deliveries and collaborative procurement" (Martinez, Gadsby and Vargas, 2018).

There was little about exploring private purchasing behaviour, save for Cherrett et al. looking at student purchases and Aditjandra et al. looking at private purchasing by University staff -

the latter a parallel piece of work to this thesis (Aditjandra, Zunder and Carnaby, 2014; Aditjandra and Zunder, 2017; Cherrett *et al.*, 2017).

There was a small and emergent literature on Higher Education Institutions (HEI) and procurement behaviour, with or without reference to freight. The work in the literature was largely written in parallel with this thesis, and in collaboration with colleagues from the Amsterdam Academy of Sciences, as well as a top-level overview with the Universities of Southampton and others (Aditjandra *et al.*, 2013; Zunder, Aditjandra and Carnaby, 2014; Mcleod *et al.*, 2015; Adtjandra *et al.*, 2016; Balm *et al.*, 2016; Aditjandra and Zunder, 2017; de Radiguès, Verlinde and Macharis, 2019).

There had been some discussion of logistics and sustainable procurement from Walker and Brammer (2009) in the mainstream procurement journals, and also a piece of research on the interrelationship between sustainable procurement and supply chain logistics, from Murphy and Poist (2003), written from a supply chain management perspective. Of particular note was the clear statement that sustainable procurement purchasing power can "influence the behaviour of private sector organisations" to achieve "social, environmental (and other) benefits". However, with regard to organisational barriers to sustainable procurement, they noted unwillingness to accept higher invoiced costs as the key barrier to adoption in the UK public sector (Walker and Brammer, 2009). Also of relevance to the barriers to sustainable procurement was the action research work of Meehan, Ludbrook and Mason, on institutional explanations of legitimised resistance, and how "strategic avoidance responses" such as "symbolic tick-boxing" can "entrench operational barriers" (2016). The call from Meehan, Toubolic and Walker was to engage with action research in purchasing and supply chain management, so as to avoid "practical irrelevance, failure to provide new insights, and a disengagement from organisations and society" (2016).

Little or no theory development was evident in the literature. With the possible exception of 'logistics sprawl', the field was largely empirical observation with a potential tendency to 'naïve empiricism'(Meehan, Ludbrook and Mason, 2016). The field of logistics research as a whole had been weak in the late 20th and early 21st centuries in two areas: theory and explicit discussion, and statement of research philosophies (Solem, 2003; Adamides, Papachristos and Pomonis, 2012; Borgström, 2012). The inability to address 'meta' issues may explain the difficulty in both developing theory and also "that much of the debate and criticism over methodology involves researchers who are failing to communicate with one another because they hold varying basic assumptions about their subject" (Mangan, Lalwani and Gardner, 2004). The gap was a need to develop theory and, given the import of locality noted in urban freight, probably theory from case study research (Eisenhardt, 1989).

Little of the peer-reviewed literature was on the use of electric vehicles (EVs) in freight, although a tranche of EU funded projects launched from c2012 provided grey literature on this theme, such as the FREILOT and Smartfusion projects (Gonzalez-Feliu *et al.*, 2013; Leonardi *et al.*, 2014; MacAndrew, 2014). Lebeau et al. developed a 'total cost of ownership' model to assess the competitiveness of quadricycles and light commercial vehicles for freight transport companies (2015). Herron and Coleman evaluated the volumes of EV chargers required for a certain volume of chargers (2018). Leonardi et al. delivered many cost-benefit analyses of urban logistics schemes, using diesel, electric and cycle vehicle solutions, as did the STRAIGHTSOL project (Andersen *et al.*, 2012; Leonardi, Browne and Allen, 2012).

2.9. Summary

In this chapter I have detailed the ongoing process of literature review that was used from commencement around 2011 to final submission in 2019. This literature review added value in placing the thesis within the wider research area in which it fitted. It covered the literature, both peer-reviewed and otherwise, to place the work in the knowledge of the more efficient management of procurement and the resulting delivery and service flows to 'large municipal organisations' emanating from it, along with existing and emergent evidence suggesting how the negative impacts of such activity could be mitigated. A two-stage approach was deployed, first scoping using a semi-systematic approach, then a narrative review, guided by the systematic review in terms of literature survey and selection.

The field was found to be new, emergent, with 77% of all articles published after 2011 - the start of this piece of research. Using a mix of peer-reviewed and grey literature and a combination of online scholarly databases, the NOVELOG toolkit database, a CASP checklist, and textual-graphical analysis using word clouds, the literature - a body of 219 works - was reviewed and key concepts identified, grouped as irrelevant, recurring, or with noticeable gaps.

These gaps would be used to inform the generation of generic research questions worthy of further investigation ***along with*** the themes of import and recurrence in the literature, all of which offered opportunity to add incremental knowledge. The key gaps identified as worthy of note at this stage were: urban freight and procurement activity; private purchasing behaviour; Higher Education Institutions (HEI) and freight; barriers to sustainable procurement; engaging with Action Research in purchasing and supply chain management; little or no theory development; and the use of electric vehicles (EVs) in freight.

2.9.1. Synopsis of Concepts

The key concepts identified, and the key years of emergence were:

- Use of rail, light rail or trams for freight delivery (2004)
- Co-operative intelligent transport systems (C-ITS) (2016 regarding freight)
- Time delivery window modelling (2000)
- Logistics sprawl (2010)
- Distribution hub locations (2002)
- 'Stem' and 'leaf' delivery legs (2012)
- Land use, zoning (2011)
- Freight trip generation and/or attraction (2010)
- Multi-stakeholder (2005)
- Need for co-operation and collaboration (2013)
- Freight quality partnerships (2013)
- "Difficult to organize, difficult to modernize" (2007)
- 'Why, who, with what, where and when' (2005)
- Poor ex-ante and ex-post data collection (2010)
- Evaluation frameworks (2004)
- Data standards (2004)
- Urban consolidation centres (1978)
- Long term financial viability (2010)
- Poor selection of location (2005)
- Controlled environments (2011)
- Non-traditional approaches to consolidation (2012)
- Bicycles or e-bikes for cargo (2012)
- Walking as a delivery mode (2017)
- Recognition of need for viable business models (2011)
- Typologies, taxonomies, frameworks (2014)
- Delivery and servicing plans (DSP) (2010)
- 'Out of hours' or as 'night delivery' (2005)
- Higher education institutions (HEI) and freight (2015)
- Barriers to sustainable procurement (2009)
- Engagement with Action Research in purchasing and supply chain management (2016)
- Private purchasing behaviour (2014)
- Urban freight and procurement activity (2012)
- Little or no theory development (2003)
- The use of electric vehicles (EVs) in freight (2012)

With these concepts identified it was possible to move on to framing a written discourse about the literature from which to formulate research questions; this follows in the next chapter.

Chapter 3. Framing

This chapter details the first development of a theoretical framework from the concepts identified in the literature review. This justified the purpose and need for the academic research alongside the pragmatic objectives of the work. Using a systems approach present in the literature review, I framed the concepts within sub-systems and groupings, and then elaborated the key themes, findings, and gaps in the field addressed by the four research questions. The framing supported the generation of generic and then specific research questions worthy of further investigation. This framing was then used to evaluate the thesis, in respect of the body of knowledge, in 0 below.

3.1. Research as Thesis

In the previous chapter I outlined the key concepts derived from the literature that framed the existing knowledge of the topics key to the international, national and local problems identified and listed in Chapter 1. As Herr and Anderson have said: "One of the explicit goals of dissertation research is ... contribution to knowledge generation or, at least, an academic conversation" (Herr and Anderson, 2014). This conversation is expressed in the thesis through the benchmarking of the contribution of the knowledge generated within the framework of the field. This justified the purpose and need for the research as thesis, alongside that of the pragmatic objectives of the work.

This thesis has parallel streams: the research as pragmatic action, and also the research as thesis (Zuber-Skerritt and Perry, 2002) both of which lead to practical knowing: "Practical knowing subsumes other forms of knowing as we draw on both theory and reflected practice so as to become skilled" (Coghlan, 2019).

The conceptual framing is separate to, and yet aligned with, the methods and techniques deployed in the action elements. Herr and Anderson note that "there is a conceptual framework that guides the data gathering and analysis as well as conceptual framework embedded in one's particular approach to … research. The former is guided by the literature that has been reviewed and the latter by the knowledge interests of the research itself" (Herr and Anderson, 2014).

3.2. Use of a Systems Approach for Framing

I adopted a socio-technical approach for the framing process, informed by previous research into urban logistics and supported by the literature review detailed in Chapter 2. This approach looked to simplify complexity through the use of an approach that placed all concepts into the following structure of '5 Ws' (Zunder and Dellinger, 2005):

- objectives (why);
- people (who);
- techniques (with what);
- place (where); and
- the place in time (when)

This aligned with the concepts that emerged from the literature review, in particular the need for 'multi-stakeholder' approaches that recognise that the issues are "difficult to organize, difficult to modernize", support the "need for co-operation and collaboration", and integrate the highly localised and time sensitive nature of "logistics sprawl", "freight trip generation and/or attraction", "poor selection of location", and the role of "controlled environments".

When deployed previously in the CITYFREIGHT project (LT Consultants Ltd and Buck Consultants International BV, 2002), the '5 Ws' were organised into three related sub-systems, consisting of:

- the society of actors involved (shippers, operators, receivers, government);
- the ensemble of techniques (technology, methods, regulations or systems); and
- the environment in which the system exists or will exist (geographic, geopolitical) (Zunder and Dellinger, 2005).

This approach was then deployed by Aditjandra and Zunder in the development of a multi-dimensional, poly-parametric typology for city logistics, with the addition of a 'how' element (Aditjandra and Zunder, 2018). The 'why' was not appropriate for the framing, as that lay in the needs of the local, national and EU level actors defined in Chapter 1. This framing had a basis in practice, and in the literature, and was deployed as represented graphically in Figure 15 below.

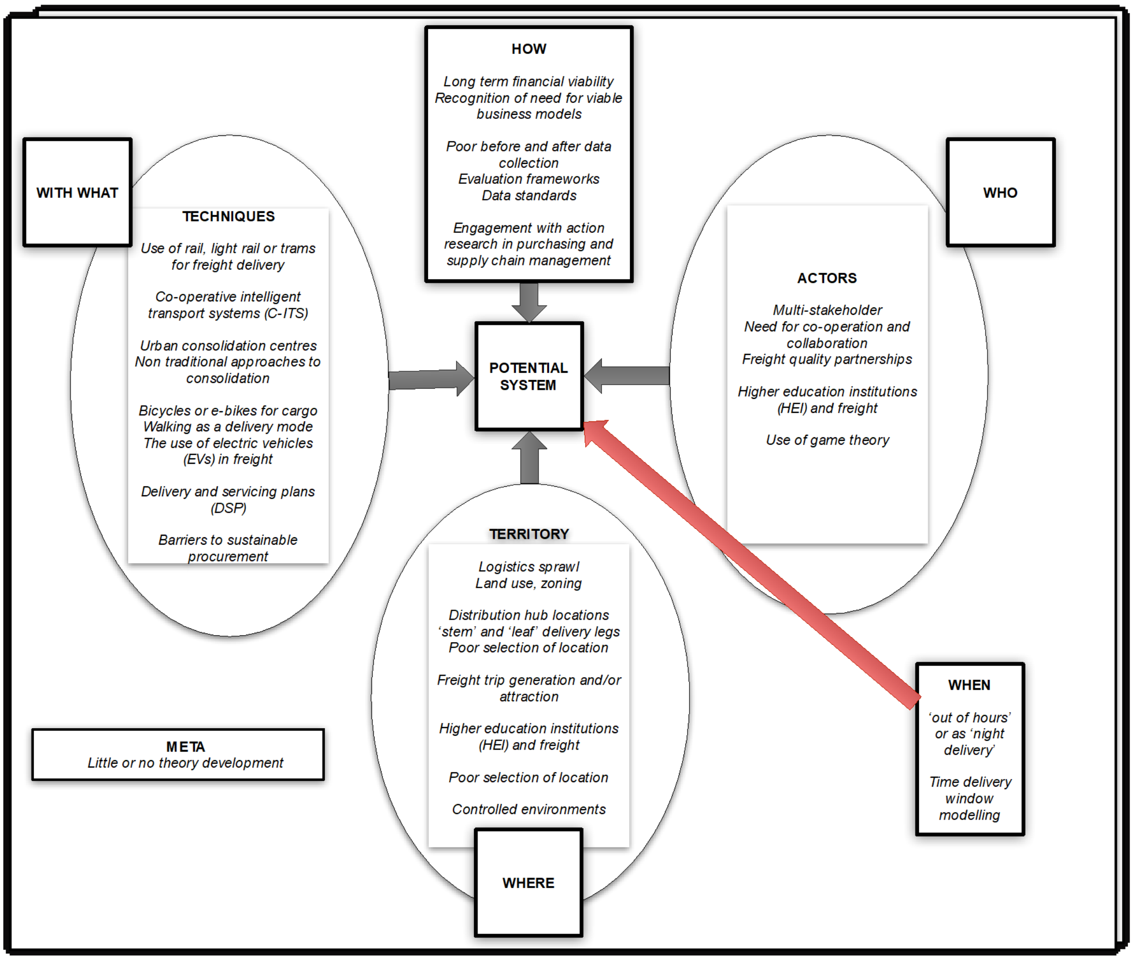

Figure 15: A 'systems approach' socio-technical framing of the relevant concepts built from the literature

In most cases the concepts from the review could be ascribed to the core 3 sub-systems (society, techniques, actors) but, in some cases, they were better assigned to one of the 6 top level groupings (5 Ws plus How). One concept: "little or no theory development" was better placed as a meta level issue, to be addressed alone. Within the structure, certain groupings of concepts were apparent, as shown above in Figure 15, and each grouping was addressed with a view to the knowledge, theory, and/or gaps present, as described in the following section.

3.3. Actors [Who]

The key importance of actors or stakeholders in urban freight was a sub-system proven key in the literature review with regard to the development of solutions in urban logistics. This was evidenced from the earliest BESTUFS (BESTUFS Consortium,

2008) project reports, through to emergence in peer-reviewed conferences and journals (Dablanc, 1997; Allen, Thorne and Browne, 2007; Anand, Quak, *et al.*, 2012).

One way to categorise who is involved in urban freight was to use the taxonomy of 'urban freight markets', first proposed by the European Commission in 2012 (MDS Transmodal and Centro di recerca per il Trasporto e la logistica (CTL), 2012) and augmented by the CIVITAS WIKI project in 2015 (CIVITAS WIKI consortium, 2015). An aggregated table of this approach is shown in Table 7 below.

Markets	Sub-cluster
Retail	City distribution; food products; milk deliveries; bakery products; goods on pallets; and beverages
Express, courier and post	Postal and package deliveries; city distribution; parcels; goods on pallets; and money deliveries
Hotel, restaurant and catering	Food products; beverages; fast food deliveries; and laundry services
Construction and road services	Waste disposal services; utility services; and gardening services
Waste	Waste disposal services; and recycling materials

Table 7: UFT Markets. Source: (CIVITAS WIKI consortium, 2015)

This approach could be replaced with or complemented with a stakeholder approach, as refined in the NOVELOG project and detailed in Table 8 below.

Stakeholders	Description and potential sub-sets
Shippers	(manufacturers, wholesalers, central retailer units)
Logistics providers	(third party logistics providers, warehouse companies)
Administrators	(national, state, and city level authority)
Citizens	(consumers and residents)
Receivers	(offices, retail units, manufacturers, local retail units, homes)

Table 8: UFT Actors or Stakeholders. Source: (Aditjandra *et al.*, 2016; Aditjandra and Zunder, 2018)

Whilst these theoretical taxonomies had the potential to understand or gain insight into the social-technical system present in the University and the wider city and network, such systems are by their very nature temporal and contingent on place and people (Dewey, 1917; Trist, 1978, 1981).

3.3.1. Multi-stakeholder; need for co-operation and collaboration; freight quality partnerships

The use of freight quality partnerships, or similar, as a way to facilitate co-operation and collaboration was well documented (Ballantyne, Lindholm and Whiteing, 2013; Quak *et al.*, 2016) and made this group of concepts, as well as alternative methods of facilitating multi-stakeholder collaboration - such as ‘living labs’ in cities - a key part of the framing of the thesis.

3.4. Techniques [With What]

This sub system includes technologies and methods for operational change.

3.4.1. Use of rail, light rail or trams for freight delivery

The potential use of rail, light rail and/or trams for urban logistics was well explored in the literature. Newcastle upon Tyne had an extensive metro rail system, one of three in the UK, and much of that network was originally heavy rail, thus having gradients and curves appropriate to freight wagons. The SPECTRUM rail project (Jackson, Islam, *et al.*, 2013; Jackson, Matsika, *et al.*, 2013; Jackson *et al.*, 2015) explored the development of high performance trains for low density high value goods with suburban rail deployment, making this a concept of potential. Against the likelihood of deployment was the need for substantial infrastructure, equipment, and operational investment, during a time of austerity in the UK.

3.4.2. Co-operative intelligent transport systems (C-ITS) and urban freight

C-ITS was not a viable concept for deployment for urban freight at the start of my work, due to inadequate standards and infrastructure, but appeared to be a developing area for the future (C-LIEGE, 2012), as evidenced by more recent work on ‘data, people and parcels’ by Bates et al. (2018). Trials of limited C-ITS solutions in Newcastle upon Tyne during the early 21st century, worked on in parallel by colleagues (Blythe *et al.*, 2016), provided the opportunity for contribution to knowledge in both directions.

3.4.3. *Urban consolidation centres; non-traditional approaches to consolidation*

As a key theme for urban logistics research since the 1970s, but with few long-term successes, the need to address the potential of a viable consolidation centre in Newcastle upon Tyne was evident from the literature review. It was also key to the region, in that the LTP3 (Tyne and Wear Integrated Transport Authority, 2011a), had a policy commitment to develop and deploy just such a scheme. The option of non-traditional approaches to consolidation, including virtual consolidation through supplier management, was a concept to note for consideration and/or benchmarking.

3.4.4. Bicycles or e-bikes for cargo; walking as a delivery mode; the use of electric vehicles (EVs) in freight

Freight delivered by non-polluting modes in urban areas was a policy objective at the local level in LTP3 (Tyne and Wear Integrated Transport Authority, 2011a) with a commitment to trial electric vehicles for delivery, and at EU level in the 2011 Transport White Paper (European Commission, 2011) and the 'European Green Car Initiative' research call, through which the Smartfusion project - and therefore much of this research - was co-funded (Zunder, 2012). The safety, employment, insurance and operational role of walking, bicycles and e-bikes was evidenced in the literature, and the extent to which walking as a delivery mode on campus was evident and/or viable was a theme deemed relevant to the work.

3.4.5. Delivery and servicing plans (DSP)

DSP was a methodology that focused on establishment surveys and a receiver-led approach to inbound urban logistics. The approach was novel when developed in the Trailblazer project (Wagdahl, 2010) and informed the underlying conceptual approach to these research questions as demand driven, rather than supply-side or a matter of transport logistics alone. To that end there were several elements that informed this work and also suggested the likely potential for this thesis to contribute to theoretical or practical knowledge, e.g. survey methodologies, demand analysis, and operational solutions.

3.4.6. Barriers to sustainable procurement; private purchasing behaviour; urban freight and procurement activity

The literature contained key pieces of work detailing how initiatives towards sustainable and/or collaborative procurement in the UK public sector had been thwarted by "legitimised resistance", primarily through isomorphic pressures rather than organisational barriers. Isomorphic responses reclassified as: coercive, referring to convergence of responses driven by compliance or legislation; normative, seen through adherence to professional standards; or mimetic, where an organisation copies the structures and/or practices of others that are seemingly successful (DiMaggio and Powell, 1983; Brammer and Walker, 2011; Walker and Jones, 2012; Meehan, Ludbrook and Mason, 2016). It was likely there would be potential for contributions to knowledge with regard to process and attitudes to change.

There were no references to 'power buyers', or to differences between buying choices, or private purchasing behaviour, at the start of this work. There was a theme of emergent ideas and proposals for mandatory municipal freight consolidation in Swedish cities, see 2.8.2 above. These would be key gaps in the knowledge to which I could look to add. With the addition of the literature delivered parallel to this thesis, this was a key group of techniques for the thesis to target, both at the commencement and in terms of benchmarking contribution, at the end.

3.5. Territory [Where]

The local nature of urban logistics was a key theme from the literature, that resonated with Yin's comments about the role of a case study as an inquiry "within its real-world context, especially when the boundaries between phenomenon and context may not be clearly evident" (Yin, 2009, p. 16). There were many concepts that fell within this subsystem; I grouped them as follows:

3.5.1. Logistics sprawl; land use, zoning; distribution hub locations; 'stem' and 'leaf' delivery legs; poor selection of location

This group gathers together the foundational work on logistics sprawl of Dablanc et. al. (2010; 2014); land use and zoning from Holguín-Veras et. al. (2011; 2014); the interaction with the location of distribution hubs (Leonardi, Browne and Allen, 2012); and the subsequent effect on 'stem' and 'leaf' delivery leg distances (Edwards, Mckinnon and Cullinane, 2009; Leonardi, Browne and Allen, 2012). The potential contribution to knowledge from the thesis was noted from the beginning as high.

3.5.2. Freight trip generation and/or attraction

Traditional trip generation models may be less suited to certain types of urban logistics and the literature showed emergent work on addressing the attraction of freight to a locale, institution, or campus. This had roots in the foundational work of Trailblazer (Wagdahl, 2010), in Europe, and inter-related to the land use and zoning work carried out in North America (Holguín-Veras *et al.*, 2011). It would be important to integrate this knowledge, both into the research and also into the thesis, for the purpose of benchmarking the results.

3.5.3. Higher education institutions (HEI) and freight

At the start of this work in 2011, there was little if any research on this concept in the literature. It was a clear gap and, as the research for this thesis proceeded, publications by the author, colleagues (Aditjandra, 2013; Zunder, Aditjandra and Carnaby, 2014; Adtjandra *et al.*, 2016; Aditjandra and Zunder, 2017), and others in the Netherlands, Brussels and UK (Balm *et al.*, 2016; McLeod *et al.*, 2016; de Radiguès, Verlinde and Macharis, 2019) confirmed this as a gap in the knowledge that would be of value to investigate, both in the operational research and in the thesis.

3.5.4. Controlled environments

The degree to which a regulator, government, or landlord controlled the environment in which an urban consolidation centre operated had been noted as key to the success or failure of such schemes (Marinov, Zunder and Islam, 2010). The Heathrow Airport scheme, the Monaco consolidation centre, and construction site schemes like Hammarsby Sjostad in Stockholm, and Potsdammerplatz in Berlin, had shown that the ability to control an environment could ensure a scheme's success (Browne *et al.*, 2005; Zunder and Marinov, 2011). This could be linked with the potential for low emission zones to change the nature of logistics operations in a city. As such, whilst the concept is seen most clearly in UCCs, I viewed it as potentially relevant to many different interventions and therefore grouped it alone.

3.6. When

This part of the grouping sits outside of the core sub-systems of society, techniques and actors, and allows groups concerning chronology, history and timing to be examined, utilised and benchmarked. In some systems approaches this might include some concept of chronology, or history, and as such it was important to note that this research started in 2011, the core funded project ended in 2015, consolidation activities were paused in 2016, and the thesis was written up in 2019.

3.6.1. 'Out of hours' or as 'night delivery'

The development of delivery outside usual windows was evidenced in a mechanical engineering 'noise reduction' approach in Europe through the PIEK programme (Goevaers, 2011), and in Manhattan (Holguín-Veras *et al.*, 2014), with early morning deliveries. The potential for such research issues to be relevant to the thesis was there from the beginning, but would out of hours be possible and, if not, was any noise reduction required?

3.6.2. Time delivery window modelling

This conceptual area of intensive computational modelling to best optimise time delivery windows, primarily in Japanese urban areas, was foundational and led by Taniguchi (Taniguchi, Kawakatsu and Tsuji, 2000; Taniguchi and Shimamoto, 2004), who also set up and led the International Conference on City Logistics and edited many books on the field. However, the degree to which this approach would have been applicable to this work depended to what extent this would be stakeholder or expert led research, since the approach was highly discrete and objective.

3.7. How

This part of the grouping sits outside of the core sub-systems of society, techniques and actors, and allows concepts concerning methods and techniques to be examined, utilised and benchmarked.

3.7.1. Long term financial viability; recognition of need for viable business models

The failure of innovation in urban logistics, not just UCCs, was evident in the literature, particularly in the grey and peer-reviewed literature, and was summarised well in 2018 by the Transport Systems Catapult (TSC). They concluded that there were three factors that had led to failure:

- Long term financial viability – use of a UCC adds an additional leg into the supply chain, adding cost. In the past, this extra cost had often been offset by public sector subsidies which had proven to be unsustainable in the long term.
- Poor selection of location – the lack of sufficient accessibility to UCCs and the proximity to the area it served, had led to failures in the past.
- Controlled environments – evidence suggested that UCCs often required support from Local Authorities through enforcement of controlled environments, such as Clean Air Zones (CAZ) (Martinez, Gadsby and Vargas, 2018).

The literature review identified that the most common and largest barrier to the uptake of UCCs had been financial viability. The TSC's hypothesis was that enhanced visibility of the cost and benefits would stimulate greater interest among potential client organisations.

From 2011 there had been developments in the modification and deployment of the CANVAS Business Model Framework, as adapted to urban logistics (Macário, Rodrigues and Gama, 2011; Posthumus *et al.*, 2014; Quak, Balm and Posthumus, 2014). The requirement of the EU to deploy a version of business model generation in all Intelligent Energy Europe (IEE) programmes was a clear statement that the need for long term viability was recognised as key; initial research and pilots gave way to innovation and deployment (Tumasz, 2016). These were therefore key concepts for the framing for contribution and subsequent benchmarking.

3.7.2. Poor ex-ante and ex-post data collection; evaluation frameworks; data standards

The paucity of good ex-ante and ex-post data collection, coherent evaluation frameworks (Leonardi, Browne and Allen, 2012; Jacques Leonardi *et al.*, 2015) and the lack of data standards across Europe (Ambrosini and Routhier, 2004) were highlighted most clearly and convincingly in the literature. The need for quantitative data, ex-ante and ex-post, and for coherent evaluation, was a key concept for this research undertaking, as well as looking to see how the thesis had added knowledge to the theoretical or methodological state of the art.

3.7.3. Engagement with Action Research in purchasing and supply chain management

'How' can equate to methodology and, whilst there was little research on urban logistics and procurement in 2011, there was an emergent and clear call for the deployment and evaluation of Action Research in the area of purchasing and supply chain management. As such there was a significant gap that could be addressed by deploying such a methodology and adding to the theoretical knowledge about doing so.

3.8. Meta: Little or no theory development

I viewed this as a 'meta' issue, lying outside of the systems approach, but potentially affecting or being contributed to by the whole framework. The opportunities to address the two key weaknesses identified: theory, and research philosophies, as well as to find a mutual understanding of the subject at hand, were challenging and yet a clear opportunity.

3.9. Generic Research Questions

Based on the rationale detailed in sections 1.3, 1.2, locally and internationally, the literature review in Chapter 2, and the subsequent framing in Chapter 3, the research questions for this work were considered, reconsidered, refined and decided upon.

The published research in the field, as of 2011 and progressively through the period of the research, suggested key concepts and gaps that would merit further investigation. The literature review showed a recent upsurge in publication suggestive of an emergent field as shown in Figure 10 above.

Since the work was both a practical intervention with benefits to the University, and of subsequent value in contributing to the body of knowledge in the field, one potential question to be asked was 'How to improve the sustainability of urban freight at a University campus?'. However, this was too broad a definition, so others were considered. Other potential questions were: 'How to facilitate change in an academic institution to achieve sustainable city logistics'; and 'Was method X effective in achieving change for sustainable city logistics in a large institution?'

3.10. Refined Research Questions

The first research question was to address the needs of the University and the region with regard to local sustainability; a second question was needed about the gap in the literature on procurement and urban freight; then a third question to advance knowledge about research itself. Finally, there should be a question to draw out a sustainable, enduring policy advice with value to practitioners and policy makers in the field.

> *RQ1: How to improve the sustainability of logistics on the Coherent Campus at Newcastle University?*
>
> *RQ2: To what extent can sustainable HEI logistics only be achieved through sustainable procurement practices?*
>
> *RQ3: How effective were participatory research approaches in facilitating this improvement?*
>
> *RQ4: What novel approaches for policy and practice locally, nationally and at an EU level could be developed from this work?*

3.11. Relevance of Newcastle University

The choice of Newcastle University as the case study for the thesis was a combination of the pragmatic needs of the key actors detailed in Chapter 1: the University (for which I worked) and the European Union (with whom I had a contract) - and the concepts and gaps framed from the published literature. The problems and needs were detailed in Chapter 1. The key groups of the framing, where the University case showed potential to add to knowledge, are summarised below.

<u>Urban consolidation centres</u> and <u>non-traditional approaches to consolidation</u> were key issues for the LTP3, and hence for the region and city, as well as being a key theme in EU research and interventions and in the published literature. In the Newcastle case, the low level of success for such initiatives to achieve <u>long term financial viability</u> was seen as approachable via the development of <u>viable business models</u> - a key need from research partners. <u>The use of electric vehicles (EVs) in freight</u> was a local government policy commitment. With both the ability to operate inside a large higher educational institution (HEI) with full access to purchasing and delivery data and the ability to utilise a novel approach to <u>delivery and service plans,</u> choosing the University case was clearly a relevant opportunity. It was also a relevant choice for the issues of <u>freight trip generation and/or attraction,</u> although less likely to offer much towards land zoning, given how UK planning differs from that of the USA.

Working with the purchasing function from the inside would allow for closer examination of some of the key gaps in the literature: barriers to sustainable procurement; urban freight and procurement activity. Working with suppliers and logistics companies would address the important issues of distribution hub locations, stem and leaf delivery legs, and poor selection of locations. Working as a consortium within a multi-stakeholder process, and with a locally successful freight quality partnership, would maximise the opportunities to explore the need for co-operation and collaboration.

The institutional campus was a controlled environment - seen as a key factor in the success of urban freight interventions - and would allow exploratory research into the relationship between higher education institutions and freight. The control of the campus, and access to databases of operational transactions, would directly address the poor ex-ante and ex-post data collection noted in the literature and allow the deployment of well-informed evaluation frameworks.

The literature review had shown little or no theory development or alternate research paradigms; as such it was justifiable as 'exploratory' research or, as Yin lists as a justification for a single case: 'revelatory' (Yin, 2014, p. 8). The literature had shown an emergent interest in engagement with Action Research in purchasing and supply chain management, as well as broader use in logistics and supply chain management. To that end the opportunity to adopt an Action Research approach was supported by the literature. In Chapter 5, I report further on the methodological choices made and the research philosophy adopted.

3.12. Summary

Chapter 3 detailed the development of a theoretical framing from the concepts identified in the literature review. This justified the purpose and need for the research as thesis, alongside the pragmatic objectives of the work. Using a systems approach present in the literature review, I framed many of the concepts within 3 sub-systems: Actors, Society and Techniques, within the overall groupings of Why; Who; With what; Where; When, and How. Within this framing I elaborated the key themes, findings, and gaps in the field. The framing supported the generation of generic and then specific research questions worthy of further investigation. This framing was then ready to be used to evaluate the thesis in respect of the body of knowledge, at key chapter ends, and in the final evaluation of contribution to theoretical knowledge. The relevance of the case of Newcastle University was justified, with reference to the framing.

The next chapter is about the general conception of the nature of the enquiry within which the scientific endeavour proceeds. It incorporates such top-level concepts as epistemology, procedures of reasoning, ontology, axiology and therefore the overall philosophy of this research.

Chapter 4. Research Philosophy

This Chapter is about the general conception of the nature of the enquiry within which the scientific endeavour proceeds. It incorporates such top-level concepts as epistemology, procedures of reasoning, ontology, axiology and how the approach to each was used to develop the overall philosophy of this research.

This research was about the interaction between the society of actors, an ensemble of techniques, and the environment in which the system of goods and services supply to the University existed, as detailed in section 3.2 above. A myriad of research methods and techniques might have been adopted with this combination of action, entities and qualifiers; it was therefore important to have clarity about the possible approaches and why specific choices were made.

Researchers must understand and choose the philosophical approach they will adopt, state it, and explain why it was chosen. This allows a common understanding between audience and researcher and, more importantly, can affect the nature and process of the research itself. The field of logistics research had been weak in two areas: theory and explicit discussion, and statement of research philosophies (Solem, 2003). It had been implicitly positivist, with a strong bias towards quantitative data collection and analysis.

In the 21st century, the academic journals had published papers showing an increasing interest in methodological questions and, explicitly, the assumptions about knowledge, the nature of entities, and the reasoning approach to make. Examples of this emergent focus included Näslund (2002) discussing the dominance of the positivist approach and quantitative methods in logistics research; Arlbjorn and Halldórsson (2002) describing and reflecting on content, context and processes of logistics knowledge creation; Solem (2003) reviewing and identifying the potential benefits of a wider set of philosophies; and Mangan and others (2004) expressly developing mixed methods that merged different traditions.

As Solem (2003) says: “Our ability, however, to formulate and solve logistics problems depends not only on technology and different kinds of sciences, but also on our philosophies, worldviews, and attitudes. Maturity in a discipline can be judged by its practitioners’ capacity for philosophical reflection on the fundamental assumptions they make about reality, i.e., ontology, and the process of learning about it, i.e., epistemology, to use two of the main concepts from the Theory of Science or Philosophy of Science."

Mangan has noted "that much of the debate and criticism over methodology involves researchers who are failing to communicate with one another because they hold varying basic assumptions about their subject" (Mangan, Lalwani and Gardner, 2004). It was therefore appropriate to address key epistemological questions about the context and research approaches that could have been (and were) considered to facilitate understanding and communication of the final results.

4.1. Domain and Discipline

This research was in the transport domain - an important and significant part of modern society. Transport used around a third of all energy in the EU, thereby producing a highly significant part of the carbon emissions in urbanised areas, where over 73% of EU citizens lived. Transport generated significant volumes of air pollutants, noise and congestion, but also enabled mobility - ensuring improved quality of life, social cohesion, and economic growth over larger areas than before (European Commission, 2013). Global logistics, facilitated by a combination of the ISO shipping container and the World Trade Organisation liberalisation treaties, had enabled the globalisation of trade, with concomitant benefits and dis-benefits in manufacturing, costs, prices, employment and economic interdependence.

Transport was "a cornerstone of European integration and ... firmly linked to the establishment of the Single Market, which promotes jobs and economic growth" (European Commission, 2018). As one of the first common policy areas of today's European Union (EU), it was seen as vital for fulfilling three of the four freedoms of a common market, as established in the Treaty of Rome in 1957: the free movement of individuals, services and goods. The transport sector on its own constituted a crucial sector of the economy: in 2015 it represented some 9 % of the total Gross Value Added of the EU economy and 9 % of the total EU employment. In 2016, 17.2 % of the EU's total exports of services were transport related. However, transport also generates negative societal effects such as accidents, greenhouse gas emissions, air pollution, noise, and environmental effects. Overall, in 2011, external costs due to transport had been evaluated as approximately 4 % of GDP (European Commission, 2018).

This important and significant domain was the concern of a ministry in all the (then) EU28 and of the Directorate General MOVE, in the European Commission. Transport was addressed by funding bodies as a single area for research and innovation in the EU, and in many member state research and innovation programmes, but in academia it did not exist as a single discipline with a single paradigm or domain. The UK Engineering and Physical Sciences Research Council (EPSRC) — the UK's main agency for funding research in engineering and the physical sciences — did not recognise transport as a research priority in its own right.

Rather, academia's approach to transport was to view it through the lens of existing disciplines. Some examples were: civil and electrical engineering, or geography, for infrastructures; mechanical, materials and electrical engineering for vehicles; management science and operations research for operations and business; sociology, psychology, geography, and management science for the role of people as users and clients; environmental studies, civil engineering, geography, and medicine for the impacts on people as citizens; and economics or management science for the trillions of euros turned over every year in the transport domain. Even this short list is incorrect: researchers and lecturers in almost every discipline engaged in some sort of academic endeavour that worked with knowledge from, or for, the transport domain.

This complex situation made for a complex choice, when looking to approach a transport research endeavour. Should the researcher adopt a holistic and therefore multi-disciplinary approach, or narrow down the field of enquiry to reduce the complexity, but hopefully enhance the utility, of a research outcome? Answering this question did not alone resolve the discipline into which the work should fall since, in many disciplines, it was possible to adopt either approach. The choice of discipline may actually seem redundant: most researchers come from one tradition or another, regardless of their discipline, and bring with them the disciplinary nomenclature and shared understanding of terms and of epistemological and ontological approaches.

4.1.1. Humanities, Natural Sciences, or Social Science?

This research has been viewed through the broad lens of social science approaches. It was not appropriate for me to view it in terms of the humanities, as part of a PhD in the Science, Agriculture and Engineering faculty; nor did it fit well with the body of research so far in this subject. It could have been approached from a natural sciences perspective, as indeed was much of transport research. However, I chose a social sciences approach, because I wished to explore the socio-technical system (see 3.2 above) that created demand for goods, delivered goods, created freight traffic, and returned value for those activities. This suggested that the role of organisations, of individuals and their roles, and of systems that incorporated people, would be an important part of the work, making a social sciences approach likely more appropriate. This was an important distinction to make, since the philosophies of the natural sciences and the social sciences had evolved since the mid 20th century, with each creating variant definitions of the same terms (Bryman, 2012).

Within the context of social sciences, the areas of academic endeavour that mapped best to this research were logistics and procurement research, both of which sometimes fell within the broad discipline of management science, although they could be found to reside in departments as varied as geography, civil engineering, economics, civil or mechanical engineering and maritime science.

4.2. Epistemological Positioning

Epistemology is the consideration of what is or should be acceptable knowledge in a discipline. As a starting point in social science, this can be split between two key schools of thought: 'positivism' and 'interpretivism', which can then be augmented by 'realism' - a third philosophy, which itself splits into two.

Positivism is the philosophy that advocates the application of the methods of the natural sciences to the study of social reality. As described in (Bryman, 2012), this approach is made up of the following principles:

- Only phenomena and hence knowledge confirmed by the senses can be genuinely warranted as knowledge (the principle of phenomenalism[19]).
- The purpose of theory is to generate hypotheses that can be tested and that will thereby allow explanations of laws to be assessed (the principle of deductivism).
- Knowledge is arrived at through the gathering of facts that provide the basis for laws (the principle of inductivism).

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[19] *Not to be confused with phenomenology which is a term from the opposing tradition.*

- Science must (and presumably can) be conducted in a way that is value free (that is objective).
- There is a clear distinction between scientific statements and normative statements and a belief that the former is the true domain of the scientist.

In recent years, multiple authors had noted a positivist approach to be dominant in logistics research. Näslund noted that “Logistics research in general, and perhaps US logistics research in particular, can be characterized as significantly influenced by a positivist paradigm” (Näslund, 2002). A review of the supply chain and logistics research literature 1999-2003 found that 57% of all peer reviewed articles in the key journals were empirical (Sachan and Datta, 2005).

Interpretivism is a term that focuses on epistemological intellectual traditions that view the subject matter of social sciences as the *understanding* of human behaviour, as opposed to its explanation. The position is often seen from a ‘phenomenological’ approach, based on the work of Alfred Schutz (1899-1959), in which the key concepts are seen to be:

- Social reality has a meaning for human beings and therefore human action is meaningful; humans act on the basis of meanings, not external objective factors.
- It is the job of the social scientist to gain access to people’s thinking and interpret their actions from their point of view.

Concurrent to this is the influence of the ‘symbolic interactionist’ tradition, based strongly on the work of George Herbert Mead (1863-1931). Some symbolic interactionists argued that the individual continually interprets the symbolic meaning of her environment, including the actions of others, and acts on the basis of this imputed meaning.

These two positions were in fact neither inconsistent nor accurate portrayals of the broad traditions they appeared to be. As will be seen later in this chapter, one could adopt many of the epistemological approaches of the positivist whilst following a human meaning or symbolic viewpoint - as have done many social researchers. It may also be suggested that the definition social scientists once placed on positivism was more often used as a benchmark to define a different, contrasting approach.

There had been an emergence of interpretivist epistemology in wider management science in the closing decades of the 20th Century and beyond and, although there had been an emergence of qualitative based methods in an empirical manner, it was with Mangan et al in 2004 that research was published using a mix of positivist and phenomenological approaches (Mangan, Lalwani and Gardner, 2004).

Realism was the third epistemological position that could be seen in the core literature. This also posited that the approaches of social scientists should be the same as those of natural scientists, with regard to data, reasoning and explanation; the researcher is objective and there is an external reality - separate to meaning or symbolism - to which scientists direct their attention. The 'realism' school of thought then had two major variants: 'empirical realism' - which simply asserted that through the appropriate methods, reality can be understood (in the main, the positivist position) - and a second, more nuanced variant known as 'critical realism', that recognised the reality of the natural order but posited that the scientist's conceptualisation of it is a way of knowing the reality. As (Bhaskar, 1989) says: "Science, then, is the systematic attempt to express in thought the structures and ways of acting of things that exist and act independently of thought. The world is structured and complex and not made for men."

Critical realism had been seen in the limited literature on logistics and epistemology and had been called, by some, a way to address the "tension in logistics research between the heavy reliance upon rule-governed acts, or causality, as scientific explanation on one hand, and the on the other hand the increasing use of case studies as a research approach" (Aastrup and Halldórsson, 2008). It was presented as a way to map qualitative research into an empirical realist approach that was more comfortable to those with a positivist tradition.

Critical realism had many characteristics in common with the philosophical tradition of 'pragmatism' - a North American philosophy originated by the chemist Charles Sanders Peirce (1839–1914), promoted strongly in psychology, social science and education by John Dewey (1859–1952), and which had seen periods of popularity, obscurity and resurgence, especially with its development by Richard McKay Rorty (1931-2007)[20].

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[20] *As is often the case with 'isms', Peirce preferred "pragmaticism", Dewey preferred "instrumentalism", and Rorty is viewed as a "neo-pragmatist". Pragmatism will suffice for our purposes.*

The key themes of this tradition were disavowal of the objective observer of knowledge, and replacement with the experimental *theory* of knowledge, which sees all knowledge as provisional and values it according to its usefulness, rather than judging or validating it against an objective measure (Dewey, 1917). Not only is knowledge only of value through use, but Rorty further argued that pragmatism lies in a divergent train of philosophical thought that encompasses Wittgenstein, Heidegger, and Dewey:

“For all three, the notions of "foundations of knowledge" and of philosophy as revolving around the Cartesian attempt to answer the epistemological skeptic are set aside. Further, they set aside the notion of "the mind" common to Descartes, Locke, and Kant - as a special subject of study, located in inner space, containing elements or processes which make knowledge possible. This is not to say that they have alternative "theories of knowledge" or "philosophies of mind." They set aside epistemology and metaphysics as possible disciplines” (Rorty, 1979).

Pragmatists such as Dewey and George Herbert Mead (1863–1931) also viewed knowledge as created through action and interaction; reflective thinking arose in response to a problem that needed resolving and, since action was contingent on the temporal and local context, knowledge, process and action would change over time and place. This contextual approach led pragmatists to believe in the accumulation of collective knowledge and that the “experiences of whoever is engaged in an inquiry are vital to the inquiry and its implicated processes” (Strauss and Corbin, 2015). This last point was of key importance in the research approach chosen.

Pragmatism set aside the traditional debate about the nature of epistemology, stating that: “Knowledge leads to useful action, and action sets problems to be thought about, resolved, and then converted into new knowledge” (Strauss and Corbin, 2015). It adopted the view that any of our ideas must be open to doubt (including this one), but not all at once. It has been said that Pragmatism is a conceptual toolset where, in the long term, one has to replace all the tools - but only one at a time (Bryant, 2009).

“Another key aspect of Pragmatism, and an exceedingly useful one, is what might be termed the "so what?" principle, or the difference principle—i.e. for any argument, particularly one about metaphysics or foundations or similar, one must ask "what practical difference would it make if either I or my opponent was correct/incorrect?" If the answer is "none", then forget it!” (Bryant, 2009)

4.2.1. Pragmatic

For this research the key problems were contained in a domain that lay inside many academic disciplines, that could be approached with multiple philosophies about the nature of knowledge. The likely data were to be a mix of qualitative and quantitative, and the scope was to include people, roles, and organisations, as well as vehicles, goods, ground plans and infrastructures. The researcher was an experienced supply chain and procurement manager, with additional experience as a transport researcher. The key drivers of the ‘clients’ of the research were practical and agnostic to metaphysics. Critical realism met many of the criteria for the combination of subject, place, organisation and researcher, but it also had a strong positivist stance. Pragmatism, on the other hand, had a pluralist approach to most epistemological divides, as well as fitting all the other factors. On this basis, the most appropriate position on knowledge for this work was that of pragmatism.

4.3. Reasoning

The choice of pragmatism brought to the fore another facet of the research philosophy to be considered: the nature of the reasoning to be utilised. Traditionally there have been two theories of reasoning, that date back to the Ancient Greeks: deductive and inductive. The pragmatists and critical realists promoted a quite different approach, known as either ‘abductive’ or ‘retroductive’ - an approach also viewed as having its pedigree in classical times.

The deductive approach, often viewed as the choice of natural scientists, was that of a generalised theory leading to hypothesis, an experiment leading to data, and testing of the hypothesis and conclusions.

In modern science, deduction is often paired with the concept of falsification (Popper, 1959) - a process whereby a possible outcome of an experiment that conflicts with predictions deduced from the hypothesis must exist, otherwise the hypothesis cannot be meaningfully tested. This role of falsification is important, since it is rejected as a validation in many areas of social research, especially case studies (Yin, 2014).

The inductive approach, often incorporated as a sub-process of the scientific method, began with data and induced theories that matched that data: a theory-generating tool, moving from a specific case of collection of observations to a general law.

The abductive approach (promoted for logistics research by Kovács and Spens, 2013), stemmed from the insight that most great advances in science neither follow the pattern of pure deduction, nor of pure induction, but rather emerge from intuitive leaps, unexpected observations, and the creative-intuitive nature of the researcher herself.

This is best illustrated diagrammatically, as in Figure 16 below:

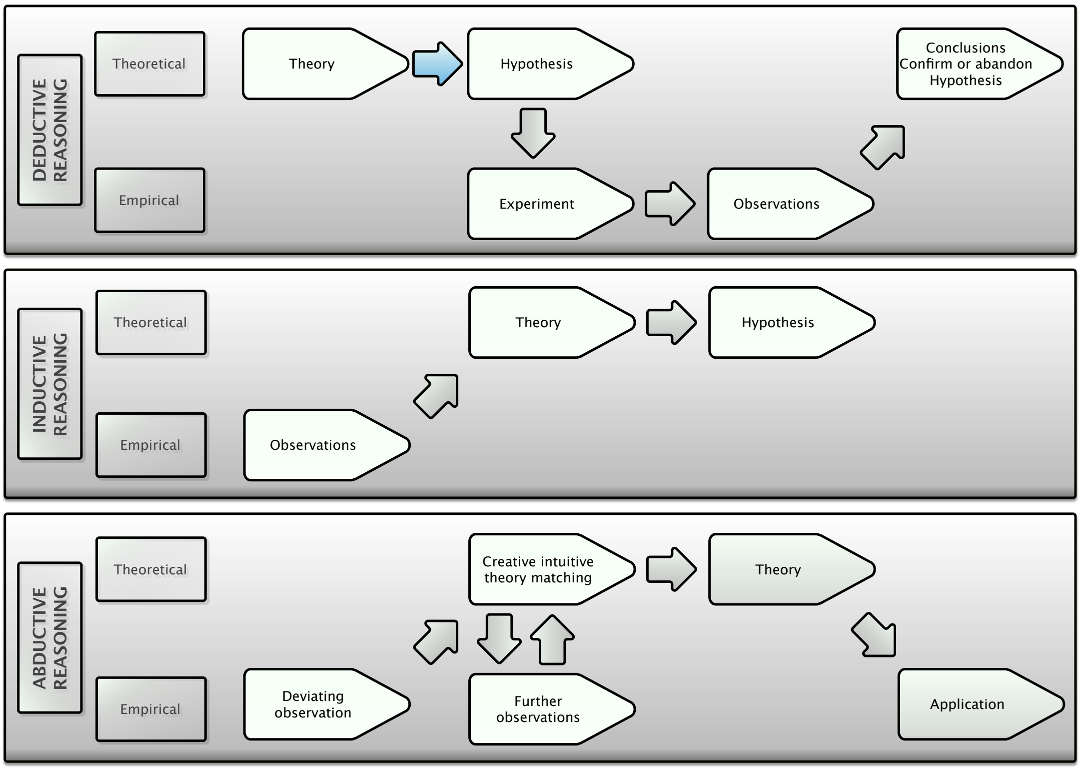

Figure 16: Deductive versus Inductive and Abductive Reasoning

The research in this thesis began with a deductive reasoning approach - a linear flow from a hypothesis - which then met with data and was adapted. All ideas of hypothesis were then placed on hold, while data were collected and analysed statistically, looking for inductive insights. Then, one day, as I looked out of my window and noticed all the trucks and vans unloading goods, and the delivery people coming to and from the building in which I was working, and an intuitive leap occurred - a classic example of abductive reasoning. Based on my experience and the collective knowledge built up in the field of urban freight logistics research since the late 1990s, I realised that the empirical evidence I saw - trucks on campus - was probably caused by my own institution, not the operators or the suppliers. From empirical observation, an intuitive leap had suggested multiple possible theories which might have answered my research questions; this then led me to the further observations and outcomes that made up this research. I had begun to follow abductive reasoning.

4.4. Ontology

Ontology is the study of the underlying assumptions about what entities exist or may be said to exist, and how such entities may be grouped - sometimes in a hierarchy - and/or subdivided according to similarities and differences. In science and technology this had a practical application, especially in information and communication technology (ICT), where an ontological analysis of objects was a key part of system architectures. In social science, the key separations were between ‘objectivism’ and ‘constructionism’, according to Bryman (Bryman, 2012).

Objectivism stated that social phenomena confront us as external facts that are beyond the reach of influence. Organisations are tangible objects, with rules and regulations, procedures, mission statements, and roles for employees and their employer. This organisation exists separately to the people who work, are served, or are taught in it. People conform to the organisation: it defines them.

Constructionism stated that social phenomena were constructed and reconstructed by action and interaction between and upon the people occupying them (physically, virtually or logically). Rules, regulations and procedures were flexible and often ignored or renegotiated over time; secondary, undocumented systems existed; stated missions may be less important than unstated ones; etc. The organisation and the people adapted and reconfigured to *each other,* over time and place.

Ontology was a key choice in this research. The work was in an institution with multiple rules, regulations, procedures, hierarchies, sub-hierarchies, departments, schools, and faculties. The research addressed commercial negotiations between suppliers, transport operators, buyers and end users. In the main, logistics research had adopted an implicit positivist objectivist approach to these issues, the field being “practice-oriented and solution-based … developed under strong influence from physical sciences by making non-living phenomena its study objects” (Aastrup and Halldórsson, 2008). In so doing it had underestimated the interaction between people, firms, agents and roles - in and outside of organisations - through their choices and intentions that were dependent on the meanings placed on them, not necessarily the system’s apparent stated objectives.

Everything in my previous work practice and current research experience had signalled to me that organisations were rarely the same in practice as they were on paper, leading to my selection of constructionism as the preferred choice of ontology.

4.5. Axiology

Axiology is the study of the nature, types, and criteria of values and of value judgments. This can be encapsulated as the researcher's view of the role of judgement. The positivist tradition tended to view judgement as value-free: thus, the researcher was objective and independent. A realist would tend to accept research as value-laden: all researchers bring biases to the work and these have impact. In similar vein, an interpretivist would go further and say that the researcher is herself part of the research: having values that then become of the work and make it subjective. Pragmatists would step to one side, acknowledging that values play a role, but that in some cases and situations they can be ignored or even fully embraced - *dependent on the utility.* Therefore, a pragmatist could adopt both objective and subjective approaches, dependent on the context, method or techniques adopted (Saunders, Lewis and Thornhill, 2012). This was another key issue to address and, given the mixed traditions of approach, and the utility of the positivist, realist and interpretivist perspectives, the pragmatic approach to axiology was adopted.

4.6. Research Philosophy

Much of the literature and many theses adopted the term 'paradigm' to describe the research philosophy or world-view adopted in the work. The most commonly used definition of 'paradigm' was based in the work of Kuhn and described by Bryman as "a cluster of beliefs and dictates which for scientists in a particular discipline influence what should be studied, how research should be done, [and] how results should be interpreted" (Bryman, 1988). This was a good working definition, appropriate in many endeavours, but it had some problems for this work. Transport and logistics research was multi-disciplinary and research into urban freight was nascent. A paradigm is defined within a discipline and is incommensurable - meaning inconsistent with any other because of their divergent assumptions and methods. This had been used as an argument against cross-cutting and/or mixed method research, especially work based on pragmatic reasoning. It had been noted that many researchers/practitioners found many positive features in more than one paradigm and that there were benefits to "thriving on our differences and on intellectual tensions" (Johnson, 2017).

To that end, the term paradigm was not adopted for this research; instead the term research philosophy has been used to describe the underlying philosophical choices, and the final constructed approach to domain, epistemology, reasoning, ontology and axiology.

4.7. Summary

In this chapter, the issues of the underlying philosophical issues related to social science research have been considered and explained. Following a discussion of domain and discipline that led to the choice of social sciences for this research, the epistemological theory of knowledge has been explored and the different philosophical positions of positivism, realism, interpretivism, critical realism, and pragmatism evaluated. My choices at each step where informed by the four research questions identified, the mixed traditions of the research background, and the construction of a systems approach socio-technical framing of the literature. The process of adopting the research philosophy is shown as a flowchart, in Figure 17 below.

Social sciences was chosen as the best domain fit (section 4.1 above). This was in line with the framing, the rationale for the work, and the personal history and competencies of the researcher. Key here was that RQ2 to RQ4 are about procurement, participation and policy - all socially negotiated activities. Pragmatism was chosen for epistemology (section 4.2 above) due the 'temporal and contingent' nature of urban freight research and practice, clearly revealed from the concepts identified and listed in section 2.9.1 above.

The adoption of abductive reasoning has also been explained, in preference to deductive or inductive reasoning (see section 4.3 above), while all of my professional experience to date has led me to choose the ontology of constructionism (section 4.4 above).

A clear statement was made on the adoption of 'research philosophy' rather than 'paradigm', given the multi-disciplinary nature of the pragmatic problems and the theoretical diversity of the literature (see section 4.6 above).

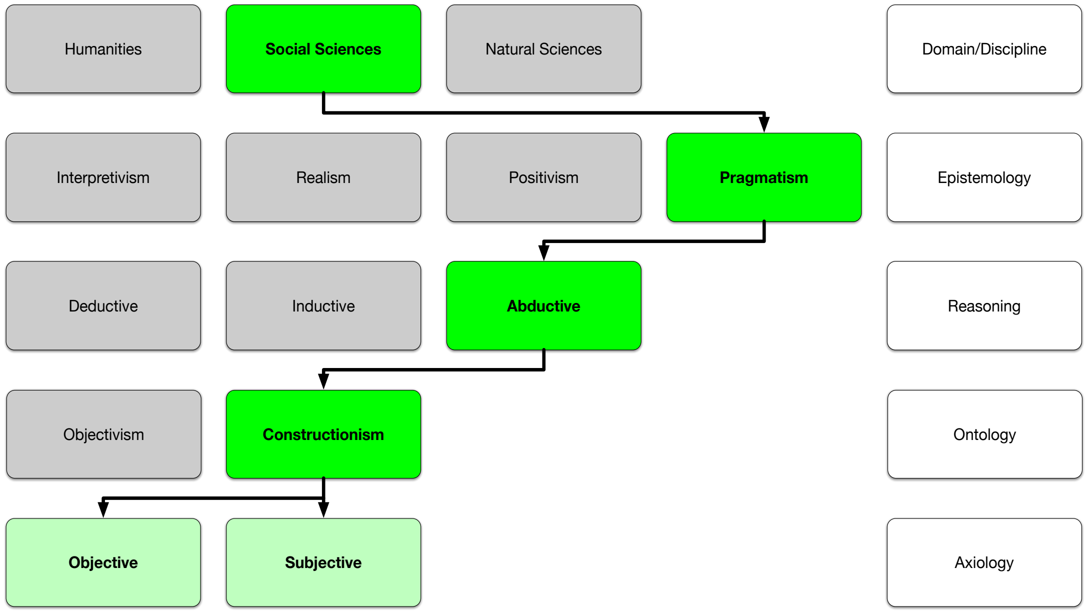

Figure 17: Research Philosophy Flowchart based upon the Research Questions for the Pragmatic and Theoretical Work

This research philosophy set, it was possible to consider the actual methods and techniques to be employed in the work itself, within a research framework. This research framework, and the methods and techniques contained therein, is set out clearly in the next chapter.

Chapter 5. Framework: Methods and techniques

This Chapter describes the methods and techniques that were considered for the research, the approaches evaluated, and the design process used. The final framework, and the complementary methods and techniques within, are detailed and the final research project design summarised.

As detailed in Chapter 1, the work was set in the context of a case study at Newcastle University, specifically: the operations and management of Purchasing and Estates, connected to the full range of employees using those resources; freight vehicle intrusion on campus; and the suppliers and associated logistics providers. The work was therefore a case study set in the wider international context of EU energy and transport policy, with particular reference to clean city logistics and focusing on the reduction of carbon emissions and noxious air pollutants.

Context and scope were wide, potentially encompassing: procurement policies; procedures; ICT systems; estates access; vehicle technology; environmental monitoring; vehicle types; propulsion systems; warehousing and distribution choices; and local, national and EU regulation of traffic. This complex combination of people, physical operations, policies, procedures, ICT and regulation is best referred to as a 'system'.

5.1. Systems Approaches

Problems can present themselves in differing scales of complexity, not just in depth but in scope. A clearly defined problem, or one with a narrowly defined area, might be referred to as a 'difficulty'. For example: 'how to adjust the lead-times of a purchasing system to best offset stock availability versus supplier lead-time' is easily solvable by a common algorithm (Emmett, 2005). Another problem type can be called a 'mess' (Ackoff, 1974) – often one that is complex in scale and falls between different domains of endeavour, presenting not just a difficult task to solve, but a difficulty in *even identifying the actual problem(s)*. A 'mess' tends to have multiple, different interlocking and interdependent aspects, systems or actors; it may exhibit network effects, and there will be a high level of uncertainty. It could be said that this is a product of what Coghlan (2019) has described as a volatile, unpredictable, complex, and ambiguous

(VUCA) world. Urban freight logistics had been seen as such a ‘mess’, being identified as “difficult to organize, difficult to modernize” and having integrated city logistics solutions that are likely to “never work” (Dablanc, 2007; Muñuzuri *et al.*, 2012).

Systems approaches aim to simplify our thinking and help manage complex things in a holistic way, by selectively handling the detail so as to reveal features, aspects, relationships, physical systems, and non-physical procedures that underlie what can appear indeterminate ‘messes’ of confusion. This can be informed by the value of previous experience and knowledge, as well as by methods of analysis and categorisation.

Systems thinking had two core standpoints on the nature of systems: ‘thinking about systems’ and ‘systems thinking’ - also often referred to as ‘hard’ and “soft’. Whilst this division influenced many approaches, the field adopted the position that systems were essentially social constructs used to model and understand complex reality (M Reynolds and Holwell, 2010). This essentially critical realist position was then developed into a tripartite division of system approaches: ‘hard’, ‘soft’ and ‘critical’; critical approaches introduced explicit attention to the power relationships in any system and the boundary judgements accordingly made.

System thinking came to the fore when research into living things encountered limitations to the concepts and principles of reductionism (Descartes, 1637; Flood, 2010). In cities, the tendency of transport planners to perceive urban freight transport as an analogue for public transport had often led to interventions at the operator level, whereas growing evidence suggested operators had the least control over the transport and supply chains involved (Holguín-Veras *et al.*, 2015).

Similarly, single causes and associated effects had often been focused upon, such as the development of a more capable battery system for propulsion, the growth of home delivery systems, or the use of time-based delivery windows. The adoption of a narrow focus was often associated with a focus on measurable quantifiable outcomes. This had often achieved much in fields such as operations research: for example, manufacturing process optimisation through such measures as statistical process control. Similar close focus interventions – such as traffic cost-benefit safety analysis —had an associated and recognised ‘number of fatalities’ measure.

As the literature review and framing showed, the domain of urban freight transport is complex, highly dependent on “why”, by “whom”, “with what”, “where”, “when” and “how” it was enacted, as developed in section 3.2 above.

Systems thinking countered these pitfalls - not by refusing the role of investigation into sub-systems, but by maintaining a holistic viewpoint that began with, and continued to adopt, a whole system approach, while recognising that the system edges could be fuzzy. Systems thinking fitted well with the rationale and context of the research outlined in Chapter 1 and the pragmatist philosophy adopted in Chapter 4.

5.2. Multiplicity of Approaches

More systems approaches existed than even the experts in the field could effectively utilise. Reynolds and Holwell talked of the development of one hundred, one thousand, or three thousand “methods”, “streams”, “systems” and “cybernetics” (2010). However, the prevailing methods that had been deployed in recent times, in Anglophone operations research and management science, are listed in Table 9. From here, the most appropriate were then considered with my research team and previously published as work in progress (Zunder, Aditjandra and Carnaby, 2014). I then re-evaluated the suitability of the approaches, using the concepts identified in Chapter 2 and the socio-technical systems framing of Chapter 3. This is reported further in 5.3 below.

Systems ‘type’	Exemplar systems approaches
Hard systems	General systems theory (Bertalanfy 1956)
	Classical (first order) cybernetics - ‘mechanistic’ cybernetics (Ashby 1956)
	Operations research (Churchman et al. 1957)
	Systems engineering (Hall 1962)
	Socio-technical systems (Trist et al. 1963)
	RAND-systems analysis (Optner 1965)
	System dynamics (Forrester 1971; Meadows et al. 1972)
Soft systems	Viable Systems Model (VSM) (Stafford Beer, late 1960s)
	Inquiring systems design (Churchman 1971)
	Second order cybernetics (Bateson 1972)
	Soft systems methodology (Checkland 1972)
	Strategic assumption surface testing (Mason and Mitroff 1981)
	Interactive management (Ackoff 1981)
	Cognitive mapping for strategic options development and analysis (SODA) (Eden 1988)
Critical systems	Critical systems heuristics (Ulrich 1983)
	System of systems methodologies (Jackson 1990)
	Liberating systems theory (Flood 1990)
	Interpretive systemology (Fuenmayor 1991)
	Total systems intervention (Flood and Jackson 1991a)
	Systemic intervention (Midgley 2000)

Table 9: Three traditions of systems thinking (adapted from Reynolds & Holwell 2010)

In order to evaluate the major types and developments in system approaches the most topical, appropriate or influential were selected for first consideration. These five key approaches were:

- System Dynamics (SD) developed originally in the late 1950s, by Jay Forrester;
- Viable Systems Model (VSM), developed originally in the late 1960s by Stafford Beer;
- Strategic Options Development and Analysis (SODA: with cognitive mapping), developed originally in the 1970s by Colin Eden;
- Soft Systems Methodology (SSM), developed originally in the 1970s by Peter Checkland; and
- Critical Systems Heuristics (CSH), developed originally in the 1980s by Werner Ulrich.

After the initial consideration, and once possible methodological choices were made with my colleagues and reported (Zunder, Aditjandra and Carnaby, 2014), I continued my reading into recent developments in logistics and supply chain research. In that reading, appropriate action research (Näslund, 2002) was called for, and I recommenced my evaluation having added:

- Action Research as a Systems approach, originating primarily in the work of Kurt Lewin, in the mid-1940s.

These six approaches are each described below and then the process of selection is reported and discussed.

5.2.1. System Dynamics (SD)

System dynamics was a 'hard' objective systems approach to understanding the behaviour of complex systems over time and was founded by Jay W. Forrester, with the establishment of the MIT System Dynamics Group, in the late 1950s. Forrester applied his knowledge and skill with electrical engineering systems more broadly. SD focused primarily on internal feedback loops and time delays and how these changed the behaviour of entire systems. These feedback loops, stocks and flows were particularly effective in displaying nonlinearity in complex systems. SD was used to model the 'Bullwhip Effect' of distribution in supply chains (Forrester, 1961). It was discussed as a methodology for city logistics in Japan and Australia (Taniguchi *et al.*, 2007).

5.2.2. Viable Systems Model (VSM)

VSM was another 'hard' objective systems approach that focused on the necessary and sufficient conditions for the viability of systems. Developed by Stafford Beer in the 1970s, this was the foundation of Organisational Cybernetics, where a viable system maintained an independent existence by being able to meet the demands of surviving in a changing environment - adaptability being key. Used extensively by cyberneticians worldwide, VSM had been deployed in contexts ranging from guiding major environmental policy at national and regional level, to very local promotion of efficiency in small communities and societies (Martin Reynolds and Holwell, 2010).

5.2.3. Strategic Options Development and Analysis (SODA)

SODA was based around cognitive mapping - a technique for revealing and actively shaping the mental models that people used to understand, contextualise, streamline, and comprehend complex situations and problems. It was a constructionist 'soft' approach, but with a very strongly 'automated' and objective observer approach to data analysis. Developed by Colin Eden, the cognitive mapping process constructed meanings from intensive workshops with people and transcribed them into a database, where they were analysed. This process, used and designed to work at the individual level, was designed to facilitate negotiation and arrival at agreed action plans. It was commercialised as a strategic thinking tool in the software JOURNEY and was promoted as the methodology for cultivating organisational change, through attention to and valuing of individual perspectives in a concerted manner (Ackermann and Eden, 2010).

5.2.4. Soft Systems Methodology (SSM)

Peter Checkland, and colleagues at the University of Lancaster Systems Department, developed SSM through a 20-year programme of AR to analyse complex, 'messy' situations where divergent views about the definition of a problem existed. A 'soft' constructionist approach, using an interrogative device to enable debate amongst concerned parties, its use had been as diverse as the custody of mentally disordered offenders; disaster planning; Inuit fishing; homelessness; and the NHS (Checkland and Poulter, 2010), as well as investigating changes in transport planning policy where rational comprehensive approaches had proved inadequate (Kane and Del Mistro, 2003).

5.2.5. Critical Systems Heuristics (CSH)

CSH adopted a constructionist view of organisations and was originally developed by Werner Ulrich, in the 1980s. It was the first systematic attempt at providing both a philosophical foundation and a practical framework for critical systems thinking, enabling boundary critique – systematically and critically handling boundary judgments and the power relationships that generated them. Boundary judgments determined which empirical observations and value considerations counted as relevant and which others were left out or considered less important. Because they conditioned both 'facts' and 'values', boundary judgments played an essential role in assessing the meaning and merits of a claim. CSH enabled system designs, or proposed designs, to be queried for partiality and design criteria for genuine debate between stakeholders - both those involved in design and those affected by the designs but not empowered in the end system. Examples of use include natural resource management (Jackson, 2000; Ulrich and Reynolds, 2010) and a systematic comparison of adversarial and collaborative approaches to the transport policy process (Baumann and White, 2012).

5.2.6. Action Research as a Systems Approach (AR)

Kurt Lewin was a psychologist interested in human groups and their dynamics and is credited with slogans such as “Nothing is as practical as a good theory” and “The best way to understand something is to try and change it”. AR in organisational development grew particularly strongly in the USA (French and Bell, 1995), in the industrial democracy tradition in Scandinavia (Greenwood and Levin, 1998), and in the socio-technical work of the Tavistock Institute in the UK (Trist, 1981). Peter Checkland’s SSM had developed from a multi-decade programme of AR in the health services. Näslund saw AR as intimately connected to systems thinking, as the foundation for understanding and interpreting interrelationships - through participative, democratic research *in action,* leading to positive and enduring change *in and through practice*. This ‘soft’ constructionist approach had the researcher as a wholly embedded change agent in the process. AR had a well-defined and robust overall process of iterative cycles of reflexive learning, for the action and for wider knowledge. Academic practitioners defined a robust set of quality tests and standards that aligned well with the goals, the organisation, and the researcher. AR had been promoted and evidenced for use in operations management (Coughlan and Coghlan, 2002) and deployed for collaborative improvement within the extended manufacturing enterprise (Middel *et al.*, 2005)[21]. Flood wrote a paper exploring the relationship between ‘systemic thinking’ and AR, drawing on the potential that systemic thinking, from a critical perspective, offered to AR a liberating praxis (Flood, 2010). I saw an equivalence or symbiosis between the two that perhaps would allow me to build a conceptual shape of the work, with AR as the top-level methodology.

5.3. Evaluation of Systems Approaches

I considered SD as a potential approach to adopt, perhaps developing a quantitative model of the relationship of <u>urban freight and procurement behaviour</u> to explore <u>higher education establishments and freight</u>. System dynamic modelling had the advantage of rapidly designing a system (i.e. structure), executing it and analysing model results based on a graphic display in a time series modelling environment. Unlike purely

[21] *Additional reflections on the validity of viewing AR as a systems approach are in Chapter 9.*

mathematical models, system dynamic models use a graphic process to conceptualize, design, and display the structure and relationships of the model, as well as to graphically present model inputs and outputs (Koubaa, 2016). This could have addressed both RQ1 and RQ2, exploring the extent to which HEI logistics could only be achieved through procurement practices. However, SD would not yield results to answer RQ3, with regard to participatory research approaches, and would not necessarily provide novel policy approaches to address RQ4. In addition, the primarily quantitative feedback loop approach was considered inappropriate for a revelatory case study, for exploration of participatory research, and for the call in the literature for more deployment of AR in both logistics and procurement research.

VSM might have been deployed to address the broad points of RQ1- sustainability of logistics on campus. It would have been conceivable to deploy VSM to investigate more closed or discrete systems associated with urban freight, such as <u>use of rail, light rail or trams for freight delivery, 'stem' and 'leaf' delivery legs,</u> or the explicitly <u>controlled environments</u> described in the literature. However, the focus on the independent viability of very local systems seemed at odds with the multi-actor and multi-level nature of the problems detailed in Chapter 1.

SODA had much to offer all four research questions and many of the concepts in the framing. The construction of meaning through cognitive mapping could be used to address the <u>multi-stakeholder</u> nature of urban freight, and the <u>need for co-operation and collaboration</u> through negotiated agreed action plans, thus addressing the questions raised in RQ3 and RQ1, with potential to inform policy approaches in RQ4. As a pragmatic systems approach, it could have initiated change in procurement practices, rendering SODA a strong candidate for use.

SSM offered a route to address the 'mess' of urban freight that was defined as <u>difficult to organize, difficult to modernize,</u> with an interrogative approach able to manage the divergent views of the <u>need for</u> <u>co-operation and collaboration</u> in a <u>multi-stakeholder</u> project. The focus would have supported the Actors/Who sub-system of the framing well, but I was not convinced it had pedigree in operations management research. Much of Checkland's understanding of how research in action within one's own organisation could work was appealing and, since SSM had been developed *from* a programme of AR it could have addressed the call for <u>engagement with AR in purchasing and supply</u>

chain management. SSM did assume that problems and their resolution could be resolved objectively by a researcher independent of the people and the systems being researched.

CSH focused strongly on a central tool of boundary critique, questioning boundary judgements and power relationships in coercive environments. Power relationships, particularly related to procurement, could have been a route to explore the concepts of barriers to sustainable procurement; private purchasing behaviour; controlled environments; and the need for need for co-operation and collaboration. However, CSH did not have a methodological approach for pluralist, non-coercive systems; as such, it was not clear it would be appropriate to deploy.

In order to finalise the evaluation of the various approaches, the system of systems methodologies (SOSM) process, developed by Jackson and Flood (1990), was followed. This process had the primary aim of allowing both the choice of appropriate approaches and their complementary approach, where appropriate. Using the delineation above, it classified a system in two dimensions: complexity (simple or complex) and degree of shared purpose amongst participants (unitary, pluralist, coercive) - see Table 10 below. The latter dimension used the metaphors of ‘machine’ for hard system, ‘living organism’ for soft system, and ‘prison’ for coercive system.

		Participants		
		Unitary hard system based on ‘machine’ metaphor	Pluralist soft system based on ‘living organism’ metaphor	Coercive critical system based on ‘prison’ metaphor
‘Systems’ and problem situations	Simple	Simple unitary: e.g. systems engineering	Simple pluralist: e.g. strategic assumption, surfacing and testing	Simple coercive: e.g. critical systems heuristics
	Complex	Complex unitary: e.g. systems dynamics, viable systems models	Complex pluralist: e.g. soft systems methodology	Complex coercive: currently not available

Table 10: System of System methodologies (adapted from (Jackson, 2000)*)*

SOSM could be criticised for suggesting that any or all cases fit neatly into any one box, especially when dealing with ‘messes’ where the whole point of the process is to uncover and reveal what may be obscured. Furthermore, the metaphor of prison for ‘coercive’ was troublesome, because it applied not just to wholly controlled situations, where the power relationships may appear one sided, but also to a business or society with clear hierarchies, procedures, and penalties for breaking the rules - such as a University. The ‘coercive’ systems approach might apply to many social organisations, but in the University ethos, most rules and penalties were viewed more for guidance and negotiation. Power relationships in many businesses probably influence situations - in particular the boundaries between what has value, relevance or recognition - but can be difficult to assess.

To a pragmatist, models and methods are tools with utility to help achieve the tasks at hand and, if used with a critical eye and resisting dogma, their use is well suited. With these provisos, a first pass comparison was made, based on the literature. A qualitative evaluation was made, including a provisional SOSM type, summarised in Table 11 below using a four point scale: --/-/+/++.

System approach	Summary	Strength	Ratings for Newcastle University study	SOSM type
Systems Dynamics (SD)	An approach for thinking about and simulating situations and organizations of all kinds and sizes by visualising how the elements fit together, interact and change over time. Uses feedback structure and behaviour, causal loop diagrams, dynamics.	Strategic planning and evaluation.	++ for planning and evaluation; - for understanding from actor perspective; -- use of equations not sympathetic to non-technical actors; -- stated as 'difficult' for novices; -- 'hard' objective systems thinking	Complex unitary
Viable System Model (VSM)	A conceptual model built from the axioms, principles, and laws of viable organisation. Can be used to compare against an actual organisation to identify weaknesses, mismatches or missing elements in diagnosing a problem, and then as a framework for organisational design to resolve a diagnosed problem. Understands that autonomy exists within an apparently hierarchical and objectively 'real' organisation.	Modelling difference between reported and perceived organisational structures.	++ weakness identification; -- process is not actor led, and therefore relies on the practitioner's interpretation not the users/actors; -- 'hard' objective systems thinking; ++ adopts constructionist approach to organisations	Complex unitary

System approach	**Summary**	**Strength**	**Ratings for Newcastle University study**	**SOSM type**
Strategic Options Development and Analysis (SODA)	Enables a group or individual to construct a graphical representation of a problematic situation and thus explore options and their ramifications with respect to a complex system of goals or objectives. In addition, the method aims to help groups arrive at a negotiated agreement about how to act to resolve the situation.	Group focused negotiated construct to explore options	++ actor led; group focused; ++ adopts constructionist approach to organisations; + inductive; - less focused on solution planning; + off the shelf software and accompanying process available	Single pluralist
Soft systems methodology (SSM)	An approach for tackling problematical, messy situations. An action-oriented process of inquiry into problematic situations in which users learn their way from finding out about the situation, to acting to improve it.	An organised process in which the situation is explored using a set of models of purposeful action.	++ predicated on differing world views, which may never be resolved; ++ looks for solutions that are feasible; -- appears to assume problems are objective	Complex pluralist

System approach	Summary	Strength	Ratings for Newcastle University study	SOSM type
Critical systems heuristics (CSH)	A framework for reflective professional practice, organised around the central tool of boundary critique. Boundary critique is presented as a participatory process of unfolding and questioning boundary judgements rather than as an expert-driven process of boundary setting.	Working constructively with tensions between opposing perspectives as they arise.	++ adopts constructionist approach to organisations; + addresses interventions and methodology; -- literature shows an expert-driven method	Simple coercive
Action Research	A collaborative embedded approach to research that aims both at acting and creating knowledge or theory about that action. It has broad relevance to practitioners and applicability to unstructured or integrative issues.	Outcome focused collaborative, flexible, adaptive.	++ pragmatic change focused; ++ interpretivist outlook; ++ constructionist approach to organisations; ++ predicated on differing world views, which may never be resolved; ++ key role of researcher as change agent; -- lack of clear methods or techniques	Complex pluralist

Table 11: Analysis of System Approaches using SOSM

5.4. SOSM Analysis

Which SOSM type best suited the problems, the framing, and the case? The problem was not simple: even at local level there were various differing physical, non-physical, procedural, policy, political and social issues mixed up with the operational, technical and environmental, immediately leading to adoption of the ‘complex’ situational tag.

One could argue that the “machine’ metaphor would apply - and it would have been very possible to adopt such an approach, but it had not yielded much success in the field, since the very activity of moving goods through cities was deeply political. The role of the state as city, nation, or federal structure always affected this very civic activity, in the form of policy, regulations, research funding, market interventions, congestion charging, vehicle EURO standards, etc. (Munuzuri *et al.*, 2005; Lindholm and Browne, 2013; Ville, Gonzalez-Feliu and Dablanc, 2013). Therefore, the apparently technical sat within a pluralist political system that affected it directly.

Commercial considerations drove freight transport - a wholly induced demand activity. No-one ordered freight transport to enjoy the sight of a truck entering their premises. Freight transport only happened when goods or services were demanded and physically delivered. Many city transport planners had failed to understand this, perceiving the activity through the lens of the public transport provider, or the private car demand manager. Goods flowed because customers demanded goods or services from a supplier, who used a logistics provider (or a visiting tradesperson) to deliver them (Balm *et al.*, 2016). Therefore, a series of pluralist commercial relationships worked to affect the flow of urban freight transport.

The University may have been a single legal entity, but at the time of the research it had over 144 schools, departments and institutes, in more than 80 buildings, and used more than 220 delivery locations. The traditions of ‘collegiality’ meant that most operated as semi-autonomous units, with circa 500 ‘expert’ buyers able to place orders. The ‘staff’ segment was subdivided, as follows:

‘Purchasing staff’, representing all staff and the University.

‘Expert buyers’ who processed the formal and informal purchasing onto the P2P system, either recording the ad hoc demand already expressed informally, or following the formal processes.

‘Shoppers’ who found and expressed demand for goods and services through formal requisitions, often on behalf of others.

‘Non-purchasing active’ staff who apparently were not part of the system, save for asking the first three segments to act on their behalf.

The Estates and Purchasing functions had agendas and policies set by the same Executive Board, yet they either placed different emphasis, or viewed the same policy through differing languages and worldviews. For example, the Purchasing department focused almost all its attention on the top 5% of suppliers, whereas the Estates department focused on the campus infrastructure and the perceived excessive level of vehicles intruding upon it. Neither department had ever incorporated freight planning into any capital planning or procurement activity. The Executive Board tended to place prestigious new building projects into the hands of academic managers unconnected with the two professional services teams who inherit them. The University itself then, was a pluralist body of people, policies, commercial practices, and infrastructure.

To assess the potential application of the SOSM ‘coercive’ type, an anecdotal and yet informed overview of the situation was necessary. The University was pluralist, with varying and devolved levels of autonomy. Local politics has been uniformly socialist, but with pluralism within the governing party. The city and wider state had very broad and stringent powers over freight transport - and the University also had clear and defined procedures and penalties for not following such, however variably enforced, the degree of enforcement for a clerical assistant being probably quite different to that of a lecturer. In the commercial arena, the University paid all invoices and held the power to place contracts with and pay suppliers. On the whole the boundary judgements between autonomy, compliance, commercial needs, and regulation, were as much based on power relationships as in free exchange of ideas or preferences.

This showed the weakness of the Jackson SOSM approach, suggesting any social construct is as much about power relationships and boundary judgements as any other considerations. Did the City’s ability to regulate traffic, the University’s to discipline variant purchasing behaviour, or Purchasing’s ultimate sanction being to place contracts or not, make this a ‘complex coercive’ situation? If so, there would be a problem, since SOSM postulates no systems approach to meet that need. Critics of this approach therefore had a point.

5.5. Chosen Approach – Action Research

The SOSM approach suggesting the case to be ‘complex pluralist’, with strong elements of potential or actual coercion, I chose AR as the preferred systems approach. Part of the reasoning was that AR incorporates the researcher as change agent in a process that is abductive, outcome oriented, pragmatist, and flexible, whilst capable of generating a contribution to theoretical knowledge. This suited the case of Newcastle University and would allow for 'revelatory research' (Yin, 2014): a unique case from which novel but local results would inform the wider field.

This decision had supporting voices in the literature review concepts: the call for <u>engagement with AR in purchasing and supply chain management</u>; the <u>need for co-operation and collaboration</u>; and the perception that there was <u>little or no theory development.</u> The participatory nature of AR would address the Actors/Who subsystem well. The outcome-oriented approach would support the development of a potential system, with an agnostic view on the How and Techniques subsystems, but a clear method to address the development of these subsystems within the revealed Territory.

The framing described in Chapter 3 was developed from the ideas of a socio-technical system, as developed by Eric Trist (1909-1993) in his work at the Tavistock Institute for Social Research in London. A socio-technical system was best defined as: " a set of rules – cognitive routines, shared beliefs, social norms and conventions, regulations, industry standards, protocols, contracts, laws and so forth – that fulfil a societal function (e.g. everyday mobility) and thereby condition the practices through which the technology, infrastructure, markets, cultural values, user practices, maintenance and repair, regulation and formal knowledge that make up socio-technical systems are reproduced" (Schwanen, 2015).

Trist noted that socio-technical studies needed to be carried out at three levels: primary work systems, whole organisation systems, and macrosocial systems. He also clearly stated that not all social systems were socio-technical: they needed to be "operative", not merely "regulative". Organisations that were primarily operative produced outputs based on material means and resources and the interaction between a nonhuman and human system(s) (Trist, 1981). The Newcastle University case was made up of multiple primary work systems: Purchasing, Estates, suppliers, logistics providers, departments etc.; whole organisation systems: the University; and macrosocial: managers, employees, city, regulations, customs, procedures and policies.

Trist defined socio-technical design as an "action research program (sic)", and this was taken up by Checkland, one of the leading lights of systems thinking, who ran a 25-year programme of AR, intertwined with SSM, at Lancaster University and posited a strong model for systems-based AR using the concepts of Framework (F), Methodology (M), and Area (A) of concern (Checkland and Holwell, 1998).

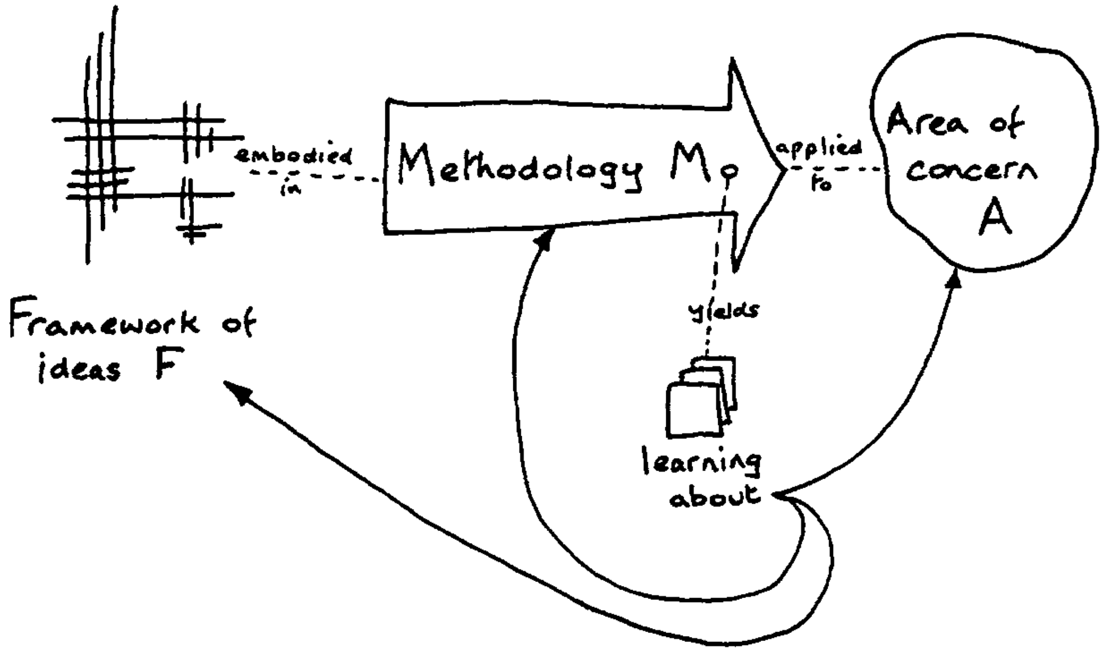

Figure 18: Checkland's Structure of Research (Checkland and Holwell, 1998)

Checkland's key posit was that, unlike many other forms of research, the AR process could iteratively adjust the F, M and A as the process developed - as illustrated in Figure 18 above, which can be seen as a variant or primitive version of the AR cycle. This inherent flexible and pragmatic approach fitted well with uncertainty and the need to adjust to changing revelations and fitted well with the key concept of learning in AR: organisational and individual, thesis and praxis. Näslund called explicitly for increased AR in logistics, to broaden the methodological and thus theoretical basis of the emergent field, to engage in self-critical use of multiple methodologies to explore alternative findings, and to develop the theory very absent from logistics research (2002).

This meant our research methods must also change - requiring more ethnographic research and also AR (Näslund, 2002). The close connection between logistics and systems thinking provided further logic for using AR in logistics - and therefore in this work. AR was emerging in the literature (see 3.7.3 above) as an approach being proposed for logistics and associated research; it would be novel to adopt and test it here. As Näslund said: "Logistics problems are often ill-structured, even messy, real-world problems. Modern logistics is based on holistic and system thinking and uses multi-disciplinary and cross-functional approaches. Thus action research case studies are especially suited for an applied field such as logistics since they strive to advance both science and practice" (Näslund, 2002). Of particular note for this work was the growing evidence of AR within organisations, where practising managers undertook AR projects in and on their own organisations (Bartunek and Louis, 1996; Coghlan and Brannick, 2014). This supported the role of this researcher as both change agent and researcher.

There had been a strong tradition in urban freight research across Europe, in funded projects and others, to collect and discuss the multi-stakeholder nature of urban freight, and the concomitant need for co-operation and collaboration (Allen, Thorne and Browne, 2007; NICHES_Consortium, 2007; BESTUFS Consortium, 2008; SUGAR, 2011; BESTFACT, 2015). There had been a growing interest in the successful, if limited, use of Freight Quality Partnerships to manage freight across Europe (Lindholm and Browne, 2013). The role of people in urban freight and potential city logistics solutions had often been reported in policy recommendations to the European Commission and elsewhere. As detailed in section 2.9 there had been little theoretical or methodological novelty in this empirical observation.

CSH, and consequently SOSM, placed great emphasis on the power relationships in boundary judgements, with SOSM stating that there was no complex pluralist approach for systems thinking, only complex coercive systems. At this stage in the research the degree to which the power of procurement, as opposed to that of local government, traffic regulation, commercial relationships between shipper and carrier, or between internal departments such as Estates, Finance and Purchasing, was not clear; in choosing methodology therefore, all possibilities were still open. The clear problem with methodology was that, whilst SOSM recognised the existence of complex pluralist systems, it recognised no system approach that could be deployed. The degree to which such a focus on the boundary judgements became the core focus of the research, when core pragmatic problems needed to be addressed and solved with operational activities, made it weaker as a core method.

AR in all its uses had a deeply participative and self-critical approach, always questioning not just the process, but who decided the process and why, and who would benefit from it. Whether the commonly stated AR goal to subvert power structures and enhance participatory democracy was appropriate in this case was a valid question to answer - and indeed forms RQ3: "*How effective were participatory research approaches in facilitating this improvement?*" To that end AR could be used to incorporate a view on power relationships to answer *RQ2: "To what extent can sustainable HEI logistics only be achieved through sustainable procurement practices?",* whilst addressing other key concepts and all subsystems of the adopted socio-technical system.

5.6. Action Research

"Action researchers take a close look and act to make things better than they already are. Taking a closer look is action in and of itself and that research, that knowledge creation – any action taken based on that research – has the potential to transform the work that we do.." (Coghlan and Brannick, 2014).

"... action research is a participatory process concerned with developing practical knowing in the pursuit of worthwhile human purposes. It seeks to bring together action and reflection, theory and practice, in participation with others, in the pursuit of practical solutions to issues of pressing concern to people, and more generally the flourishing of individual persons and their communities." (Reason and Bradbury, 2008, p. 4).

5.6.1. Characteristics of AR

AR is defined as having broad characteristics which are research *in* action, rather than research *about* action: participative and democratic with an embedded researcher as change agent; concurrent with action; a sequence of events and an approach to problem solving. AR is particular, situational and out of praxis. In AR, the data are contextually embedded and interpreted. In positivist science, findings are validated by logic, measurement and the consistency achieved by the verification of prediction and control. In AR, the basis for validation is the conscious and deliberate enactment of the AR cycle (Coughlan and Coghlan, 2002; Zuber-Skerritt and Perry, 2002; Coghlan and Brannick, 2014).

First, AR works consciously and deliberately within a given context, and for a specific purpose, through a cyclical four-step process: diagnosing, planning, acting, and evaluating the action (leading to further diagnosis and so on).

Secondly, AR is participative. In contrast to traditional research, where members of the system are objects of the study, members of the AR system being studied participate actively in the cyclical process outlined above.

"Sharing the power of knowledge production with the researched subverts the normal practice of knowledge and policy development as being the primary domain of researchers and policy-makers. Action Researchers work on the epistemological assumption that the purpose of academic re-search and discourse is not just to describe, understand and explain the world, but also to change it. The issue is not so much the form of the knowledge produced or the methodology employed to gather data / evidence, but who decides the research agenda in the first place, and who benefits directly from it" (Coghlan and Brannick, 2014).

Thirdly, AR is research concurrent with action. The goal is to make that action more effective, while simultaneously building up a body of scientific knowledge.

In addition, AR is both a sequence of events and an approach to problem solving. As an approach to problem solving, it is an application of the scientific method of fact finding and experimentation, to practical problems requiring action solutions and involving the collaboration and co-operation of the action researchers and members of the organisational system.

Furthermore, the desired outcomes of the AR approach are solutions to the immediate problems, but also important learning from outcomes - both intended and unintended - and therefore a contribution to scientific knowledge and theory. This fitted well with a pragmatist epistemological approach to knowledge.

The positivist scientist's relationship to the setting is one of neutrality and detachment, while the action researcher is immersed in the setting. In short, the contrast of roles is between that of detached observer in positivist science and of an actor and agent of change in AR. This is summarised in Table 12 below.

	Aim of research	Type of knowledge acquired	Nature of data	Validation	Researcher's role	Researcher's relationship to setting
Positivist science	Universal knowledge Theory building and testing	Universal Covering law	Context free	Logic, measurement, Consistency of prediction and control	Observer	Detached neutral
Action research	Knowledge in action Theory building and testing in action	Particular, Situational, Praxis	Contextually embedded	Experiential	Actor or Agent of change	Immersed

Table 12: Comparison of positivist science and action research (Coughlan and Coghlan, 2002)

5.7. The Action Research Process

5.7.1. Frame, Scope, Access & Contract

The opening steps of AR were to *frame* the issue. This may well be highly provisional, and the nature of the actual problems or actors may be messy, but it could be as top level as "How to improve the sustainability of logistics on the Coherent Campus at Newcastle University?" Once the framing started then *scoping* needed to begin and this work began with 'local, in practice to the city campus' and 'internationally, in the context of EU policy'. It was then necessary to gain *access*; this was done by directly contacting the Estates and Purchasing departments, with whom I had a shared language and culture from my previous career, and by negotiating all the way to the Executive Board for access. By doing so I secured the final step: a *contract* and a role as the change agent to carry out the work. At this stage, given the nature of a University, the contract explicitly recognised the work as research in action, to meet the practical desire to reduce freight vehicles on site and, simultaneously, to contribute to wider EU policy and scientific knowledge.

5.7.2. The Action Research Cycle

Like many late 20th century processes, AR was built around an iterative cycle[22], the core AR cycle being composed of Constructing-Planning-Action-Evaluation, within the overall Context & Purpose.

5.7.3. Pre-step: Context and Purpose

The pre-step involves naming the general objective and questioning the rationale for the action and the research both. AR differs from consultancy in that it has two explicitly parallel strands: solving practical problems, and contributing to theoretical knowledge. When used for a Masters or PhD qualification, the pre-step always has two purposes: one for the research as action, and one for the research as thesis (Zuber-Skerritt and Perry, 2002; Coughlan and Coghlan, 2016).

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[22] *Such as the very similar Deming quality cycle Plan-Do-Study-Act which Moen and Norman convincingly map directly back, through Shewart and Lewis, to the pragmatist leading lights of Dewey and Peirce* (Moen and Norman, 2010).

AR begins with asking what the rationale for the action (why) is and in what context (where and when). The rationale and context have been clearly stated in Chapter 1: to improve the sustainability of the logistics on the Newcastle University campus and contribute to the development of policy and practice at a European Union level. In this pre-step, detailed in Chapter 1, a clear understanding of the project at a broad level was made. Using the *'systems approach' socio-technical framing* of Chapter 3, a society of actors (who) was envisaged, possibly including: Estates; Purchasing; University Executive; researchers; city planners; and EU research partners. A range of potential methods and techniques (with what) were available, both soft techniques and hard technical options.

The pre-step should ask if and how AR is an appropriate methodology; this has been fully addressed in this current chapter, recognising both the strengths and weaknesses of the approach and placing it in the context of a constructionist abductive pragmatist research philosophy, as detailed in Chapter 2.

5.7.4. Constructing

Constructing is the provisional naming of the issues and a working theme - in this case improving the sustainability of logistics - on the basis of which action will be planned and taken. It involves articulating the theoretical foundation of the action and stating it clearly. This is a collaborative process and, given that the process is iterative, as the work proceeded these constructs would evolve and change. Data are seen as core to constructing: these can be hard data, such as traffic surveys or procurement archives, or soft data, such as formal or informal interviews, workshops, or meetings. In many ways, the first constructing process is concurrent to, or at the same time as, the pre-step stage. In this work, this stage was a combination of the abductive moment of realisation, the meetings with Estates and Purchasing, the alignment of the work within the context of ongoing EU funded research work led by me, and then the first participative workshop.

5.7.5. Planning Action

In the planning stage(s) the actors address key questions, such as 'What needs to change?'; 'In which parts of the organisation?'; 'What types of change are required?'; 'Whose support is needed?'; How is their commitment to be built and their resistance managed?' A key feature of AR was that it saw resistance as potentially an important part of the democratic process and indeed Chapter 7 will detail how resistance identified both barriers and flaws in the original planning of this work. The planning stages varied, depending on the actors involved and the methods and techniques deployed.

5.7.6. Taking Action

The organisation acts; this may be incremental change, towards another iteration of the cycle, or it may be the substantive action to which the work was directed. This stage requires the active engagement of the team and the researcher, and may be confusing, changeable or require flexible adaptation. Large volumes of hard and soft data may be generated at this stage and, since it may be confusing to assess the relative merits of data, record keeping of all kinds is key.

5.7.7. Evaluating Action

The evaluation stage asks a range of questions. Given that this is an iterative process, it is an ongoing system of evaluation, rather than a single act at project end. Key questions address whether the construction in the first phase was correct, whether the actions taken were effective and, as part of meta learning (see below), were the research philosophy, framework and methods appropriate? AR had a clearly stated set of standards for quality and rigour detailed in section 5.7.9 below. These added value to the research given that urban freight research had been notoriously lax in ex-ante and ex-post evaluation (Leonardi, Browne and Allen, 2012) and indeed many firms did not engage in post-project reviews at all (Koners and Goffin, 2007).

5.7.8. Meta learning

Meta learning, in the core AR project, is part of the iterative cycle, each cycle feeding evaluation into the diagnosis step of the next cycle, as well as the parallel contribution to theoretical knowledge.

Meta learning is grounded in reflection - often an end process in much research - but an integral part of AR, based on the Mezirow (1991) three forms of reflection:

- Content:
    - Core: thinking about issues and what is happening.
    - Thesis: challenge the contribution to knowledge by the work.
- Process:
    - Core: think about strategies, procedures, and how things are being done.

    - Thesis: think about the strategies, data generation processes and how one coped with difficulties.
- Premise:
    - Core: critiquing underlying assumptions and perspectives within the organisation
    - Thesis: critique underlying assumptions re the role of action in research to generate actionable knowledge.

As an action researcher engaged in an academic programme leading to a doctorate, it has been important to understand and clarify the difference between core action research and thesis action research: that is, between improving the sustainability of logistics on the campus (praxis) and independent action research in reflecting upon and reporting the work and preparing the thesis (contribution to knowledge) (Zuber-Skerritt and Perry, 2002). Meta learning is a key part of AR, both in the action and in contribution to knowledge. To that end, the reflection upon the work had to be fully evidenced, which I have done: at the end of each of the key chapters on action (7,8,9), where the meta learning focused primarily on content and process, and also in Chapter 11, which is dedicated to this process and all three forms of reflection. The meta-learning for the thesis was based on the reflection of the action and the degree to which the content or process had import to the research questions - and specifically to the socio-technical subsystems of the framing in Chapter 3.

This constituted both the pre-step and the meta-step in this thesis and, at each iteration, I applied the content, process and premise reflections.

The full but generic AR cycle for this work is portrayed graphically as Figure 19 below.

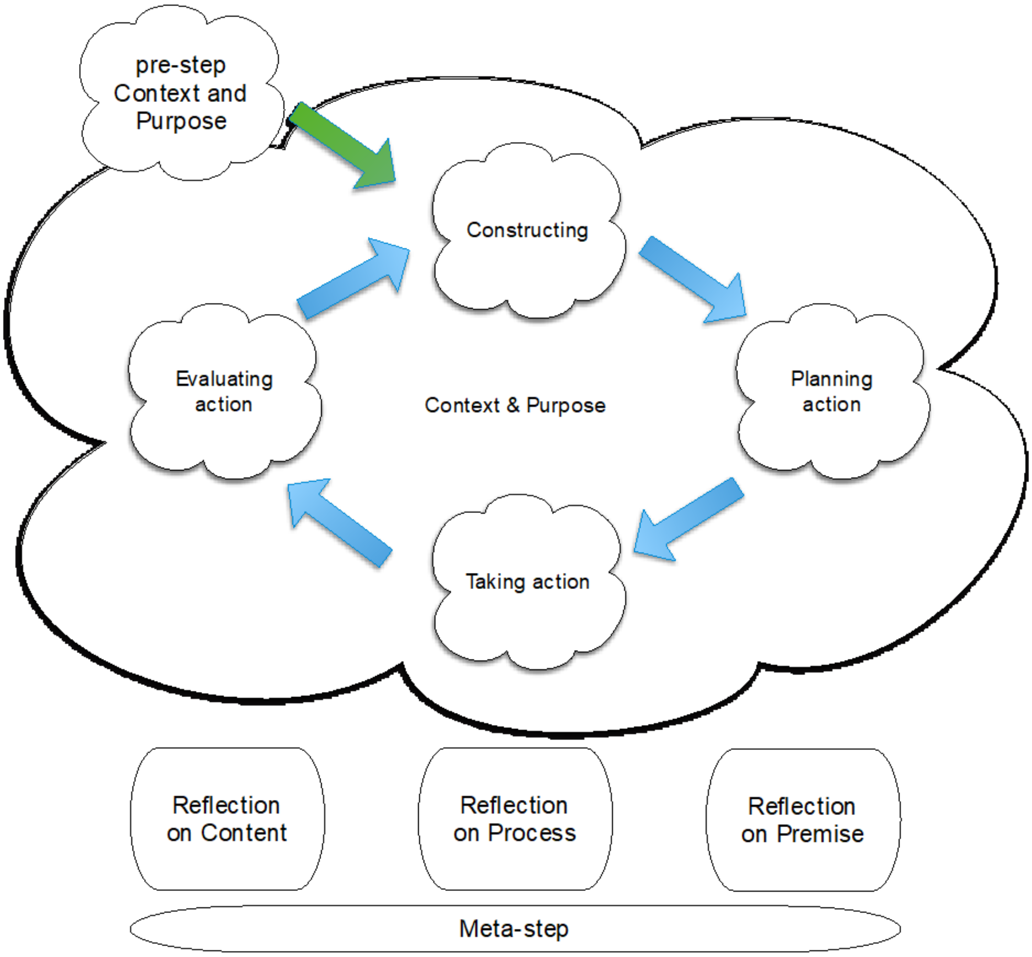

Figure 19: The Action Research Cycle inspired by (Coghlan and Brannick, 2014)

5.7.9. Quality and rigour in AR

AR was an approach to research that aimed both at acting and at creating knowledge or theory about that action. It had broad relevance to practitioners and applicability to unstructured or integrative issues. It could contribute to theory. "For many types of research question, detached observation or archival study is indeed appropriate. However, the range of these questions does not define the range of research issues relevant to operation management (Coughlan and Coghlan, 2002)". The central idea here was that AR used a scientific approach to study the resolution of important social or organisational issues, together with those who directly experienced them. Whilst case study research (Corbin and Strauss, 1990; Yin, 2014) and grounded theory approaches shared many of the features of AR, they adopted a stance of the researcher as objective, and disengaged from the activity researched, whereas engagement with practical action, and verification of knowledge through utility, fitted with the pragmatist approach most suited to this research and researcher.

However, AR - like much situational case research – could not be evaluated on the basis of verifiability, simple replicability, or adherence to a predetermined series of methodological steps. AR researchers, and the associated peer reviewed journals, had therefore developed the following set of key quality criteria, developed to test such research against the agreed processes, aims, and twin objectives of action and contribution to knowledge (Bradbury-Huang, 2010; Coghlan and Brannick, 2014, pp. 15–16):

- Is the AR explicit in developing a praxis of relational participation? In other words, how well does the AR reflect the co-operation between the action researcher and the members of the organisation?
- Is AR guided by a reflexive concern for practical outcomes? Is the action project governed by constant and iterative reflection as part of the process of organisational change or improvement?
- Does AR include a plurality of knowing? AR is inclusive of practical, propositional and experiential knowing and so as a methodology is appropriate to furthering knowledge on different levels.
- Does AR generate significant insights in content and process having meaning and relevance beyond an immediate context in support of persons, communities, and the wider ecology?
- Does the AR result in new and enduring infrastructures? In other words, does sustainable change come out of the project?

The aim was to enact and record a process recoverable by anyone wishing to scrutinise the research. Any theory generated would be situation specific, emergent, and incremental. It would be situation specific so therefore not universal, emergent from the synthesis of the process and the data thus generated - all this meaning that theory generation would be incremental, proceeding from the particular to the general (Coughlan and Coghlan, 2016). It is indeed quite probable that such theory may then be tested more universally, using quite different research approaches, but that was not the role of AR. ‘Generalizability’ was seen by Bradbury-Huang (2010) as not the primary role or strength of AR; rather, it was the growing accumulation of local knowledge that might be later exploited using different paradigms.

Herr and Anderson (2014, p. 61) noted that “Quality, goodness, validity, trustworthiness, credibility and workability have all been suggested as terms to describe criteria for good action research.” Their chosen term was ‘validity’, so to resonate with positivist researchers. They posited that “most academic researchers are part of a positivistic tradition inherited from the natural and physical sciences, they consider the notion of validity to be of utmost importance in all research” (Herr and Anderson, 2014, p. 62). They then suggested five validity criteria: outcome, process, democratic, catalytic and dialogic. For these criteria they suggest the goals of:

- The generation of new knowledge;
- The achievement of action-oriented outcomes;
- The education of both researcher and participants;
- Results that are relevant to the local setting; and
- A sound and appropriate research methodology.

(Herr and Anderson, 2014, p. 67).

This view of good AR fitted well with the needs of the pragmatic operations research carried out for the EU and the University, e.g. the achievement of action-oriented outcomes; education of both researcher and participants; and results relevant to the local setting. For the thesis and the EU, the generation of new knowledge, the education of the researcher, and the development of a sound and appropriate methodology were highly appropriate.

An approach consistent with the broader one of Herr & Anderson, was that developed for operations management by Coghlan and Shani (2014, pp. 529–530). This adopted nine criteria for quality, with a key judgement made on the essence of the work, and then its rigour, reflective quality and relevance. Each criterion and judgement can be described qualitatively in a matrix, as shown in Table 13 below. Bradbury-Huang (2008; 2010) stated that: “If there is a rule in action research on the creation of quality, it is to be transparent about the choice-points we make and the limitations that come as a result of these choices.” Following this advice, these considerations and questions led me to adopt the Coghlan and Shani checklist for quality and rigour in AR, forming section 11.8 below

	The essence	**Rigour**	**Reflective**	**Relevance**
Purpose and rationale for the action and inquiry	Case for why action and research are necessary or desirable? What contribution is intended?	Does it provide a clear rationale for inquiry and action? To what extent the focus addresses a gap in the scientific literature? Does it display the data to justify the purpose and rationale for the study?	Is it linked to past research and scientific literature? Is it linked to contemporary business and organizational issues?	Does it describe why action is necessary or desirable? (To achieve what for whom)
Context	Understanding the business, organizational and academic context	Is the contextual data captured in a scientific, systematic and holistic way?	Does it build on past and present scientific research that is central to the focus of the study? Does it build on past and present organizational experience that is central to the issue studied?	To what extent relevant analytical frameworks applied to understand the context?

	The essence	Rigour	Reflective	Relevance
Methodology and method of inquiry	The role of the action researcher: • Ethical issues • Contracting • Establish learning mechanisms	To what extent is the process of contracting, selection of methods of action and inquiry collaborative? To what extent are the methods and inquiry process described with sufficient details? To what extent are alternative LMs tapestries explored? Are appropriate modes of AR selected and justified?	To what extent are the action and research cycles described? To what extent is the LMs tapestry involved in the development of the methodology and inquiry method?	To what extent are the methods of action and inquiry driven by the organization's needs and scholarly criteria?

	The essence	Rigour	Reflective	Relevance
Design	Data collection and generation Cycles of action research Building relationships	To what extent is the project designed and implemented to ensure rigor? To what extent the data is collaboratively and rigorously generated, collected and explored?	To what extent is the project designed and implemented collaboratively? To what extent attention is paid to the development of the quality of the relationship?	To what extent is the research design directed to meet the organization's needs, as well as those of academic rigor?
Narrative and outcomes	Describe the story and outcomes (intended and unintended)	How well is the story told, with an appropriate level of detail? To what extent are facts and values distinguished?	To what extent does the story demonstrate collaborative inquiry and action in the present tense?	To what extent does it capture what happened? What were the outcomes, both intended and unintended?

	The essence	Rigour	Reflective	Relevance
Reflection on the story and outcomes	Analyse story and reflection Make judgments on the process and outcomes	To what extent do the narrative and description of outcomes meet the standards/criteria of research?	To what extent is the story reflected on collaboratively? To what extent is shared meaning created? To what extent did dialogue about meaning and possible actions among different organisational groups/units/ communities of practice take place?	To what extent are story and outcomes' meaning focused on the organization's needs? To what extent are story and outcomes' meaning focused on addressing the scientific needs?

	The essence	Rigour	Reflective	Relevance
Discussion Extrapolation to a broader context Articulation of actionable knowledge	Link story to theory (existing and emerging theory) Discuss the story and outcomes Discuss the action research process, quality of relationships, and sustainability of the outcomes Articulate contribution to both theory and practice	To what extent does the entire account (purpose/rationale, methodology and methods, design, narrative and outcomes, reflection, the quality of the action research process, the quality of relationships) contribute to practical knowing?	To what extent does the entire account (purpose/rationale, methodology and methods, design, narrative, outcomes, sustainability of the outcomes and, reflection) fit the quality of the action research process and the quality of relationships?	To what extent does the entire account (purpose/rationale, methodology and methods, design, narrative and outcomes, reflection) contribute to sustainable outcomes for the organization and practical knowing for scholars? To what extent does the AR approach demonstrate returns that make the process and effort worthwhile?

Table 13: Action research as rigorous, reflective and relevant. Source: adapted from (Coghlan and Shani, 2014, pp. 529–530)

5.7.10. Ethical Considerations

The general principles of ethical AR were widely stated to be grounded in authentic relationships between researcher and those collaborators with whom the research was carried out. Hilsen suggested three pivots: human interdependency, co-generation of knowledge, and fairer power relations (2006). Herr and Anderson stated this to be an "ethical demand" to take responsibility for how our acts and practices as researchers affect the lives of our collaborators (2014, p. 153). AR was contingent and iterative, so any ethical processes developed for the work needed to be both ethically sound and approved by the relevant bodies (University and EU in this case) but also be integrated into the AR cycle to inform decision making as the project proceeded, often in processes or actions unclear at the beginning (Coghlan and Brannick, 2014, pp. 148–149; Herr and Anderson, 2014, pp. 145–146). The process of research itself has ethical issues, but those associated with the publication or dissemination of the research outcomes may be also as great - or greater. These findings may include commercially confidential, personally confidential, or potentially embarrassing information related to organisations, members, stakeholders, or the researcher themselves (Holian and Coghlan, 2013; Coghlan and Brannick, 2014, p. 149).

The University and the EU had ethical review procedures in place which were followed when the research proposal was written and submitted. These reviews were focused largely on medical research, or research likely to cause health risks or environmental damage. They did raise a series of questions about the interviewing of individuals, but were weak with regard to some of the issues with regard to trust and the confidentiality of personal or corporate data. Neither review considered the potential of research to change and create new ethical challenges during execution.

The data created in the project would have been covered by the provisions of the UK Data Protection Act 1998 (Her Majesty's Government, 1998), which enacted the EU Data Protection Directive of 1995 (European Union, 1995) into UK law. Since the original operational work was completed, these laws had been repealed and replaced with the UK Data Protection Act 2018 and the EU General Data Protection Regulation 2016. This changing legislative context meant that the collection and handling of data during the project, and those appropriate to publication, were different, and consideration had to be given as to whether data collected and utilised under the first laws were still valid for later use.

The AR pre-step and meta-step allowed for the ethical issues to be reconsidered at each cycle; the process of constructing generated new approaches and new opportunities emerged. Some were potentially foreseeable - there was a provisional budget for traffic surveys at project start, so a standpoint was taken on data collection and use (see 6.1.1 below). Others, such as the option to demonstrate an electric vehicle in Newcastle upon Tyne, were provisional and ethical issues with regard to operation or data were the same. Each was considered in the pre-step and thereby reported in each relevant chapter.

5.7.11. Potential Weaknesses or Gaps in the Action Research Approach

There are few well-defined methods and techniques in AR beyond the action cycle, causing Coghlan to explicitly state that one can and should adopt methods, techniques and other frameworks (Coghlan and Brannick, 2014, p. 111). I noted that Checkland had developed SSM inside an AR programme and that the concept of meta learning was key to Senge's Fifth Discipline (Senge, 1993), alongside SD. Indeed, the plurality of practice in AR suggested it was best deployed as the top-level framework - with appropriate methods and techniques then deployed inside it - even if in some other research work these may be viewed as self-contained. This was developed further later on, when mixed-method research was evaluated.

There was a question from the early stages of the research about the degree to which this process could be democratic, since in some ways a commercial purchasing contract, or a contract of employment, was negotiated yet also coercive once in place. AR had a strong tradition of subversion, of "sharing the power of knowledge production with the researched"; of querying "not so much the form of the knowledge produced or the methodology employed to gather data / evidence, but who decides the research agenda in the first place, and who benefits directly from it" (Coghlan and Brannick, 2014). AR challenged the customary practice of knowledge and policy creation as being the primary responsibility of researchers and policymakers. Since action researchers worked on the pragmatist assumption that the purpose of academic research and discourse was not just to describe, understand and explain the world, but also to change it, would this be acceptable in an organisation with defined roles and procedures?

The context in the city of Newcastle seemed appropriate for this approach. The region had already embraced innovative thinking, in developing a successful Freight Partnership to address such issues. The University was undergoing substantial infrastructure development and had identified a clear need to address the associated dis-benefits. Lastly, Universities have a long tradition of autonomy and 'collegiality', making the question "is AR appropriate" in and of itself an excellent path to enquiry.

A final consideration was that as an insider action researcher there were potential advantages and disadvantages that comes from preunderstanding, Coghlan (2019) has drawn attention to this "as a key challenge for insiders, that is, to build on the closeness they have to the setting and to achieve a critical questioning of what it is they don't know or are blind to". The wider research group, with whom top level strategic discussions happened through the process was intended to mitigate this.

This weakness/mitigation process is summarised in Table 14 below.

Potential weakness of AR	**Mitigation Strategy**
Lack of formal processes	Adoption of a mixed methods approach inside the AR framework
Fit of participative democracy inside a situation where some processes may be coercive	Recognition of potential tension between approach and revealed systems from and foremost in reflection process
Preunderstanding blindness	External research group casting a critical eye

Table 14: Mitigation Strategies for Action Research

5.8. Mixed Methods Research

If AR was to be the framework, needing methods and techniques to be deployed within, how was this to be achieved? The deployment of methods and techniques, as a plurality inside another, called for a review of research methods. Here, the research choices were, according to Saunders et al. (2012):

- Mono methods
- Multiple methods:
    - Multi-method:
        - Multi-method quantitative studies

        - Multi-method qualitative studies
    - Mixed-methods:
        - Mixed-method research
        - Mixed-model research.

5.8.1. Choice of Mixed Method Research

I have clearly stated the basis for adopting mixed-method research inside AR and I saw complementarity, development, and expansion as the primary justifications for this choice. The iterative nature of the AR cycle would be used to drive hard and soft data between methods, with the intent that integration be not only a research goal, but key to the success of the action.

When reviewing both the access and the obligations that my contracts (see Chapter 1 above) with the University (internal and informal) and the EU (broader research and development research funding) had set me, it was clear that a multiple method approach suited the wide range of data that would be available:

Procedural documents from the University policies;	A need to quantitatively assess the environmental impact of change;
Transactional data from the SAP system;	Access to a body of interested stakeholders;
Access to funds to carry out traffic surveys.	A requirement to assess stakeholder methods for change.

Table 15: Range of data available

These multiple sources and needs were both quantitative and qualitative in nature, thereby ruling out multi-method research in one or the other. Since it was likely that only modelling approaches would suit, that left mixed-method research as the most viable approach.

The choice adopted therefore was mixed methods research – explicitly: methodological pluralism - mixing quantitative and qualitative research methods in an integrated fashion. The use of multiple methods allowed a developmental complementarity, as the quantitative informed the qualitative work and the qualitative work developed plans and hypotheses to test against further quantitative data. It allowed for a complementary elaboration and clarification of results from one method to another. For example, the statement “I have quantitatively assessed a high level of freight” led to the qualitative question “can your people tell us if, or why, this is a problem?” I had hoped to find paradox and contradiction in initiating new perspectives from one method to the other, as questions or results were explored in each.

This approach was based on the five justifications for combining quantitative and qualitative research, developed first by Greene et al (1989, p. 259)[23]:

- Triangulation
    - seeks convergence, corroboration, correspondence of results from the different methods. To increase the validity of constructs and inquiry results by counteracting or maximizing the heterogeneity of irrelevant sources of variance attributable especially to inherent method bias but also to inquirer bias, bias of substantive theory, biases of inquiry context.
- Complementarity
    - seeks elaboration, enhancement, illustration, clarification of the results from one method with the results from the other method. To increase the interpretability, meaningfulness, and validity of constructs and inquiry results by both capitalizing on inherent method strengths and counteracting inherent biases in methods and other sources.
- Development
    - seeks to use the results from one method to help develop or inform the other method, where development is broadly construed to include sampling and implementation, as well as measurement decisions. To increase the validity of constructs and inquiry results by capitalizing on inherent method strengths.
- Initiation
    - seeks the discovery of paradox and contradiction, new perspectives of frameworks, there casting of questions or results from one method with questions or results from the other method. To increase the breadth and depth of inquiry results and interpretations by analysing from the different perspectives of different methods and paradigms.

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[23] *Bryman (2012) had a longer list developed from this in his textbook, but the Greene justifications had a concise approach that resonated with and had better 'fit' in this piece of work.*

- Expansion
    - seeks to extend the breadth and range of inquiry by using different methods for different inquiry components. To increase the scope of inquiry by selecting the methods most appropriate for multiple inquiry components.

Of these five justifications, Triangulation was the one often used for mixed-method research, notwithstanding some confusion over terminology. Three positions could be identified: Triangulation as a subset of mixed methods; mixed methods as a subset of Triangulation; and mixed methods and Triangulation as interchangeable synonyms. Bergman convincingly argued it was least confusing to use Triangulation as a type of mixed-methods research that aimed at convergence (Bergman, 2011). It was also of value where divergence was found (Kern, 2016); however this needs to be checked closely for sampling errors. This definition conformed to the Greene et al approach and Triangulation aiming at convergence was adopted for this research.

This mixed-methods research in the field of logistics and supply chain management was planned to answer the many calls in the literature for the "generation of deep and rich insights into phenomena associated with the adoption of SCM practices through the use of research designs that incorporate strong qualitative components" (Sweeney, Grant and Mangan, 2015). It fitted well with the trend to methods and approaches that provided a middle ground between the contrasting positivist and phenomenological paradigms and perspectives. Quantitative and qualitative methods, when integrated fully, "increasingly provide multidimensional insights into many management research problems" (Mangan, Lalwani and Gardner, 2004).

The adoption of a systems approach for framing (section 3.2) with the foci of why, who, with what, where, when and how, was best met by the use of multiple sources and types of data (see Table 15 above) and then synthesised with Triangulation to achieve convergence to answer the four research questions. RQ1 is a broad question, but focused tightly on a locality; it will therefore be best answered by using the heterogenous local data. RQ2 is a broader, more generalised question, looking to draw out lessons for the wider HEI grouping beyond the local, requiring an attempt to develop validity through convergence for re-use elsewhere. RQ3 explicitly asks for an evaluation of participatory approaches, as noted as a key concept in the framing of

Actors [Who] and the important concepts: multi-stakeholder; need for co-operation and collaboration; and freight quality partnerships (section 3.3). Finally, RQ4 asks what novel approaches for policy and practice could be developed from the work, both of which in praxis are a synthesis of qualitative and quantitative data alongside the role of commercial and political considerations.

5.8.2. Criticisms of Mixed-Method Research

Criticisms of mixed-method research fell into three main arguments. The first was that research methods have an embedded epistemological and ontological position, making it impossible to mix incompatible underlying philosophies. I adopted the 'technical' and 'pragmatic' view that research methods are indeed highly interchangeable and can be 'pressed into service' for many philosophical positions. The second major criticism was that research methods fell into one paradigm or another. Given the literature of urban freight logistics, the considered reviews of experts in urban freight transport reveal no clear discipline, no nascent or absent theory, and no obvious paradigm(s), making the criticism irrelevant to this work. It did, however, raise a potential criticism that this work might become naïve empiricism, or empirical research conducted with no reference to the theory of the domain. This was addressed by placing the work into the socio-technical framing developed from the literature in Chapter 3 above.

Thirdly, Bryman noted, in his field work with researchers, a problem with genuinely integrating quantitative and qualitative findings. He suggested that, in the eyes of mixed-method researchers, significant difficulty was to be found in merging analyses of quantitative and qualitative data to provide an integrated analysis. He suggested that a clear approach to counter this was to not lose sight of the rationale for conducting mixed-method research in the first place (Bryman, 2007):

> *"So, you know, the standard PhD thesis says in Chapter 5, I'll do the interviews in Chapter 6, I'll report the survey. And as a supervisor I'm always saying but how do you put them together? And there's a—there's a silence if people aren't sure how to do that integration."*
> *Respondent quoted by Bryman* (Bryman, 2007)

5.9. Context and Observations: Empirical Surveys and Archival Analysis

To support the constructing phase of the AR cycle, data were required. Allen, Browne and Cherrett (2012) had identified 12 different types of urban freight transport survey techniques, from an extensive review of 162 studies over 18 countries and 50 years Given the need for hard data to aid in this stage, these 12 were all given due consideration, as summarised in Table 16 below.

Survey technique	**Description** **(from Allen et. al., duplicates intentional)**	**"Fit' with Newcastle University Study**
Establishment survey	Used to collect data about total goods vehicle trips to/from surveyed establishments and variation by time, day and month. Can also be used to capture data about type of goods delivered/collected. Allows collection of information about the delivery/collection process but some respondents may not be very sure about certain issues including: vehicle types, time taken to load/unload, where vehicles stop, method of goods movement from the vehicle, and origin of vehicle/goods trips.	++ walk the site; talk to building managers and security team. -- time consuming method of data collection for such a large number of autonomous departments and over 220 delivery locations
Vehicle observation survey	Involves surveyor/s being positioned on-street at establishments to record data about total goods vehicle trips to/from establishments by time of day (and variation by day of week). Can also capture information about vehicle type, time taken for delivery/collection/servicing, methods of moving goods from vehicle, etc.). Similar to establishment survey in terms of data collected.	++ traditional survey for transport planners; high level of recognition; budget available for longitudinal survey.
Parking survey	Similar to a vehicle observation survey but only used to capture information about vehicle loading/unloading/parking activity (e.g. vehicle type, time taken, illegal activity) rather than total delivery/collection trips at establishments and method of moving goods from the vehicle. Can also be used to study the use of space allocated for goods/service vehicles by other road users.	++ walk the site; photograph parking violations; talk to security
Driver survey	Similar to a vehicle observation survey but only used to capture information about vehicle loading/unloading/parking activity	+ walk the site; talk to drivers; understand truck to

Survey technique	**Description** **(from Allen et. al., duplicates intentional)**	**"Fit' with Newcastle University Study**
	(e.g. vehicle type, time taken, illegal activity) rather than total delivery/collection trips at establishments and method of moving goods from the vehicle. Can also be used to study the use of space allocated for goods/service vehicles by other road users.	desk delivery issues. - ad hoc
Commodity flow survey	Similar to an establishment survey, but used to collect detailed information about type and quantity of goods flowing to/from particular establishments, rather than focusing on goods vehicle trips (although basic information about the transport mode is often collected).	++ high level of access to SAP archives of procurement activity
Roadside interview survey	Normally involves working with the police or suitable law enforcement agency to pull over vehicles and interview drivers at the roadside about their current trip. Typically used to capture data about origin/destination, trip purpose, goods carried, and vehicle type. Usually a relatively brief survey so as not to disrupt drivers and avoid causing unnecessary traffic congestion.	- certain degree of coercion required and potential to disrupt traffic flows
Vehicle trip diaries	Used to collect detailed information about the activities of a single vehicle (usually over a single day/ few days). Involves driver or operator recording trip and activity data. Can provide data about exact locations served, route, arrival and departure times, delivery/collection/servicing times, type of goods/service, etc.	-- very limited scope from an inbound demand side perspective
GPS survey	GPS equipment can provide data on vehicle location at frequent intervals (thereby providing route information), as well as vehicle speed. Can also be used to record loading/unloading/parking stops. Therefore, similar to vehicle trip diaries.	+ potentially powerful, but again limited scope when addressing the large fleet attending the campus
Freight operator survey	Provides opportunity to collect wide ranging data about freight operator goods vehicle activity patters in the urban area. Data can be obtained on the entire vehicle fleet rather than single vehicle/ round (as with vehicle trip diary, the two types of survey can be used in conjunction). Also provides opportunity to obtain qualitative information	- the sheer number of fleet operators seen on site militates against such a large undertaking.

Survey technique	Description (from Allen et. al., duplicates intentional)	"Fit' with Newcastle University Study
	about problems encountered by the company in urban freight operations. Can be used to collect data about loading/unloading activity and movement of goods from the vehicle to the establishment but this is usually best gathered via a driver survey or vehicle observation survey.	
Supplier survey	Used to gather information from suppliers about the goods they dispatch to urban establishments and the vehicle activity that supports this goods flow. Not commonly used, but sometimes undertaken in conjunction with establishment surveys (establishments first identify their key suppliers). Can provide more detailed information about vehicle activity if suppliers operate their own goods vehicles to make deliveries (then data captured are similar to freight operator surveys).	+ potentially revealing given the fact that the University is customer, but doubts that a supplier's logistics team, as opposed to sales team, can be reached.
Service provider survey	Similar to a freight operator survey, providing wide ranging data about the pattern of service provider vehicle activity in the urban area. Allows opportunity to obtain data about the entire fleet rather than a single vehicle/ round (as with vehicle trip diary, the two types of survey can be used in conjunction). Can be used to collect data about service vehicle parking activity.	- the sheer number of fleet operators seen on site militates against such a large undertaking.
Vehicle traffic count survey	Road vehicle traffic is counted and disaggregated by vehicle type. Can provide details of the types of goods vehicles on selected roads or routes, or crossing specified cordons, by time of day and day of week. Can include all vehicles and provide data on goods vehicles as a proportion of all traffic	++ traditional survey for transport planners; high level of recognition; budget available for longitudinal survey.

Table 16: Urban Freight Transport Survey Techniques (c)

My research funding from the EU supported vehicle traffic surveys as empirical observation. This was a very traditional approach and was therefore a sound bedrock, having high acceptance. The opportunity to repeat the surveys over time was seen as valuable longitudinal data generation for this and other research. These data would be interrogated using statistical techniques in SPSS, in the event of correlations, and also explored inductively for questions, paradoxes and also potentially answers, in the iterative process.

Archived purchasing data, and indeed ongoing access to all purchasing data, was part of the access agreed to with the University Purchasing department; as such it was available for both archival and continuous analysis and use during the work. Complemented by an analysis of the procedures for procurement - itself complemented with some informal interviews - a good understanding of the procedural nature of the demand generated was made available throughout the work.

The empirical observation was designed to be primarily a procedural review of purchasing and an archival analysis of SAP purchasing data, complemented by a quantitative vehicle traffic count. In terms of the categorisation of survey techniques in Table 16 above, the work covered 'commodity flow survey' and 'vehicle traffic surveys'. I then needed to evaluate a suitable stakeholder engagement tool.

5.10. Stakeholder Engagement: Logical Framework Approach

Following the research philosophy developed in Chapter 3, a stakeholder-led process to enable all parties to mutually define problems, causes, objectives and solutions was called for. AR had been deployed with many other methodologies within it and I was interested in processes novel to the field of urban freight logistics. One such group of stakeholder-led processes was the Logical Framework Approach, drawn to my attention by a colleague in Panteia[24]. I pursued my interest in this and assessed which version would be most appropriate.

The Logical Framework and the Logical Framework Approach were two separate elements of a methodology often combined into one. It helps to understand them separately at first. The Framework was developed by Rosenberg et. al. in 1970, for the U.S. Agency for International Development (USAID). "To help separate USAID manageable interests from factors beyond their control, we define two roles for the [TA] Project Manager. First, he manages inputs to produce outputs --concrete and objectively

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[24] *My friend and colleague Jarl Schoemaker had deployed the approach in multiple projects in China and suggested it for consideration: https://www.panteia.com*

verifiable results. Second, he is testing the hypothesis that producing those results will achieve some larger purpose" (Rosenberg, Posner and Hanley, 1970; Dale, 2003).

5.10.1. Logframe

Since the 1970s, the Logical Framework - often shortened as 'the logframe' - had been adopted and made a mandatory requirement for many aid and development agencies worldwide, moving in and out of acceptance up to the modern day. As Gasper (2000a) said: "The logical framework (LF or logframe) can provide a convenient overview of project objectives and encourage attention to possible higher-level justifications, external conditions, and the information needs of monitoring and evaluation. The overview it gives is especially convenient for busy senior officials but could act as an aid to exchange of views between all involved in a project if real consultation and negotiation are accepted." A logframe was a way of describing an intervention design. A 'project' converted inputs to outputs, in a case theoretically screened from external forces, and it aimed for impact on higher levels of objectives.

5.10.2. Development into Logical Framework Approach

By the 1980s the logframe matrix had become viewed by many as weak, in that it did not express or directly refer to underlying people-related problems - these being the very rationale for any planned development intervention. Stakeholders and stakeholder concerns were not clarified, and the underlying analysis of opportunities and constraints may have been limited to constraints, since only these were given explicit attention. The logframe had nothing to say about organisation and management, delivery or sustainability of any planned intervention (Dale, 2003).

Therefore, in the 1980s, the German technical cooperation agency developed a second phase, broadly described as the 'logical framework approach' (LFA). In this approach, practice became a process for problem formulation through stakeholder participatory analysis, as well as one of selection, monitoring and evaluation. The outcome was ZOPP (Gasper, 2000b), the German acronym for objectives-oriented project planning - an upgraded LFA. The first ZOPP stage: Participation Analysis, or 'stakeholder analysis', identified the groups and viewpoints involved in a problem area. There followed linked steps of: defining a Problem Tree; converting it into an Objectives Tree; identifying and assessing Alternative Actions concerning those factors over which one had control or much influence; and then selecting one action path from the Objectives Tree - thus converting the Objectives Tree into a Project Matrix, including specified assumptions concerning the important external influences which one could not control (Gasper, 2000b). These developments from the original logframe, developed in 1970, made the process suited to a participatory and stakeholder-driven process. Of these, a key example was the Design and Monitoring Framework (DMF), an LFA approach developed and adopted by the Asian Development Bank (ADB).

5.10.3. Design and Monitoring Framework

The ADB (ADB, 2007) defined the logical framework that is the basis of DMF as: "A simple but powerful design and management tool [Which] helps build consensus with stakeholders and create ownership of the proposed project. It organises thinking and

Figure 20: Stakeholder Analysis Sri Lanka: Source ADB (ADB, 2007)

relates activities to expected results." The ADB model provided a structure for monitoring and evaluation, where planned and actual results could be compared. Therefore, logical frameworks tended to be more specific than programme logic models. Logical frameworks followed the same reasoning as logic models, but extended further - to the identification of indicators for each component, their means of verification (or sources of data), and their assumptions. The DMF structured the project planning process and claimed to communicate essential information about the project to stakeholders, in an efficient, easy-to-read format.

The ADB's DMF matrix comprised 14 frames with 4 major headings/columns. The design summary outlined the main elements of the project and showed the vertical logic of the DMF - explaining the means-ends relationship, also referred to as the results chain. It was important to note that the Logical Framework Approach (LFA) – such as the DMF approach – was a project design methodology, while Logical Framework (Logframe) – the DMF Matrix – was a document. The DMF Matrix could only be completed after stakeholder analysis, was followed by development of a problem analysis that turned into an objectives analysis, with focus on an alternatives analysis that then led to a mutually agreed set of desired outcomes and a design (plan) that could be mapped onto a matrix.

Step 1 – The stakeholder analysis

In Japan, the Asian Development Bank further elucidated the process of the stakeholder analysis. For the ADB (ADB, 2007) it was not just about the construction of the Problem Tree and the Objectives Tree, but also clearly understanding the stakeholders. Therefore, the first step in the process was to declare the stakeholder, the stakeholder's perception of the problem, their interests, their resources and their mandate. This opening statement of *perception, interests, resources and mandate* was key to the essentially subjectivist nature of these second generation uses of LFA. The result from this step was a table consolidating this information, see Table 17.

Stakeholder Name	**Interests relating to problem**	**Perception of problem**	**Resources**	**Mandate**

Table 17: Example Stakeholder Table

Step 2a – Problem analysis

The second step was to identify the major issue based on the views of the stakeholders. This was further broken down into 'causes' - defining the different sources of the issue - and 'effects', which were a direct implication of the issue. For example, unsustainable urban freight could be caused by lack of regulation, infrastructural issues, unawareness etc. At the same time, this could have a strong impact on costs, congestion, noise, emissions and safety. The end result of this step was a Problem Tree, whose roots analysed the causes and whose leaves presented the effects.

Step 2b – Objectives analysis

In this step, Problem Tree was translated into an Objectives Tree. More specifically, the causes were transformed into means, and the effects into ends. Each identified sub-problem was refigured as a desired situation; for example, the infrastructural issue (*the issue*) was translated into a well-functioning network (*the desired situation*). Following the same rationale, the effects were transformed into ends: the increased traffic congestion being refigured as smooth traffic flows. The main issue was redefined as the development objective.

Step 3 – Alternatives analysis

The alternatives analysis developed from the problem and objectives analysis. The main issue was broken down into different types of sub-issues, each one forming its own trajectory in the root of the Problem/ Objectives Tree. These separate trajectories (see Figure 21) formed the different alternatives that could contribute to the alleviation of the main issue. For example, when the main issue was unsustainable urban freight transport, and one of its sub-issues the insufficient infrastructure, then one alternative could be the improvement of infrastructure.

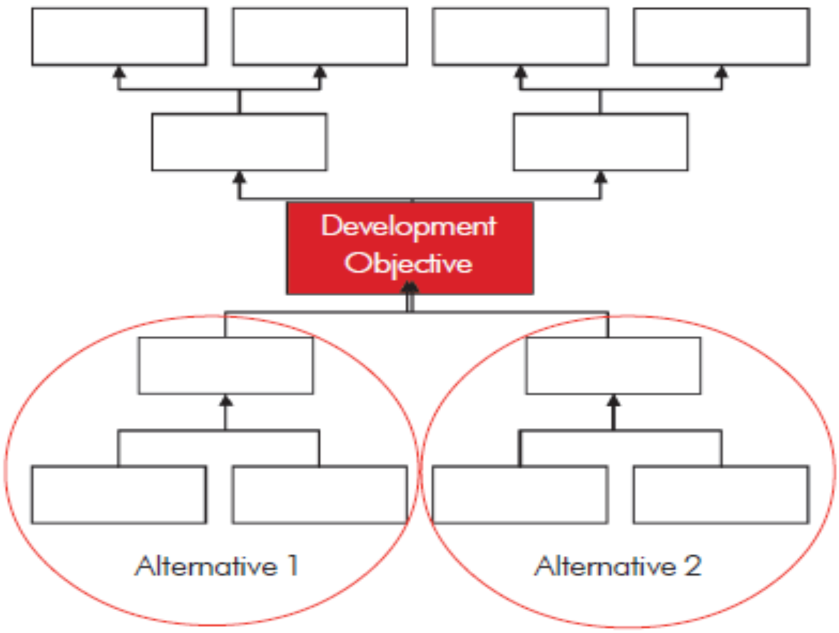

Figure 21: The definition of alternatives Source (ADB, 2007)

The results chain was derived from the Objectives (analysis) Tree, as can be seen in Figure 21. The centre frame of the Tree table was a statement, aimed at addressing the issue in question. The sub-frames, below the main frame, were various issues that had to be addressed, via a number of stakeholders. Each selected alternative should be mapped onto a single DMF, as shown in Figure 22.

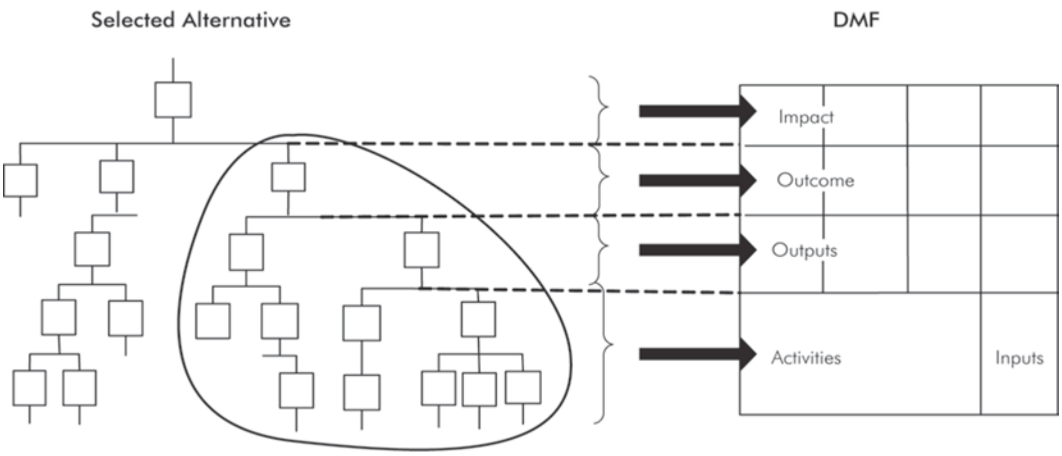

Figure 22. Linkages between objectives tree and matrix. Source ADB 2007

In brief, following stakeholder engagement involving all parties concerned, a Problem (analysis) Tree could be developed with inputs from all participants. This subsequently led to the development of an Objectives Tree, a selected alternative, and a DMF matrix, as shown above in Figure 22. The activities involved could include problem(s) and stakeholder(s) identification; interest(s) clarification; perception comprehension; resources specification; and an outline of mandate(s).

5.10.4. Evaluation of LFA

A Logical Framework Approach, and particularly the later generation variants such as the DMF, was participatory through stakeholder workshops; they were self-reflexively constructionist, in that they acknowledged the assumptions of all participants and reached a mutually understood definition of problems, objectives, solutions, an action plan, and a monitoring framework. This framework was defined in the terms of the owner(s) of an action. It addressed the key issues of power, in looking for which actors have ‘interest’, ‘mandate’ and ‘resources’. It could be criticised for being a linear logical model (horizontally and vertically), but in many ways that suited the worldview of the actors involved and was able to deal with meanings and people, as much as vehicles and processes (Roduner, Schläppi and Egli, 2008).

Many of the dis-benefits associated with LFA approaches were criticisms of the practice of earlier versions in development work, with consultants coming in to drive the process, tick the boxes, fill the forms, gain the funding, and then moving on (Bakewell and Garbutt, 2005). As an experienced project and commercial manager, I perceived two potential weaknesses: a lack of actual implementation planning, and a dearth of viable ongoing business models to support the change in an ongoing fashion. The ADB DMF would be an excellent way to support the first and second iterations of the AR cycle, but a technique to adapt the final DMF output into a viable business model would be needed, in the next iterations.

5.11. Business model generation

Having adopted LFA, but recognising that once a ‘DMF matrix’ was defined it was static and did not in and of itself support implementation, or long term economic viability, it was sensible to consider approaches to solve the concern over business models and viability (Macário, Rodrigues and Gama, 2011; SUGAR, 2011; Quak, Balm and Posthumus, 2014). A recurring message from the literature reviewed in Chapter 2 above was the lack of long term financial viability and the recognition of need for viable business models (Macário, Rodrigues and Gama, 2011; SUGAR, 2011; Quak, Balm and Posthumus, 2014), also see Synopsis of Concepts on page 50.

repeated development and piloting of operational and technical solutions to urban freight problems, followed by growing realisation that no viable business model had been developed, and the closing down of the initiative at funding end. Following the research philosophy developed in Chapter 4 above, a stakeholder-led process for the development of a viable business model was appropriate. I reviewed the range of business model frameworks available, to determine the most appropriate.

5.11.1. What Is a Business Framework?

Whilst many companies and organisations had internal processes to construct business plans, and many experts had deconstructed businesses in order to understand the underlying model, others had developed business frameworks with which business models could be designed. These varied from quite complex system analysis methods to broad brush simple toolsets. Business frameworks, even when they used the word 'model' in the title, were separate to the business models they created. The key business frameworks evaluated for use follow.

5.11.2. V4 Business Model Framework:

Developed by Al-Debei & Avison (2010), this framework had four main dimensions encapsulating sixteen elements. The four were:

- **Value Proposition**: the products/services an organisation offered, or would offer; also described the value elements incorporated within the offering, as well as the targeted and segmented markets;
- **Value Architecture**: a holistic structural design, including organisational infrastructure, technological architecture, and respective configurations;
- **Value Network**: the concept's cross-company or inter-organisation elements;
- **Value Finance**: information on costing, pricing methods, and revenue structure.

The authors developed and evidenced that business models were an essential conceptual tool of alignment in digital businesses. As an intermediate layer between business strategy and ICT-enabled business processes, they had a role in the complexity of the digital economy. There was much to welcome in the V4 approach and, despite its focus on ICT and digital, it was considered a possible tool for this work.

5.11.3. Business reference model:

Concentrating on the architectural aspects of the core business of an enterprise, service organisation, or government agency, a business reference model was a means to describe the business operations of an organisation, independent of the organisational structure that performed them. Other types of business reference model could also depict the relationship between the business processes, business functions, and the business area's business reference model. The most familiar business reference model was the "Business Reference Model" (2003), one of five reference models of the Federal Enterprise Architecture of the US Federal Government. It was a function-driven framework for describing the business operations of the Federal Government, independent of the agencies that performed them.

The heavily IT-based approach did not address issues of value, revenue, or commercial practices - normal in that marketplace, but unsuited to this work.

5.11.4. Component business model:

The Component Business Model™ for the Business of IT (CBMBoIT) was developed by IBM to analyse and model an enterprise. It was clearly an IT domain approach enabling "IT leadership … to shift from focusing primarily on technological issues to learning to manage IT like a business, with IT services as the primary product produced and consumed by customers" (Ernest and Nisavic, 2007). It could be depicted on a single page and was a logical representation of business components or 'building blocks'. It was used by IBM consultants to understand the alignment of enterprise strategy with the organisation's capabilities and investments, identifying redundant or overlapping business capabilities. The approach appealed in its ability to be viewed on a single page, but was very close to the functional analysis from systems development, plus it assumed a standardised objective set of building blocks and had little room for strategy or purpose. In short, it was an IBM answer to how the offering was delivered, but without a methodological answer for why this had value to the customer. Therefore, it was considered unlikely to be appropriate for this work.

5.11.5. Industrialisation of services model:

Theodore Levitt argued (1972) that the service sector was primitive and inefficient, relative to mass-production manufacturing operations. It suffered wide variations in quality, as each service encounter was treated as an isolated event. Levitt saw the ‘production-line approach’ as one by which services could significantly improve their performance on both cost (largely through improved efficiency) and quality. Given it was less a framework than a promotion of production optimisation techniques, and since logistics distribution was already heavily optimised using similar operations research techniques, it was unlikely that this approach could be productive for this work.

5.11.6. Business Model Canvas Generation:

Developed by A. Osterwalder, Yves Pigneur, Alan Smith, and 470 practitioners from 45 countries, the business model CANVAS (BMC) approach (Osterwalder and Pigneur, 2010) was one of the most widely used frameworks for generating business models within European Union research work, and interventions such as the Intelligent Energy Europe programme.

5.12. Evaluation of CANVAS

The approach was compatible with almost any mix of activity and organisation; it was widely supported with Creative Commons licensed materials and resulted in a clear methodology to create a single page business model from which a team could develop testable hypotheses in order to either review the viability of an approach, or to amend it until a viable solution was developed. It was domain agnostic and useable to develop ‘e-business’, ‘strategic issues’ and ‘innovation and technology’. In addition:

- it was widely applicable beyond ICT and the digital economy, unlike the V4 and Component approaches;
- it had a clear understanding of the role of value and revenue generation, unlike the Component and Business Reference frameworks;
- it supported a subjective process which allowed terms and details to be developed and owned by the stakeholders, which fitted well with the DMF outputs;
- it was well supported with process and resources available at little or no cost;
- it could be conceptualised on a single sheet of A4;
- it already had a track record in research and interventions in transport, such as Smartset (IEE), LOGICON (FP7), SPECTRUM (FP7), STRAIGHTSOL (FP7) and other EU (co)funded projects; and

- for research purposes, it could also be a productive theory generation tool, since one key mechanic was the development of multiple hypotheses for assessing and testing the developed business model.

This method of business model generation was adopted, as it was extremely well suited to the next stage of the AR cycle.

5.12.1. Strength of Canvas

The great strength of the Business Model Canvas (BMC) tool lay in offering the possibility to analyse every key component of a business, to review strengths and weaknesses, and to improve. Once completed the CANVAS should be viewed as a whole; this is key to understanding how everything ties together into a working business plan and how changes made anywhere in an organisation impact the rest of the business model. With Business Model Canvas, as with the DMF, the process enables the identification of that which is most important.

5.13. Project Management

As an experienced project manager, it was very clear to me that both DMF and BMC lacked any form of project management and had no method of work to ensure that all plans happened in a co-ordinated fashion, that risk was managed, or that the use of resources was controlled. This was a clear gap in the competency of these approaches to manage holistically.

However, given that this work was done in the broader context of much wider EU research projects, for which the author was co-ordinator, principal investigator and an experienced project manager, coherent project management underpinned the process. This project management, essentially based on the PRINCE2 approach, consisting of work packages, critical path analysis, Red/Amber/Green risk management, and extensive resource management, supported this work and need not be discussed further.

5.14. Final Research Design

The final research design was written up - first as a tabular list of activities following the AR approach, populated by the main and support activities - and then the mixed methods of research that made up each stage; all are detailed below in Table 18.

Stage	Main activities	Supporting activities	Type(s) of research
Frame and Pre-step	Frame; Rationale; Scope; Access; and Contract	Meetings; negotiation; integration with funding applications	Personal, preparatory, expert knowledge
Context and Observations	First traffic counts; Parking survey	The society of actors; The ensemble of techniques; The environment	Empirical surveys and archival analysis; quantitative
Action Research Cycle 1	Constructing; Planning; Taking action; Evaluating action	LFA workshop 1: Stakeholder analysis; Problem analysis	Participative; qualitative
Action Research Cycle 2	Constructing; Planning; Taking action; Evaluating action	Review and presentation of possible city logistics interventions; LFA workshop 2: Objectives analysis; Alternatives analysis	Participative; qualitative
Action Research Cycle 3	Constructing; Planning; Taking action; Evaluating action	CANVAS Business Model Generation: stakeholder meetings, collaborative filling of template, creation of questions which are min-hypotheses	Participative; qualitative

Stage	Main activities	Supporting activities	Type(s) of research
Action Research Cycle 4	Constructing; Planning; Taking action; Evaluating action	Making the logframe, completing the CANVAS template, multiple stakeholder meetings; alignment with other and wider research projects.	Participative; operational; quantitative and qualitative
Outcomes	Quantitative and qualitative evaluation	Carried out in parallel and concurrent with all previous cycles	Participative; operational; quantitative and qualitative
Reflection	Content, Process and Premise: Core and Thesis	Carried out in parallel and concurrent with all previous cycles	Participative; operational; quantitative and qualitative; reflective

Table 18: Final Research Design (Tabular)

This tabular approach was then reimagined as a series of graphics, showing the multiple iterative AR cycles, progressing through each stage of constructing, planning action, taking action, and evaluating action, before commencing the next cycle.

These iterative cycles were used to plan progress through the work, and I have used them at the beginning of the appropriate chapters to set the context and remind the reader of which cycle and stage is being reported. With a clear research design in place, and a graphical guide to the iterations of the AR cycle, the work could commence. Having completed the work, that research design was formalised as a chapter structure for this thesis.

5.15. Summary

This chapter describes the methods and techniques that were considered for the research, the approaches evaluated, and the design process used. The final framework and the complementary methods and techniques within are detailed and the final research project design summarised.

The complexity of the rationale (international, national and local), the multi-disciplinary scope, and the wide range of actors, policies and procedures suggested that a key difficulty of city logistics solutions was that they were a 'mess'. Such a mess could be summarised as "why, who, with what, where and when". I explored the ways in which systems approaches could be used to address such issues, using hard and soft systems thinking. I evaluated six different systems approaches, using a SOSM categorisation as an evaluation tool. AR seemed to fit well the pragmatic research philosophy detailed in Chapter 4 Chapter 4 above. AR had many advantages for change in operations management; it also adopted a subjectivist researcher as agent approach, which fitted well with my contract to enable change inside my own organisation. Finally, there had been a call for further use of AR in logistics as a whole, which was seen as delivering novelty. The issues around quality, rigour and meta learning were explored and noted for later evaluation and reflection in 0 below.

Once AR had been adopted, along with the iterative approach as a framework, the methods to be used were considered. Given a mix of qualitative and quantitative data, and the need to deliver both forms of evaluation, a multiple method approach was adopted and, within that, a mixed-methods research approach using Triangulation.

Having adopted a philosophy, a framework, and a method, techniques were needed for empirical surveys, archival analysis, stakeholder work and the creation of business models. Traffic surveys and SAP purchasing data were available for statistical analysis in SPSS, and University purchasing procedures would be analysed with top-up informal interviewing. For stakeholder work, the Asian Development Bank Design and Monitoring Framework was adopted, representing the most appropriate and modern version of the approach. For the development of business models, I have detailed an assessment of five of the most common types and explained why I adopted the CANVAS approach, with its suitability and previous trialling in EU research projects.

By the end of this chapter I have completed a comprehensive version of a research onion; it is re-encapsulated as a diagram in Figure 23 below.

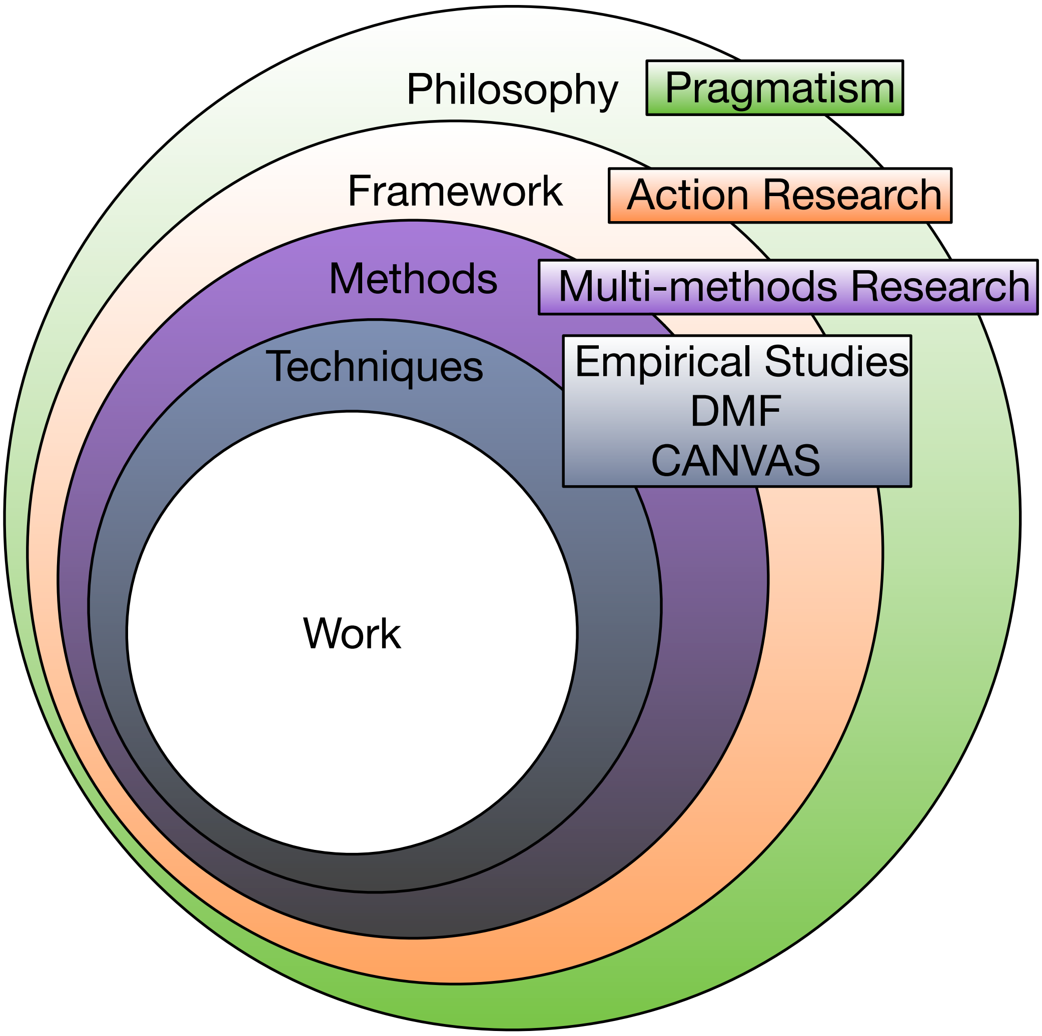

Figure 23: Research Onion for this work

Chapter 6. Identify Context and Observations

The objective of this Chapter is twofold: first, to report the context and conditions in which the work started; secondly, to provide sound ex-ante baseline data, for later ex-post evaluation, and the core statistics upon which to construct a quantitative evaluation model for use alongside qualitative analysis. During the work itself a further key purpose was to provide contextual input for the participative AR cycles that followed. Material from the later stages has been incorporated so as to enable broader data for the reader.

The chapter records the observation, recording and analysis of the empirical context of the conditions, as they existed on the ground, before any interventions. As stated in Chapter 5 above, the empirical observation was designed as a procedural review of the University purchasing systems, an archival analysis of SAP Business Warehouse purchasing data, and a vehicle traffic count survey. In terms of the categorisation by Allen et al. (Allen, Browne and Cherrett, 2012), the work covered a ‘commodity flow survey’, and ‘vehicle traffic surveys’.

The University used a financial year, or fiscal period, from August to July each year, in line with most UK Universities. I have denoted these as FPXXXX, where XXXX is the year in which the August falls, so FP2010 was August 2010 to July 2011.

This chapter therefore covers: a systems analysis of the University purchasing activity, derived from the procedures documents; purchasing demand from the University SAP system in the period from 1st August 2010 to 31st July 2012 (FP2010, FP2011 and FP2012); and *then* a traffic survey, conducted 30th April to 4th May 2012.

6.1.1. Pre-step

This chapter reports what was, in essence, the first pre-step of the AR cycle, complementing the theoretical framework developed in Chapter 3. An ex-ante and ex-post comparison 2010-11 and 2015-16 is detailed and explored in section 10.4 below. This chapter is therefore the context and observations as it formed the pre-step of the AR cycle 1.

6.1.2. *Ethical considerations*

Further to previous considerations and the initial review of the project carried out by the University, we reviewed the potential issues associated with anonymity and data collection in both the traffic survey and also the analysis of purchasing data. Following advice from my supervisor, and in line with the University policy of limiting access to the Human Resources system, no personally identifying data beyond ID was to be reported in this work. Whilst the registration plate licences of all vehicles would be collected in the traffic survey (section 6.4 below) - potentially data that could identify individuals - it would be only used to categorise vehicle and engine types in an anonymised fashion and would reported only as aggregated, anonymised data. The data would be held securely in line with the relevant data protection laws and regulations in place.

6.1.3. *Key issues to explore*

In order to provide the key metrics most likely to provide understanding of the context at the start of the work, and to inform the stakeholders at the start of the first AR cycle, the key issues to explore were:

- How did the University translate user demand to supplier demand?
- How well could I assess how that demand was expressed?
- How was that demand expressed in terms of differences between:
    - material groups which, paradoxically, could also mean non-physical goods;
    - day of the week;
    - month of the year; and
    - lead-time provided to suppliers?
- How many freight delivery vehicles visited the main campus?
- When did the freight vehicles visit?
- How long did the freight vehicles stay?
- How did those visits differ between:
    - different Sites on the campus;
    - different vehicle classes; and
    - different engine types?

6.2. Purchasing

Of interest was how the University was supplied with goods and services, at least those that generated a delivery, or a visit. The procedures extant at the beginning of the work were originally those dated 2010 (Addison, 2010), which then transitioned during the period of change in 2011 into the new 2012 version (Addison, 2015). In effect, both systems and procedures were followed differently by buyers in the multiple units during the transition. This was confirmed in ad hoc and various interviews with purchasing staff, buyers, and users, as well as during the preliminary work carried out for the processes outlined below in this chapter.

6.2.1. Purchasing as a multi-faceted organisation

The University was operating a highly decentralised purchasing organisation. The core department was small, with circa 4 full-time equivalent employees, and focused on the high spend, high turnover contracts.

Using the new 'P2P' shopping catalogue and shopping basket system implemented in late 2011, staff in the three University faculties - Science Agriculture and Engineering (SAgE); Humanities and Social Sciences (HaSS); and Medical Sciences (FMS) - selected their purchases from agreed price lists. These circa 1,100 'shoppers' had their baskets converted into purchase orders by circa 500 'expert' buyers, who could also raise and release (sometimes after authorisation) Purchase Orders (POs) for almost anything, with the Purchasing team usually only involved in large spend contracts for one-off items, or in managing the tendering processes required by law and good procurement practice. Such was the stated purchasing system and organisation, as systemised by the enterprise resource planning (ERP) software SAP R3 - a very common IT system.

However, in practice the purchasing system was not quite so simple, as further investigation showed parallel and separate systems to be in place.

Potential Power Buyers

Whilst the literature review yielded no discussion of potential power buyers, or a nascent definition, it was deemed worthy to examine the potential of same in the SAP data. In the FP 2010 80% of all line items were placed by 112 or 23% of the total number of active buyers, in line with a classic pareto split. Over the following years this pareto split held sound until the centralisation of purchasing in FP 2016. This is elaborated below in *Table 19*.

Fiscal period (FP)	Grand Total (line items)	Pareto spend	No. of buyers	Total no. of buyers	Pareto buyers
2010-11	184561	80%	112	495	23%
2011-12	165647	80%	106	545	19%
2012-13	154632	80%	98	464	21%
2013-14	164174	80%	105	503	21%
2014-15	166587	80%	112	550	20%
2015-16	167079	80%	100	511	20%
2016-17	168038	80%	49	423	12%
2017-19	167178	81%	13	284	5%
2018-19	166197	80%	21	285	7%

Table 19: Pareto Analysis of Buyers

By using anonymised buyer IDs, I explored whether certain buyers had 'power' over deliveries to specific locations on campus. I identified all locations that received more than 0.5% of total deliveries, and then looked to see if any buyers had placed >=1& and then >=10% or more of the orders at that location. This is detailed below in *Table 20*

Storage Location	***% of Total Purchase orders for this location***	***Buyers placing >1% of orders for location***	***Buyers >10% of orders for location***
Others	25.16%		
ICMB	7.49%	427,7,809,5,687,616,12	809,5
Genetic Medicine	6.02%	7,616,399	427
NICR O'Gorman	5.06%	7,306	7,306
Unstated on Order	4.68%	507	507
Chem Stores	3.66%	7,616,399	
ICM Will Leech F4	3.11%	721,427,7,687,12,616	721
IAH labs	3.10%	427,7,687,161,12	161
Neuro Henry Welc	2.79%	427,61,316,764	
ICMB CBCB	2.30%	427,7,809,5,687,616,12	809,5
ICM Cath Cook F4	2.25%	721	721
ICM Will Leech F3	2.21%	721,427	721
School of EECE	1.99%	721,507	
Chem Eng. Gen Off	1.83%	7,505,616,399	
IAH MRG	1.78%	721,427,7	
Mech Eng. School	1.61%	7,616,399	505
Agriculture Sch	1.53%	7,616,399	
NUIT Main	1.49%		
NUBS MAIN NEW	1.43%	7	
Robinson Library	1.28%	507	
Biology Ridley	1.16%	7,616,280,399	
CBC	1.10%	721,368,155,255,128,618,12,399	126
NICR Leukaemia	0.98%	427,7,81,88,81,306	7,306
ICM Will Leech FG	0.98%	721,427,7,687,12,616	721
Civil Eng. Drum	0.97%	7,616,399,674	
IHS Main	0.97%	427,827,410,809,5,687,616,12	

MCD Reception KG	0.94%		
Kings Road	0.89%		
ECLS School	0.79%	7,399	
NICR Chem Labs	0.79%	427,7,687,12,280	
Genetic Med	0.78%	427,7,687,12	
ESS Med Workshop	0.77%		
ICM Will Leech F2	0.76%	721,427,687,12	721
Marine Sci Armstrong	0.76%	7,616,399	
Mech Eng. Design	0.75%	7,616,399	
Biomed Sciences	0.66%	427,12	
Castle Leazes	0.65%	7,616,399	
Architecture Gen	0.65%	427,7,687,161,12	
Oral Biology	0.63%	427,7,687,126,12	
ICM Wolfson	0.62%	721,427,7,687,306,12	
Biology Devonshire	0.61%	7,41,399	
HASS Fac. Off.	0.55%	7,399	
Marine Sci Ridley	0.51%		
ESS	0.50%	507	507
ICM Will Leech F1	0.45%	721,427,7,687,12	721
Potential 'power buyers'		**17**	**8**

Table 20: Buyers associated with locations FP2012-2016 Aug.2012 to July.2017

The results suggested that 8 buyers were of import. These orders were largely for the Faculty of Medicine (FMS) They consisted of very large quantities of very small daily or twice daily deliveries of highly perishable biological and chemical reagents, dry ice and one-use laboratory ware.

Further analysis showed that these 8 placed 28% of all purchase orders, 26% of all line items, but only 12% by purchase order value. This seems to fit with the high volumes of very small quantities ordered daily for the research facilities.

Buyer ID	POs placed	% of POs	Line items	% of lines	Value placed	% of value
809	14400	3.39%	22325	2.72%	£ 5,927,923	0.77%
5	9236	2.18%	14942	1.82%	£ 2,488,851	0.32%
427	23777	5.60%	43929	5.35%	£ 22,263,069	2.89%
7	18408	4.34%	30856	3.76%	£ 11,681,591	1.51%
306	7245	1.71%	13371	1.63%	£ 7,245,402	0.94%
507	3811	0.90%	7925	0.97%	£ 12,902,324	1.67%
721	26894	6.34%	50659	6.17%	£ 15,345,296	1.99%
161	6353	1.50%	10434	1.27%	£ 2,830,021	0.37%
505	3844	0.91%	10008	1.22%	£ 7,093,473	0.92%
126	4249	1.00%	10075	1.23%	£ 4,631,049	0.60%
Placed by 8	**118217**	**27.85%**	**214524**	**26.15%**	**£ 92,408,999**	**11.98%**
Total	**424474**	**100.00%**	**820509**	**100.00%**	**£ 771,506,465**	**100.00%**

Table 21: Buyer ID analysis: Potential 8 power buyers' analysis FP2012-2016 Aug 2012 to July.2017

The eight individuals were invited to and present or represented at workshops (see Chapter 7 below), private purchasing surveys (below), sit down talks and the pilot customer relationship sessions (section 9.4.1 below), throughout the research, and the degree to the role of potential power buyers is discussed in section 6.8.3 below and meta learning in 0 below.

Purchasing System

The system was a mix of central control for large spend items, capital purchasing, and the agreement of contracts for items of high spend or criticality; and of decentralised control and autonomy for the bulk of the spend. The buyers were not recognisable from the SAP data provided as clerical, academic or management staff, and discussions with the Purchasing and Estates teams revealed that the contractual role of a buyer could vary greatly between Faculties, Schools, Departments, Centres and Functions.

Brezovnik et al. (2015) stated that there are no pure models of centralization and decentralization (including in the field of public procurement), but rather different degrees of tighter and looser forms of centralization or decentralization. It is "a process and a dynamic phenomenon which depends on various elements and conditions" (Brezovnik, Oplotnik and Vojinović, 2015). Thai (2008) suggested that trade-offs between centralised and decentralised organizational forms made the emergence of a perfect decentralised or centralised structure very unlikely. The potential use of procurement for the implementation of sustainability initiatives was informed by the findings of Glas, Schaupp & Essig et al. (2017) - that centralised organizations adapted differently to strategy objectives than did decentralised organizations. They further found that centralised organizations perceived up-to-date strategic objectives to be more important than did decentralised organizations, that tended to focus on the immediate needs of their local users.

This decentralised model, when promoted in US government purchasing, was promulgated as being able to “provide more responsive support to end users, eliminate bureaucratic obstacles to program accomplishment, improve inter-departmental coordination and empower service delivery managers to procure what they need without impediment by a centralised organization” (McCue and Pitzer, 2000). Levin (2003) recommended splitting the purchasing department of large multi-specialty firms into different homogenous sub-units, such as software development and equipment development, and assigning specific structure and performance measures to each, thereby providing a clearer view of the various components of the function. Elsewhere however, assessing sub-units separately was found to lack dynamism (Koubaa, 2016).

Mikalef et al. (2015) argued that the allocation of decision-rights for SCM activities would influence purchasing alignment. They noted different optimal purchasing approaches to centralization/decentralization, and other factors, based on whether a company adopted a product leadership strategic orientation, or a customer intimacy strategic orientation, and whether it was a large organization or a small to medium enterprise (SME).

None of these research approaches have been replicated in HEIs.

At Newcastle University, the theoretical inbound delivery process was ‘delivery to desk’, rather than to a central or intermediate store. The abolition of the central stores had occurred in the 1980s, on the grounds that it would save substantial labour costs and storage facilities, as well as speeding the direct delivery of goods to the end user. However, a review of the delivery locations, also known as ‘storage’, locations, and a walk around the buildings revealed the continued existence of ad-hoc stores and goods-inwards rooms across many of the SAgE Faculty facilities. These alternative models of internal delivery handling had not been found in the literature review.

Criticality, a key part of the importance of supplies and suppliers (Kraljič, 1983), was not embedded in the processes or data; however this was addressed later on in the pilot design and execution and is detailed further in sections 8.8 and 9.5.1.

The catering functions of the University - restaurants, cafes, coffee bars and event catering providers - used a totally separate purchasing system that integrated with SAP only at purchase ledger level (SAP Financials) and only then as a rolling series of invoices against ‘call off’ orders that left little or no audit trail.

Additionally, many expert buyers and managers in the University used ‘purchasing cards’ - corporate credit cards with a variety of authorisation limits, from £50 to £500 to £2000+ - for such things as travel, or small scale purchasing from suppliers not on the SAP supplier database, e.g. Amazon. In the fiscal period 2011-2012, the use of such cards accounted for 2.35% of expenditure (Newcastle University, 2012).

Years of experience as a procurement professional had left the author aware that any auditable chain of events could often differ from the stated ‘system’; in this case many POs were merely a record of a purchase and a delivery already informally completed, with only the arrival of an invoice triggering a formal record. Even then, system loopholes allowed a simple one-off payment to a supplier for an invoice, thus circumventing any *purchase order, requisition, call off, or use of a purchasing card.* Such purchases, with records created after the event, were viewed as ‘posthumous’, but were recorded in SAP as a ‘web invoice coded’ (WIC). This category existed to capture exceptional cases, yet in the fiscal period 2011-2012 it accounted for circa 23.58% of spend (Newcastle University, 2012). In addition to this ‘posthumous’ system, the staff personal expenses procedure (intended for travel and subsistence costs) could be used for the purchase of sundry items below £250, some of which were delivered to campus. Such purchases ‘on expenses’ made up 3.46% of the total expenditure in the fiscal period 2011-2012.

To elucidate the diversity of practice, the formal and informal systems are summarised graphically in Figure 24, mapping the five core routes from demand to final invoice payment.

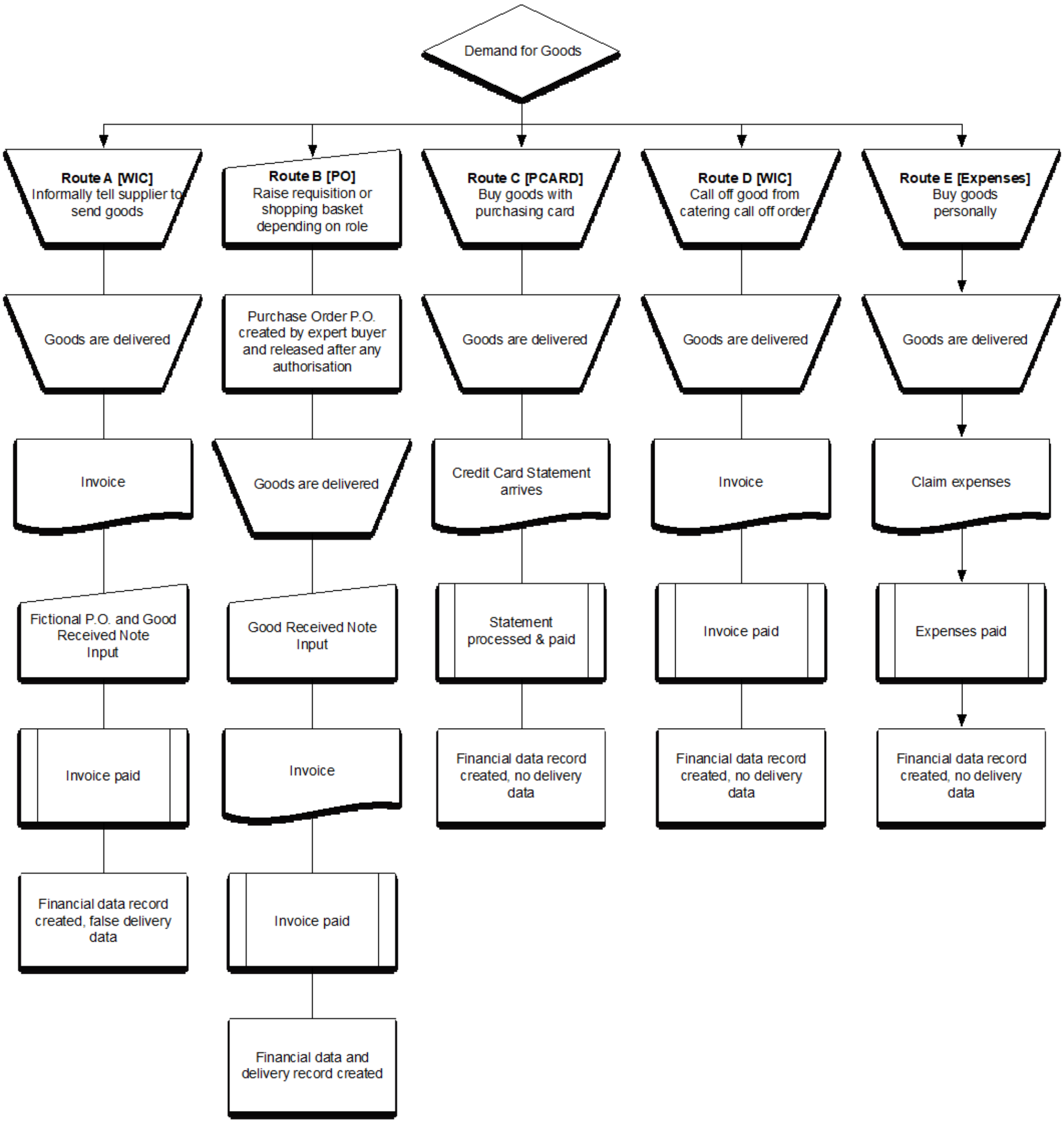

Figure 24: Newcastle Purchasing Flow: Formal and Informal for the 5 core routes

Overall purchasing expenditure splits, and their associated routing, changed over FP2012 to FP2016, detailed in Table 22 following. The expenditure splits are expressed as percentages, rather than in absolute numbers, for reasons of commercial confidentiality.

University financial year (Aug-Jul)	PO P2P (route B)	WIC (routes A & D)	Purchase-card (route C)	Expenses (route E)
2011-2012 Purchasing Analysis	70.60%	23.58%	2.35%	3.46%
2012-2013 Purchasing Analysis	72.85%	21.96%	2.47%	2.72%
2013-2014 Purchasing Analysis	78.73%	15.53%	3.00%	2.74%
2014-2015 Purchasing Analysis	80.94%	13.20%	3.11%	2.75%
2015-2016 Purchasing Analysis	82.37%	11.95%	2.97%	2.70%

Table 22: Purchasing expenditure analysis 2011-2016 , Source internal reports (Newcastle University, 2016b)

Whilst all the flows in Figure 24 above created adequate data for financial processing, only Route B created adequate delivery data - if created on the system at the correct chronological step. The purchasing card route reduced the administration burden, as did the Catering call-off route, but both left effectively no delivery data.

The flow generating the least reliable data was the 'hidden' informal Route A, where the system recorded a false PO and delivery data - potentially the more problematic since the instances were very difficult to identify. Even then, it was clear from the author's personal experience, and from talking to expert buyers, that the key delivery step of entering a goods receipt note (GRN) was often not done using an actual document from the supplier, at the actual time of delivery and – crucially - the delivery date recorded might simply have been *the date of the input.*

The default delivery date within the SAP system was set to be the day after the PO was released to the supplier. Unless this default was manually amended, the University was effectively demanding next day, just-in-time (JIT) deliveries from its supplier base, with the consequent effects on the logistics chain. Conversations with suppliers such as Office Depot confirmed that meeting a next day delivery often required a courier service, such as UPS or FedEx, whereas a 2-3 day delivery horizon could have been satisfied by a slower, but more efficiently consolidated, internal hub and spoke service.

The purchasing system suited the financial needs of the University to process payment for goods received, with a reasonable level of authorisation. The University did not function in the same way as a retailer, or a warehouse, or a manufacturing plant and, unlike some institutions, had closed its central stores many years before. The University had therefore never needed or implemented the stock control and/or bills of materials functionality that existed in most Enterprise Resource Planning (ERP) systems, including SAP.

Private Purchasing

In parallel with these institutional purchasing activities there was a known and anecdotally noted flow of private procurement activity, whereby employees and students ordered personal goods to be delivered to the workplace. My colleague Paulus Aditjandra and I investigated this in detail, in March 2014, in a piece of parallel research (Aditjandra and Zunder, 2017). The University had no official policy on private deliveries to work, and the senior management of the Estates, Purchasing and Finance functions had divergent views on whether this was to be encouraged or discouraged. Using a SurveyMonkey online survey, 5000 staff were targeted, with a response rate of 735 (14.70%). As shown in Table 23 below, 61.77% were administrative or clerical staff, 10.48% were technical and professional staff, and 19.05% were academic, research or teaching staff.

ANSWER CHOICES	**RESPONSES**	**%**
Academic – non-clinical (1)	76	10.34%
Academic - clinical (2)	5	0.68%
Research – non-clinical (3)	49	6.67%
Research - clinical (4)	5	0.68%
Teaching only (5)	5	0.68%
Administrative and Professional (e.g. Library, Clerical, Administrative, Managerial) (6)	454	61.77%
Specialist, Technical and Professional (e.g. Technicians) (7)	77	10.48%
Operational Services (e.g. Ancillary, Cleaning and Catering, Porters, Farm Workers, Grounds Staff, Maintenance, Security) (8)	28	3.81%
Graduate or postgraduate student (non-research) (9)	3	0.41%
Graduate or postgraduate researcher (including PhD) (10)	20	2.72%
Undergraduate (11)	10	1.36%
Not a member of staff or student body (12)	3	0.41%
TOTAL RESPONSES	**735**	**14.70%**
TOTAL AUDIENCE	5000	

Table 23: Breakdown of Roles in SurveyMonkey Survey on Purchasing Behaviour March 2014

8.26% of staff who responded reported purchasing goods, for personal use, to be delivered to the workplace. Typical purchases were books, literature, videos, software, music (not downloaded content), clothing, and travel tickets/ documentation. The frequency of private orders per person raised was typically less than twice a month as shown in Table 24 below. As a very broad-brush analysis, of 5000 staff, 413 were ordering between 400 and 900 items per month, with a distribution at the lower end. The mean average of line items ordered by the University was around 15,000 per month, making the potential private purchases between 2.5%-5.6% of a revised total volume.

Answer Options	Never or less than once a month	Less than twice a month	Once a week	2-4 times a week	Everyday	Multiple times a day
Office stationery	100%	0%	0%	0%	0%	0%
Repair or maintenance services	100%	0%	0%	0%	0%	0%
Catering (prepared food)	100%	0%	0%	0%	0%	0%
Chemicals (hazardous or otherwise)	100%	0%	0%	0%	0%	0%
Medical supplies	100%	0%	0%	0%	0%	0%
Books, literature, videos, software, music (but not downloaded content)	61%	39%	0%	0%	0%	0%
Food or beverages (as opposed to catering)	93%	4%	2%	0%	0%	0%
ICT equipment (computers, printers, mice, but not software)	93%	7%	0%	0%	0%	0%
Travel tickets or documentation	78%	22%	0%	0%	0%	0%
Clothing	73%	27%	0%	0%	0%	0%
Other	81%	19%	0%	0%	0%	0%

Table 24 Frequency of HOME order to be delivered to WORK address: Source: Aditjandra and Zunder working documents

Reasons for HOME at WORK goods deliveries

The respondents were asked to rate their reasons for this private purchasing behaviour on a four-point Likert scale, from ‘strongly disagree’ (1) to ‘strongly agree’ (4). The descriptive statistics can be seen in Table 25 and show the key reasons for ordering HOME goods to be delivered at WORK address to be: ‘There is no-one at home’, ‘Travelling to collect failed delivery is inconvenient’, ‘I never know when goods will arrive at home’ and ‘The goods are too big to fit through my letterbox’.

Statement	**Ranking**
There is no-one at home.	3.60
Travelling to collect failed delivery is inconvenient.	3.55
I never know when goods will arrive at home.	3.43
The goods are too big to fit through my letterbox.	3.41
I can't take time off work.	3.34
I like the convenience.	3.33
The carrier needs a signature.	3.20
I can't rely on my neighbour to receive goods.	3.10
My home address isn't secure.	1.85

Table 25 Reasons for HOME at WORK goods deliveries: Source: Aditjandra and Zunder working documents

The respondents were well informed as to campus sustainability and transport and made positive suggestions about improving freight deliveries, which showed that ideas for intervention in this area were widespread and not restricted to experts (Adtjandra *et al.*, 2016). We saw this as confirmation that bottom-up stakeholder-led interventions could generate a strong body of innovative ideas (for further discussion, please see Österle et al., 2015; Zunder et al., 2013, 2016).

Qualitative data reported by the respondents pointed to the fact that private purchasing was deemed ‘unusual’ or ‘unacceptable’ practice, although comments were made to illustrate its usefulness. Belief that the behaviour would be deemed unacceptable had no basis in University policy and appeared entirely cultural; there could be value in a comparison with similar student purchasing behaviour data reported at the University of Southampton (Cherrett *et al.*, 2017). It is unproven that administrative staff were more likely to perceive that private purchasing was not allowed, but this may also merit further investigation into the views of academic and non-clerical staff, not least because there is *no formal prohibition on private purchasing for anyone at the University* (Aditjandra and Zunder, 2017).

The University's procurement data were problematic. The formal PO route B produced data that were adequate for the 'PO raised' date, quite unusable for 'delivery date', and raised more questions than answers about 'requested delivery date'. The other routes were either financially sound but recorded no useable delivery data or, in the case of the informal ('fictional') Route A, generated misleading or false data.

The next step proceeded to analyse the data, in order to gain insight into several of the issues raised and perhaps provisionally answer one or two emergent questions.

6.3. Analysis of Purchasing Data

6.3.1. Nature and limitations of the Database

In order to assess the baseline procurement activity that generated demand for inbound logistics, the purchasing data - and especially the goods inwards data - were collected. Access was gained to the University SAP Business Warehouse management reporting systems and various reports were prepared. The University had configured and installed the database as a financial processing system, rather than as a manufacturing or distribution system. As such the database had no part numbers, no stock control, no manufacture resource planning (MRP,) no scheduling, no bill of materials (BOM) and the material groups were originally simply text codes with some relation to plain English. Any analysis of purchases could not be done at a part level, only at material group level. Whilst a potential SQL query to the SAP Business Warehouse and the HR system could have cross linked the identity of users of the system, this was classed as confidential personal data with ethical issues and access was therefore not granted.

The University did not have an approved list. SAP contained an 'active supplier' list, on whom orders could be placed, and a 'contracted' supplier list, with whom central contracts had been negotiated. The Purchasing Manager maintained more than 500 contracted suppliers – roughly the number used by his department in any one year. He stated: "Typically there are around 5500 live vendors on SAP per year. New ones get added daily and others get blocked monthly but ... [it]... is relatively stable overall around this total" (Addison, 2019). Those that exceeded an average of 4 deliveries per month formed a 'top vendors' list of 251 suppliers, generating 32,235 parcels across a standard 51-week year.

The demand data did not necessarily reflect the entire population of demand placed on suppliers, as the University allowed for non-SAP one-off purchasing (Route A); a parallel credit card system (Route C); a separate Catering supply system (Route D); and the tendency of some staff to simply ‘order things’ and either claim through personal expenses or settle up at the invoice stage (Route E). (See Figure 24.)

The data did provide a very large sample, close to the full population and covering the key material groups related to road traffic deliveries. To identify the demand patterns attributable to Route B, certain editing, deletions and adaptations of the dataset were required, which in some cases rendered the resultant datasets closer to very large samples, rather than the whole population.

6.3.2. Knowledge needed from Purchasing Data

In order to begin to understand how the University expressed demand to suppliers, a previously detailed list of questions needed to be addressed, a sub-set of which was:

- How did the University translate user demand to supplier demand?
- How well could I assess how that demand was expressed?
- How was that demand expressed in terms of differences between:
    - material groups;
    - day of the week;
    - month of the year; and
    - lead-time provided to suppliers?

6.3.3. Anachronistic dates

Of note was the transition of the University procurement process from the original SAP purchasing implementation - primarily invoice processing - to the Accounts Payable / Procure to Pay (P2P) Process, in 2011. The first pilots had started in April-May 2011, with full implementation in June-July of the same year. P2P covered the complete cycle, from Vendor Master Maintenance, through procurement and Vendor Invoice Processing and the resulting Payment Processing, to external vendors and the Period Closing activities. P2P was a more robust system, with a higher level of data integrity, material group allocation, and goods receipting, rather than simply invoice clearance. Whilst still data-poor, and with significant inconsistencies, the new system was a major advance. Anecdotal reports told of large volumes of invoice backlogs being cleared ‘en masse’ during 2011 and into 2012; it was reported in conversation that this activity generated documents for long-past deliveries, with dates that followed ‘little rhyme or reason’.

Another factor of note was that, at that time, the goods receipt date was not included in the management reports; these recorded purchase order (PO) document date; estimated delivery date; and the invoice date. Route A, detailed in Figure 24, generated false delivery data and created the PO at the time of invoice arrival – effectively, a 'posthumous' record. What was apparent was that many of these records contained anachronistic data: e.g. estimated delivery dates that were prior to the PO date. Route C created no transactional data, apart from a monthly invoice settlement with the credit card provider. Route D, however, had a quite different effect: here 'limit orders' were created, with estimated delivery dates that were months, or even years, into the future. These goods would be called off verbally, or via a parallel Catering system, creating records with estimated deliveries far in advance of the PO document date. Only Route B created transactionally sound data; the issue was whether Route B transactions could be identified from the data to allow induction?

6.3.4. 2008-2012 Overview of Purchasing

During 2008-2012, the University had had a stable purchasing activity averaging about 7,502 purchase orders a month, with a standard deviation for the whole population of 1,132.87. This varied through a year, with expected dips in activity in April (Easter), August (summer vacation), and December (Christmas). This is summarised visually in Figure 25 below.

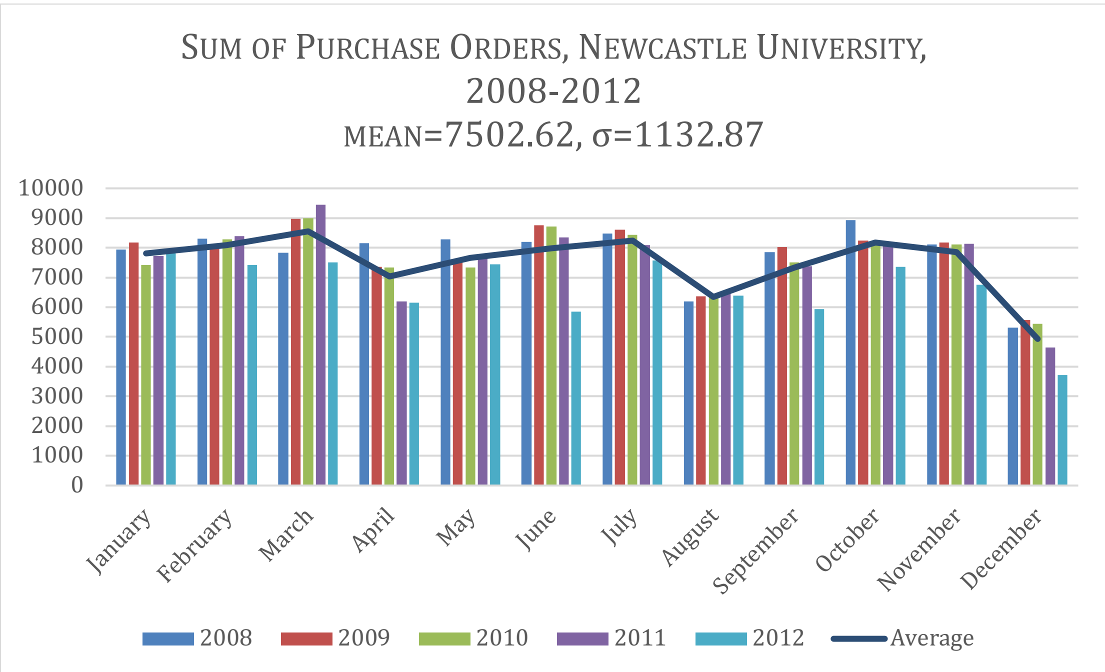

Figure 25 Sum of Purchase Orders by Month 2008-2012

In many ways, the number of Purchase Orders was less relevant than the number of line items on each and, when looking for comparisons between required (estimated) delivery dates, material groups, and demand, analysis at line item level ('schedule line item' in SAP) was more appropriate. Figure 26 showed a very similar pattern, however, with dips in activity in April, August and December. The data showed the average *monthly* number of line items per PO was a mean of 2.01, with standard deviation of the population of 0.0525.

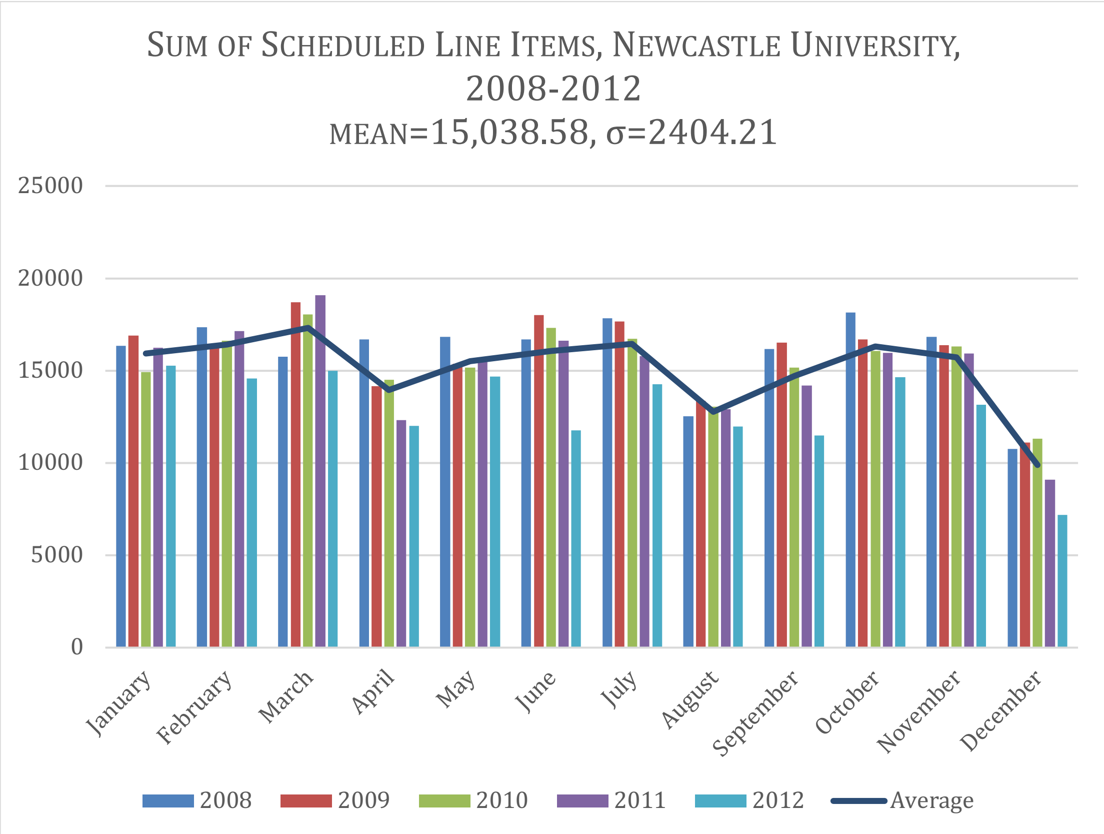

Figure 26: Scheduled Line Items by Month 2008-2012

Table 26, below, shows that the number of active suppliers per annum fell from 49,475 in 2008, to 38,568 in 2012. This was due to the University's deliberate policy of consolidation, enabled by policy and the implementation of the SAP R3 system, in 2008. Distribution of active supplier by month was similar to Figure 25 and Figure 26 and thus is not shown graphically.

Sum of Vendors	Column Labels							
Row Labels	2008	2009	2010	2011	2012	Grand Total	Average	
January	4177	4153	3831	3979	3733	19873	3975	
February	4329	4019	4181	4122	3481	20132	4026	
March	4138	4638	4764	4770	3615	21925	4385	
April	4313	3878	3804	3224	2992	18211	3642	
May	4241	3872	3755	4017	3538	19423	3885	
June	4354	4612	4625	4337	2818	20746	4149	
July	4600	4665	4633	4269	3763	21930	4386	
August	3411	3544	3501	3522	3203	17181	3436	
September	4194	4197	4069	3788	2850	19098	3820	
October	4640	4297	4173	4104	3428	20642	4128	
November	4151	4178	4282	3946	3276	19833	3967	
December	2927	3146	3027	2484	1871	13455	2691	
Grand Total	**49475**	**49199**	**48645**	**46562**	**38568**	**232449**	**mean**	**3874.15**
							std dev (p)	**599.07**

Table 26: Suppliers (vendors) 2008-2012

SAP data did record the total value of POs; however, this was impacted significantly by outliers during this period, as the University was making some very large capital investments. In consultation with other University staff, it was decided that this study should not explore PO value, due to its high degree of commercial confidentiality; in any case, other areas of enquiry seemed likely to be more fruitful. The focus would be on deliveries, not spend - an issue which later became quite important and potentially contentious, in the intervention design (see Chapter 7).

This top-level analysis set the scope; in order to drill down into the data, several filters were adopted, to focus only on weekdays, and on purchases that generated deliveries.

6.3.5. University Days of Operation

The University was primarily a weekday institution, with low levels of social and research activity at the weekends, as clearly shown in Figure 27.

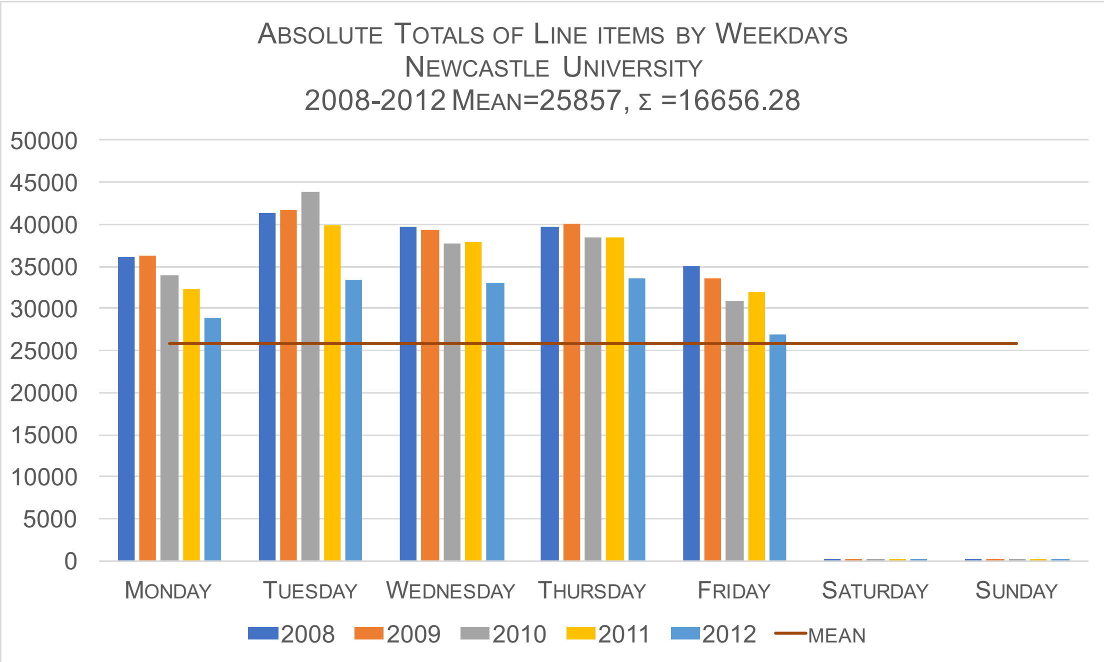

Figure 27: Absolute totals of line items by required (estimated) by day, 2008-2012

This initial assessment of required delivery date - showing that almost all freight activity happened on weekdays - meant that excluding weekends from the data analysis was appropriate.

6.3.6. Using material group to identify freight deliveries

It was widely accepted in the field that physical goods were 'freight' and generated deliveries. It was also commonly accepted that physical services, carried out by a person, were also 'freight' that could be viewed as being delivered (Ogden, 1992; OECD, 2003). Newcastle University bought physical services that would not normally be categorised as freight vehicle movements - such as audits; consultancy; agency staff; and temporary teaching staff – all of which generated passenger traffic. It also bought services, such as plant maintenance, catering, or repairs, that were more likely to arrive in light goods vehicles, than by car or bus. It was also understood that many non-physical services could be bought that had no physical delivery, whether entirely virtual (e.g. insurance); a membership fee; or an electronic delivery of an online publication – which were increasingly replacing paper copies.

The University purchasing records were categorised by ‘material groups’, which denoted families of goods and services and allow segmented analysis of the data. To that end, using my expert knowledge as a purchasing professional (MCIPS), and after extensive and iterative consultation with the Purchasing Manager, I split the data, by material group, into a) those that generated physical deliveries in freight vehicles; b) passenger movements by car, public transport or on foot; and c) those goods or services that generated no physical delivery. Examples of this division, from both coding systems, are shown in Table 27.

Two different coding systems existed during this transitional period: pre-P2P and the P2P coding system that followed it. As can be seen, the first system used all capitals and the second used sentence case; the first had no translation between a material group and its description.

material group	description	delivery
CSTAT	CONS- STATIONERY	y
CSTATCD	CONS- STATIONERY/CRD	y
CSTATPN	CONS- STATIONERY/PEN	y
CPAPER	CONS- PAPER	y
CTEACH	CONS- TEACH AIDS/AV	y
AUDITWK	AUDITOR'S AUDIT WORK	n
AUDITNA	AUDITOR'S NON-AUDIT	n
BOOKS	BOOKS & PERIODICALS	y
PUBLICN	PUBLICATIONS	y
MAPS	MAPS	y
BOOKEL	ELECTRONIC BOOKS	n
UTILELEC	UTILITIES- ELECTRIC	n
FUELOIL	FUEL OIL	y
UTILGAS	UTILITIES- GAS	n
UTILSEWER	UTILITIES- SEWERAGE	n
1RXY	Service-Int'l Agent's Fees	n
1RZY	Service-Other/General Professional	n
1SCY	Goods-Office Equipment	y
1SFY	Goods-Paper	y
1SGY	Service-Photocopying Charges	n
1SJY	Goods-General Stationery	y

Table 27: Examples of using material groups to identify transactions that generate freight vehicle movements, Source SAP database

This split by material group enabled the data to be filtered to include only those transactions that usually generated freight vehicle movements.

6.3.7. 2010-2012 Purchasing Analysis

To analyse the way that purchasing activity translated to demand for deliveries, in the period August 2010 to July 2012 inclusive, I made the following filtering decisions based on my previous observations and insights gleaned:

- Weekdays and weekends would at first be included in the dataset, since demand at weekends was present, albeit at a lower level.
- A decision would be made whether to continue with weekdays alone.
- The material groups would form part of the dataset and only material groups that usually generated physical freight vehicle deliveries would be included.
- The date of the Purchase Order would be recorded.

- The requested (estimated) date of delivery would be recorded and viewed as the University's expression of demand to suppliers.
- The following interim questions would be asked and hopefully answered:
- How many cases in the data revealed useful evidence of demand, as opposed to recording posthumous or false records?
- Did the data suggest that the University was issuing orders with very short lead-times, generating a fast response from the supplier base?
- Once appropriate material groups were taken into consideration, did the weekends show significantly different demand patterns to the weekdays?
- Did the demand for material groups differ from one to the other?

The data were extracted from SAP R3, certain fields adjusted to date formats, and some conversion made to add months and weekdays as strings. Each case was assigned a unique ID, allowing tracking back through the process, even if certain cases would later be removed from analysis. A random section of the data is shown below in Table 28[25].

The first step was to filter out the transactions that did not relate to physical freight deliveries. The original dataset, which was itself a summary report, was sorted by material group, then date of purchase order, then the estimated delivery date of each line-item. This consisted of 79,696 cases, recording 202,544 distinct POs and 350,208 line-items. After removing all cases related to material groups not usually associated with freight vehicle deliveries, the dataset was reduced to 55,842 cases, recording 157,088 distinct POs and 285,243 line-items.

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[25] *Both* Table 27 *and* Table 28 *are exemplars of a very much larger dataset, they are not intended for cross reference.*

IDNo	MaterialGroup	MG_description	PO_Date	PO_Year	Line_estimated-weekday	Line_estimated_month	Line_estimated_year	Line_Item_Estimated_Delivery	DistinctPOCount	DistinctVendorCount	ScheduleLineCount	Difference_leadtime	Deliveries
32012	1CTY	Service-External Catering	20/04/2011	2011	Thursday	June	2011	23/06/2011	1	1	2	64	y
32530	1CZY	Goods-Catering Other	28/06/2011	2011	Tuesday	June	2011	28/06/2011	1	1	1	0	y
32016	1DCY	Goods-Dental/Med Consumables	22/06/2011	2011	Thursday	June	2011	23/06/2011	1	1	1	1	y
32017	1FBY	Goods-Laboratory Furniture	23/06/2011	2011	Thursday	June	2011	23/06/2011	2	2	3	0	y
32018	1HZY	Service-Cleaning Machine Repairs	16/06/2011	2011	Thursday	June	2011	23/06/2011	2	1	17	7	y
32019	1KCY	Goods-Printer Consumables	21/06/2011	2011	Thursday	June	2011	23/06/2011	1	1	1	2	y
32021	1KEY	Service-Software	27/06/2011	2011	Thursday	June	2011	23/06/2011	2	2	2	-4	
32022	1KHY	Goods-Computer Equipment	16/06/2011	2011	Thursday	June	2011	23/06/2011	1	1	1	7	y
32533	1KJY	Service-Network Equip Installation	28/06/2011	2011	Tuesday	June	2011	28/06/2011	1	1	1	0	y
32024	1KKY	Goods-Portable Computers	16/06/2011	2011	Thursday	June	2011	23/06/2011	2	1	3	7	y
32025	1KMY	Goods-Computer Consumables	22/06/2011	2011	Thursday	June	2011	23/06/2011	1	1	1	1	y
32027	1KZY	Goods-IT Other	16/06/2011	2011	Thursday	June	2011	23/06/2011	1	1	1	7	y
32028	1LGY	Goods-Laboratory Equipment	16/06/2011	2011	Thursday	June	2011	23/06/2011	1	1	2	7	y
32538	1LHB	Goods-Molecular Biology Reagents etc	23/06/2011	2011	Tuesday	June	2011	28/06/2011	2	2	3	5	y
32033	1LHC	Goods-General Chemicals	16/06/2011	2011	Thursday	June	2011	23/06/2011	3	2	6	7	y
32539	1LHE	Goods-Antibodies	17/06/2011	2011	Tuesday	June	2011	28/06/2011	1	1	1	11	y
32036	1LKZ	Goods-Lab Consumables	18/02/2011	2011	Thursday	June	2011	23/06/2011	1	1	1	125	y
32037	1LKZ	Goods-Lab Consumables	16/06/2011	2011	Thursday	June	2011	23/06/2011	3	3	8	7	y
32542	1LLY	Service-Outsourced Lab Services	28/06/2011	2011	Tuesday	June	2011	28/06/2011	1	1	1	0	
32543	1LMC	Service-Lab Equip Maintenance Contracts	20/06/2011	2011	Tuesday	June	2011	28/06/2011	1	1	1	8	y
32544	1LMY	Service-Lab Equip Repairs	29/06/2011	2011	Tuesday	June	2011	28/06/2011	1	1	1	-1	y
32545	1LNA	Service-Gas Cylinder Rental	28/06/2011	2011	Tuesday	June	2011	28/06/2011	1	1	1	0	y
32546	1LNB	Goods-Laboratory Gases	28/06/2011	2011	Tuesday	June	2011	28/06/2011	1	1	5	0	y
32040	1LOY	Goods-Oligos/Primers	21/06/2011	2011	Thursday	June	2011	23/06/2011	1	1	36	2	y
32045	1LSY	Goods-Laboratory Plasticware	22/06/2011	2011	Thursday	June	2011	23/06/2011	4	4	6	1	y
32548	1LXY	Goods-TC Sera & Media	28/06/2011	2011	Tuesday	June	2011	28/06/2011	1	1	1	0	y
32046	1LYY	Service-Lab Waste Disposal	20/06/2011	2011	Thursday	June	2011	23/06/2011	1	1	1	3	y
32549	1MZY	Goods-Workshop/Maintenance Other	27/06/2011	2011	Tuesday	June	2011	28/06/2011	1	1	1	1	y
32048	1PDY	Service-External Print Design	23/06/2011	2011	Thursday	June	2011	23/06/2011	1	1	1	0	
32550	1PDY	Service-External Print Design	28/06/2011	2011	Tuesday	June	2011	28/06/2011	1	1	1	0	
32551	1QAY	Service-Mail & Couriers	11/07/2011	2011	Tuesday	June	2011	28/06/2011	1	1	1	-13	y
32049	1QGY	Goods-Telecoms Equipment	21/06/2011	2011	Thursday	June	2011	23/06/2011	1	1	2	2	y
32554	1RPY	Service-Training Courses	28/06/2011	2011	Tuesday	June	2011	28/06/2011	1	1	1	0	
32051	1RQY	Service-Marketing & Recruitment (not Advertising)	23/06/2011	2011	Thursday	June	2011	23/06/2011	1	1	1	0	
32052	1RZY	Service-Other/General Professional	23/06/2011	2011	Thursday	June	2011	23/06/2011	4	4	4	0	
32053	1SCY	Goods-Office Equipment	17/06/2011	2011	Thursday	June	2011	23/06/2011	1	1	2	6	y
32556	1SFY	Goods-Paper	28/06/2011	2011	Tuesday	June	2011	28/06/2011	1	1	1	0	y
32055	1SGY	Service-Photocopying Charges	23/06/2011	2011	Thursday	June	2011	23/06/2011	1	1	2	0	
32056	1SJY	Goods-General Stationery	23/06/2011	2011	Thursday	June	2011	23/06/2011	5	2	26	0	y
32558	1TAY	Service - Accommodation/Hotels	28/06/2011	2011	Tuesday	June	2011	28/06/2011	2	2	2	0	
32057	1TBY	Service-Air Travel	23/06/2011	2011	Thursday	June	2011	23/06/2011	2	1	3	0	

Table 28: Examples of the 2010-2012 dataset

The second step was to remove all transactions where the estimated delivery date was in the past, as exploration of the data and conversations with other staff had suggested these were posthumous records created after the event by Route A, or in some cases clearly data migration errors from before the SAP R3 computer system was installed in 2008. Note that I kept all records where the expected delivery date was equal to the document date, since at this stage it was not realistic to judge whether these were posthumous records, or accurate records of 'as soon as possible' (ASAP) demand. Orders with estimated delivery dates a long time into the future were left for later analysis as potential outliers, since some open ‘limit’ orders were raised to cover call-off activity (Route D in Figure 24). This filtering reduced the dataset to 47,199 cases, representing 143,619 distinct purchase orders and 267,402 line-items.

These two steps reduced the dataset as shown in Table 29 below.

	cases	% of full dataset	purchase orders	% of full dataset	line items	% of full dataset
full dataset	79695	100%	202544	100%	350208	100%
removed non delivery material groups	55842	70%	157088	78%	285243	81%
removed less than zero required delivery date	47199	59%	143619	71%	267402	76%

Table 29: Filtering of 2010-2012 purchasing data

This refined dataset was imported into the SPSS statistics package (version 24) and processed as follows:

1. Weekdays were recoded as numeric variables [Monday=1, Tuesday =2 etc.] for various analyses to work.
2. The resultant variable was recoded further into one that simply differentiated between weekends and weekdays [Weekdays=2, Weekends=1].

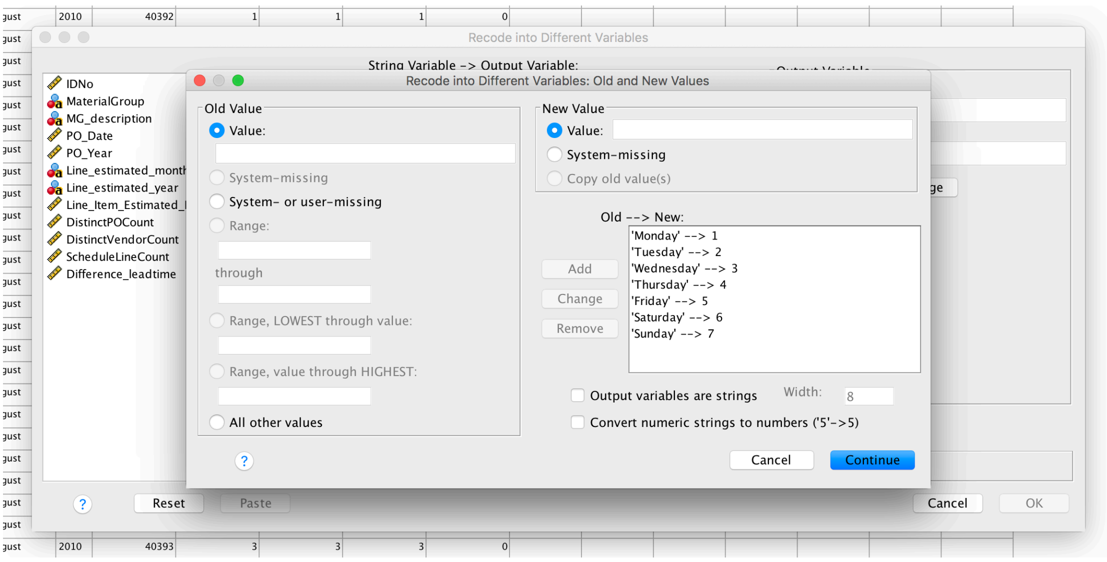
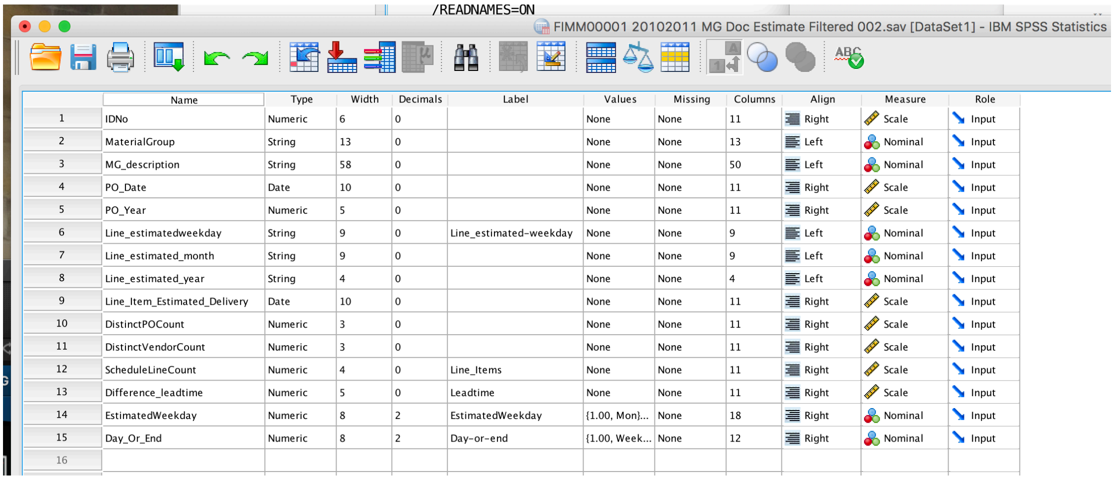


Figure 28: Recoding weekdays in purchasing data in SPSS

The useful dataset in SPSS was therefore as exampled in Figure 29



	Name	Type	Width	Decimals	Label	Values	Missing	Columns	Align	Measure	Role
1	IDNo	Numeric	6	0		None	None	11	Right	Scale	Input
2	MaterialGroup	String	13	0		None	None	13	Left	Nominal	Input
3	MG_description	String	58	0		None	None	50	Left	Nominal	Input
4	PO_Date	Date	10	0		None	None	11	Right	Scale	Input
5	PO_Year	Numeric	5	0		None	None	11	Right	Scale	Input
6	Line_estimatedweekday	String	9	0	Line_estimated-weekday	None	None	9	Left	Nominal	Input
7	Line_estimated_month	String	9	0		None	None	9	Left	Nominal	Input
8	Line_estimated_year	String	4	0		None	None	4	Left	Nominal	Input
9	Line_Item_Estimated_Delivery	Date	10	0		None	None	11	Right	Scale	Input
10	DistinctPOCount	Numeric	3	0		None	None	11	Right	Scale	Input
11	DistinctVendorCount	Numeric	3	0		None	None	11	Right	Scale	Input
12	ScheduleLineCount	Numeric	4	0	Line_Items	None	None	11	Right	Scale	Input
13	Difference_leadtime	Numeric	5	0	Leadtime	None	None	11	Right	Scale	Input
14	EstimatedWeekday	Numeric	8	2	EstimatedWeekday	{1.00, Mon}...	None	18	Right	Nominal	Input
15	Day_Or_End	Numeric	8	2	Day-or-end	{1.00, Week...	None	12	Right	Nominal	Input
16											

Figure 29: Purchasing dataset in SPSS variable view

6.3.8. Receivers of Goods

In 2011-2012 the University maintained 224 delivery addresses, as detailed below in Table 30: University Delivery Addresses 2011-2012. Of these, 52% were on the main campus, 10% were off-campus, 7% were halls of residence and 31% were medical facilities co-located with the NHS at the Royal Victoria Infirmary (RVI).

A pareto analysis of the purchasing data showed that the top 20.77% of delivery addresses (AKA as storage locations) accounted for 78.86% of all receipts, with medical and biological research facilities receiving the most items. These top receipt locations are show in Table 31 below.

Building	No Addresses	Main Campus	Off Campus	Medical Sciences	Halls of Residence
9 Kensington Terrace	1				
Agriculture Building	4	4			
Architecture Building	2	2			
Armstrong Building	7	7			
Baddiley-Clark Building	5			5	
Bedson Building	4	4			
Bowsden Court	1				1
Cassie Building	1	1			
Castle Leazes	2				2
Citygate	3		3		
Claremont Bridge	4	4			
Claremont Place	1			1	
Claremont Tower	4	4			
Close House	1		1		
Cochrane Park Sports Ground	1		1		
Cockle Park Farm	1		1		
Cookson building	6			6	
Cultural & Heritage Studies	1	1			
Daysh Building	5	5			
Devonshire Building	9	9			
Dove Marine Laboratory	1		1		
Drummond Building	3	3			
Dukesway Court, Team Valley	1		1		
Easton Halls	1				1
Fine Art Building	1	1			
Grand Assembly Rooms	3	3			
Grand Hotel	1				1
Heaton Sports Ground	1		1		
Henderson Hall	2				2
Henry Wellcome Building	2			2	
Herschel Building	4	4			
Herschel Building Annex	1	1			
International Centre for Life	4		4		
King George VI Building	8	8			
King's Gate	18	18			

Building	**No Addresses**	**Main Campus**	**Off Campus**	**Medical Sciences**	**Halls of Residence**
King's Road Centre (Loading)	4	4			
Law School	1	1			
Leazes Parade	1				1
Leazes Terrace	1				1
Longbenton Sports Ground	1		1		
Medical School	10			10	
Merz Court	6	6			
Moorbank Garden, Claremont Road	1		1		
Nafferton Farm	2		2		2
Newburn Boat House	1		1		
Newcastle General Hospital	9			9	
Old Library Building	5	5			
Paul O'Gorman Building	1			1	
Percy Building	2	2			
PLEASE SEE BELOW	1				
PO Box 1311	1		1		
Richardson Road	2				2
Ridley Building	6	6			
Robinson Library	2	2			
Royal Victoria Infirmary	7			7	
St Mary's College	2				2
Stephenson Building	7	7			
Students Union	2	2			
The Dental School	8			8	
University Sports Centre	2	2			
Washington Direct Mail Ltd	3		3		
William Leech Building	20			20	
Windsor Terrace	1				1
Wolfson Unit	1			1	
Grand Total	**224**	**116**	**22**	**70**	**16**

% of Addresses		**52%**	**10%**	**31%**	**7%**

Table 30: University Delivery Addresses 2011-2012

Storage location	Name of location	Deliveries	% of deliveries	% cumulative
UON1/M039	Institute for Cell and Molecular Bioscience (ICMBB)	10169	8.26%	8.26%
UON1/M055	Genetic Medicine	7406	6.01%	14.27%
UON1/M026	National Institute for Cancer Research (NICR) O'Gorman	7330	5.95%	20.22%
UON1/M008	ICMB Cath Cook F4	4676	3.80%	24.02%
UON1/C045	ESS Direct Works	4425	3.59%	27.61%
UON1/S005	Chem Stores	4358	3.54%	31.15%
UON1/M010	ICMB Will Leech F4	4162	3.38%	34.53%
UON1/M012	ICMB Will Leech F3	3723	3.02%	37.55%
UON1/M001	IAH labs	3453	2.80%	40.36%
UON1/M032	Neuro Henry Welc	3285	2.67%	43.02%
UON1/M040	ICMB CBCB	2927	2.38%	45.40%
UON1/S039	School of EECE	2844	2.31%	47.71%
UON1/X001	Please See Below	2743	2.23%	49.94%
UON1/M002	IAH MRG	2694	2.19%	52.12%
UON1/C005	NUIT Main	2120	1.72%	53.85%
UON1/S001	Civil Eng. Cassie	2056	1.67%	55.51%
UON1/S025	Mech Eng. School	2051	1.67%	57.18%
UON1/M031	National Institute for Cancer Research (NICR) Chem Labs	1856	1.51%	58.69%
UON1/M046	CBC	1853	1.50%	60.19%
UON1/S019	Chem Eng. Gen Off	1808	1.47%	61.66%
UON1/S027	Mech Eng. Design	1797	1.46%	63.12%
UON1/M011	ICMB Will Leech FG	1769	1.44%	64.55%
UON1/S002	Civil Eng. Drum	1607	1.30%	65.86%
UON1/C078	Castle Leazes Hall of Residence	1495	1.21%	67.07%
UON1/S011	Biology Ridley	1486	1.21%	68.28%
UON1/S031	Agriculture School	1381	1.12%	69.40%
UON1/C049	ESS Med Workshop	1369	1.11%	70.51%
UON1/M028	National Institute for Cancer Research (NICR) Leukaemia	1335	1.08%	71.60%
UON1/M014	ICMB Will Leech F2	1286	1.04%	72.64%
UON1/C039	Kings Gate (Main Admin) Level 1 Post	1251	1.02%	73.66%
UON1/M015	ICMB Wolfson	1144	0.93%	74.59%
UON1/S016	Marine Sci Armstrong	1040	0.84%	75.43%
UON1/C031	Robinson Library	1026	0.83%	76.26%
UON1/S030	INEX - Nano lab	900	0.73%	76.99%
UON1/S020	Chem Eng. Workshop	898	0.73%	77.72%
UON1/M041	Biomed Sciences	893	0.73%	78.45%
UON1/S013	Biology Devonshire	881	0.72%	79.16%

Storage location	Name of location	Deliveries	% of deliveries	% cumulative
UON1/M035	Institute of Health and Society Main	862	0.70%	79.86%
	20.77% of all delivery locations by count	98359		79.86%
	Grand TOTAL	123159		100.00%

Table 31: Goods Receipts 2011-2012, top 79.86% of receipts

Further analysis of goods flow by delivery addresses was carried out in preparation for the pilot; this is discussed further in 8.9.6.

6.3.9. Differences in purchasing volume between weekends & weekdays

The first questions with the new dataset were: Did valid purchase line items for goods that generated freight vehicle deliveries vary from weekends to weekdays and, if so, was it valid to remove the weekends from the dataset?

To answer these questions, it was necessary to test whether the frequency of line item counts was distributed normally for weekdays and weekends. Since the sample size was greater than both 50 and 2000, a Kolmogorov-Smirnov test of normality was appropriate (Royston, 1982; Razali and Wah, 2011). The null-hypothesis of this test was that the population was normally distributed. Since the p-value was less than the chosen alpha level of 0.05, the null hypothesis was rejected and the data tested were non-parametric, i.e. not from a normally distributed population; this is evidenced in Table 32 and in a Q-Q plot shown as Figure 30.

		Kolmogorov-Smirnov[a]		
	Day	Statistic	df	p-value
Line Items	Weekdays	.319	46464	.001
	Weekends	.328	735	.001
a. Lilliefors Significance Correction				

Table 32: Test of normality (K-S) of purchasing line items by weekdays or weekends, fiscal periods 2010-2011

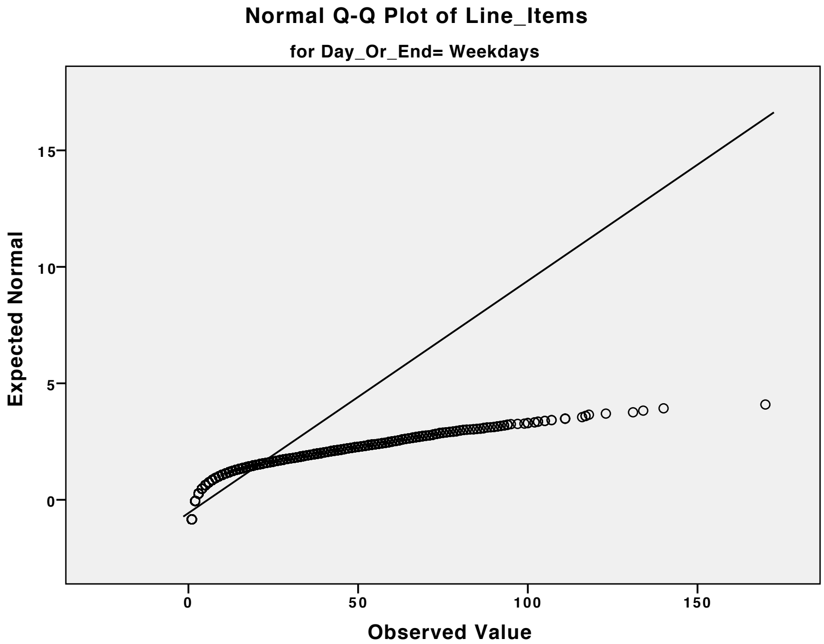


Figure 30: Non-parametric Q-Q Plot of Line Items by Weekdays or Weekends, fiscal periods 2010-2011

It was appropriate for non-normally distributed data to use a non-parametric test: in this case a Mann-Whitney test, which confirmed there was a significant difference between weekends and weekdays. This clear disparity between the two, together with the fact that the traffic survey data would be gathered for weekdays only, caused me to exclude weekends from further analysis.

6.3.10. Differences in purchasing volume between weekdays

The next clear question was whether weekdays differed from one to the other. If not, then analysis could proceed at an aggregated level, but suggestions had been made that Mondays might have differed, being the first day of the week, or that Wednesday - a traditional 'sports afternoon' day - might not have been the same.

The simple column bar chart at Figure 31 showed an apparent lower level of line-item demand on Mondays and Fridays, with no apparent difference within mid-week days.

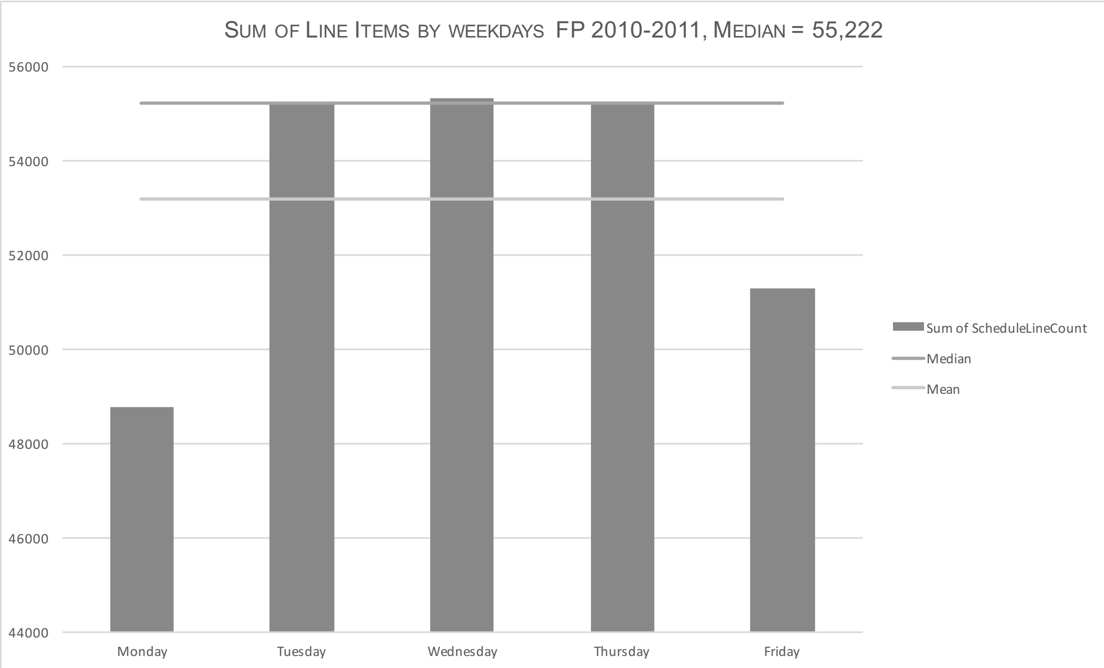


Figure 31: Purchasing line items by weekday, fiscal periods 2010-2011

To analyse the significance of this difference in SPSS, normality tests were again the first step; these showed that distribution across the weekdays was not normal and that non-parametric tests would be appropriate. The Kruskal-Wallis H test was a rank-based nonparametric test that could be used to determine if there were statistically significant differences between two or more groups of an independent variable on a continuous or ordinal dependent variable. It is considered an extension of the Mann-Whitney U test, and the nonparametric alternative to the one-way ANOVA, that allowed the comparison of more than two independent groups, thus weekends were excluded by use of ranges.

To use this test, two hypotheses were formed:

> H_0 There was no difference between the purchasing activity of line items in the data between individual weekdays.
>
> H_1 There was a difference between the purchasing activity of line items in the data between individual weekdays.

Ranks			
	weekdays	n	Mean Rank
Line Items	Mon	8863	22849.54
	Tue	9250	23432.30
	Wed	9691	23205.46
	Thu	9128	23661.10
	Fri	9532	23011.75
	Total	46464	

Test Statistics [a,b]	
	Line Items
Chi-Square	22.803
df	4
p-value	.001
a. Kruskal-Wallis H Test	
b. Grouping Variable: weekdays	

Table 33: Kruskal-Wallis H test of variance in line items between weekdays, fiscal periods 2010-2011

The null hypothesis was found false; as such the variance between days was significant. To understand which days were different from each other, a 5 x 5 matrix pairwise mapped days against each other and tested variance one from the other. Since this was non-parametric, each comparison utilised a Mann-Whitney test, since each day was assumed to be independent. This generated a matrix grid of 10 results (since testing a group versus itself was null, and the test was not handed, e.g. a versus b was the same as b versus a). There was a danger in multiple testing within the same family that this could generate false positives; since a significant result of 0.05 was 5%, 0-1 false positives could be expected. This was resolved by controlling the familywise error rate, using the Bonferroni correction. Instead of setting the critical P level for significance, or alpha, to 0.05, a lower critical value was calculated by dividing the familywise error rate (usually 0.05) by the number of tests (Field, 2013, p. 69). In this case, this was 0.05/10, or an alpha-value of 0.005.

6.3.11. Pairwise testing script for non-parametric data

The testing was non-parametric, for which SPSS had no automated procedures. I therefore drafted a small script to complete the task, as follows in Table:

```
DATASET ACTIVATE DataSet1.
NPAR TESTS
 /M-W= ScheduleLineCount BY EstimatedWeekday(1 2)
 /MISSING ANALYSIS.
DATASET ACTIVATE DataSet1.
NPAR TESTS
 /M-W= ScheduleLineCount BY EstimatedWeekday(1 3)
 /MISSING ANALYSIS.
DATASET ACTIVATE DataSet1.
NPAR TESTS
 /M-W= ScheduleLineCount BY EstimatedWeekday(1 4)
 /MISSING ANALYSIS.
DATASET ACTIVATE DataSet1.
NPAR TESTS
 /M-W= ScheduleLineCount BY EstimatedWeekday(1 5)
 /MISSING ANALYSIS.
DATASET ACTIVATE DataSet1.
NPAR TESTS
 /M-W= ScheduleLineCount BY EstimatedWeekday(2 3)
 /MISSING ANALYSIS.
DATASET ACTIVATE DataSet1.
NPAR TESTS
 /M-W= ScheduleLineCount BY EstimatedWeekday(2 4)
 /MISSING ANALYSIS.
DATASET ACTIVATE DataSet1.
NPAR TESTS
 /M-W= ScheduleLineCount BY EstimatedWeekday(2 5)
 /MISSING ANALYSIS.
DATASET ACTIVATE DataSet1.
NPAR TESTS
 /M-W= ScheduleLineCount BY EstimatedWeekday(3 4)
 /MISSING ANALYSIS.
DATASET ACTIVATE DataSet1.
NPAR TESTS
 /M-W= ScheduleLineCount BY EstimatedWeekday(3 5)
 /MISSING ANALYSIS.
DATASET ACTIVATE DataSet1.
NPAR TESTS
 /M-W= ScheduleLineCount BY EstimatedWeekday(4 5)
 /MISSING ANALYSIS.
```

Table 34: Pairwise SPSS script for line items weekday matrix

In each pairwise test, the null hypothesis was that the datasets were not different and therefore a significant result, where p was equal to or less than the alpha, would show they were probably different beyond chance. The results, shown in Table 35, showed that Monday and Tuesday, Monday and Thursday, and Thursday and Friday varied significantly one from the other in the number of line items placed.

p values	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
Monday		**0.002**	0.061	**0.001**	0.388
Tuesday	**0.002**		0.228	0.231	0.026
Wednesday	0.061	0.228		0.160	0.301
Thursday	**0.001**	0.231	0.160		**0.001**
Friday	0.388	0.026	0.301	**0.001**	
Mann Whitney pairwise, alpha = 0.005, <0.001 rounded as 0.001					
Shaded green are significant and therefore vary pairwise					

Table 35: Weekdays pairwise Mann Whitney variance testing showing significant differences between purchasing line items, fiscal periods 2010-2011

This tended to confirm the initial graphical view observed in Figure 31: Purchasing line items by weekday, fiscal periods 2010-2011 - that orders for Monday and Fridays had significantly fewer line items raised than the 3 mid-week days.

6.3.12. Difference in purchasing volume by months

In order to extrapolate from a limited time period, say a single week traffic survey, or a pilot lasting some months, it was useful to understand how the University's purchasing volume varied by month through a typical year. To that end, the broad overview of all activity shown in Figure 26: Scheduled Line Items by Month 2008-2012 was refined further, using the new filtered dataset.

		Kolmogorov-Smirnov[a]		
	month from date	Statistic	df	Sig.
Line Items	Jan	.317	3646	.001
	Feb	.322	3893	.001
	Mar	.324	4641	.001
	Apr	.311	3725	.001
	May	.320	4152	.001
	Jun	.317	4056	.001
	Jul	.313	4725	.001
	Aug	.317	3588	.001
	Sep	.319	3914	.001
	Oct	.316	3958	.001
	Nov	.315	4059	.001
	Dec	.335	2842	.001
a. Lilliefors Significance Correction				

Table 36: Test of normality (K-S) of purchasing line items by months, fiscal periods 2010-2011

A Kolmogorov-Smirnov test for normality, Table 36, confirmed that the data were not distributed normally, and a simple column bar chart of the filtered dataset, Figure 32, suggested once again that purchasing demand dropped in volume at Christmas and New Year (December and January), Easter (April), and summer vacation (August). At the same time the data showed peaks in March and July, both immediately before significant vacations at Easter and in August.

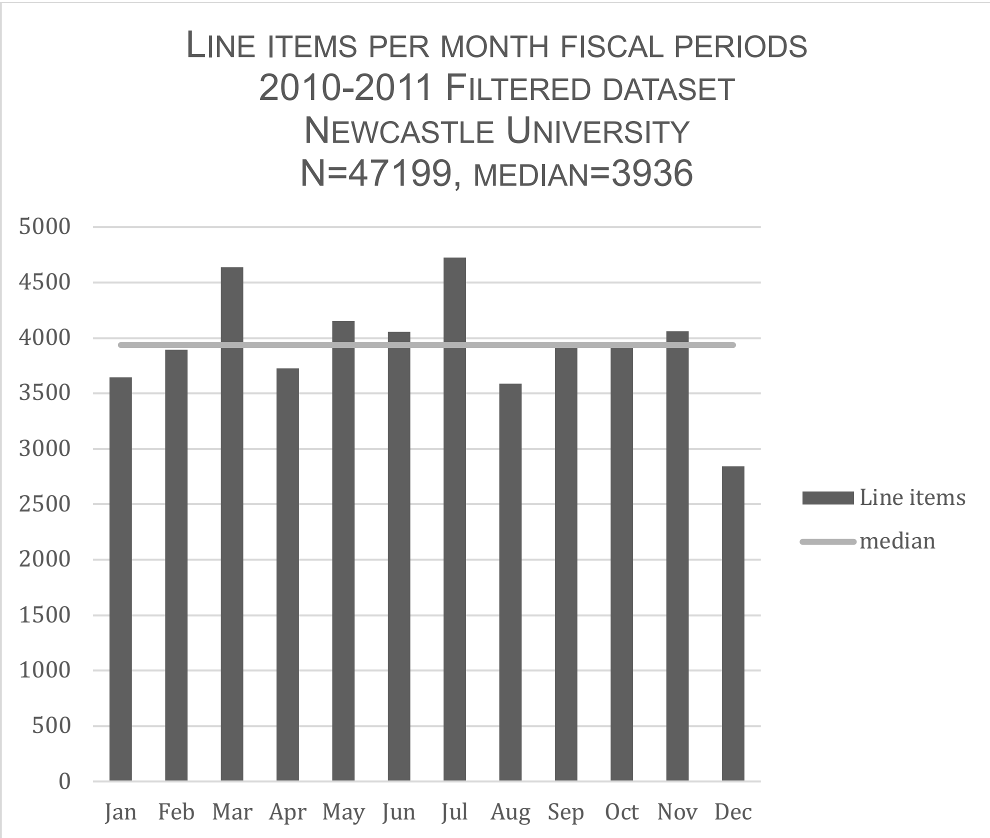


Figure 32: Line items per month, fiscal periods 2010-2011

In order to test if this apparent difference was significant, two hypotheses were framed:

> H_0 There was no difference between the purchasing activity of line items in the data between individual months.
>
> H_1 There was a difference between the purchasing activity of line items in the data between individual months.

A Kruskal-Wallis H-test showed that, with a p value of 0.002, there were significant differences between the months; H_1 was therefore most likely. The null hypothesis having been found false, a 12 x 12 matrix was constructed, pairwise mapping months against each other, and testing variance one from the other. Since this was non-parametric, each comparison utilised a Mann Whitney test, as each month was assumed to be independent, but within the same family. This generated a matrix grid of 66 results and, applying the Bonferroni correction of familywise error rate divided by number of tests (0.05/66), an alpha value of 0.000757576 was arrived at, against which to test p values for pairwise difference. This illustrated a problem with the Bonferroni correction, in that it could lead to loss of statistical power and a possible Type II error, e.g. missing genuine effects in the data. A revised, less conservative alpha of 0.001 was accordingly adopted (Elwood, 2007, p. 211; Armstrong, 2014), but with a view to applying judgement post-analysis.

After completing the pairwise analysis - and noting that in each pairwise Mann-Whitney test a significant result indicated difference - the results were tabulated in Table 37, with significant differences according to an alpha of 0.001 shaded in green, and those that would only be significant with a normal significance of 0.05 shaded in amber.

The most heterogenous month was January, as one might expect from Figure 32, but next was October, which seemed counter-intuitive to the graphic. July was significantly different from January and February, as one might have expected. July was also significantly different to October and November, but not to December. August was not different to others, despite falling almost as far below the median as January. The key phases of a University year at Newcastle were the start of term time activities in September and October; the Easter vacation; the Winter vacation in December; and the summer vacation roughly covering July and August. During the vacations most of the 20,000 students would be not attending campus regularly, and fewer of the 5,000 staff (see numbers in 1.3 above).

In addition, while the tax year started in April, the University financial year started in August. Therefore, one might have expected to see a rise in orders prior to the start of term, perhaps a fall in July/August, and a dip in December. Mapping the line item median in Figure 32 above did indeed show a dip in August and December; however, it also showed a substantial rise in line items in July - a vacation month. This may have been due to the financial nature of the data, with invoices being ‘cleared up’ before the end of the University year, and not reflective of the actual level of delivery activity.

A similar rise in March, relative to a slump in April, might have reflected the effect of the Easter vacation; however, it might equally have been caused by an annual ‘clearing’ of unrecorded invoices as POs before the end of the tax year.

What was clear was that the diversity and difference through the year indicated that any evaluative approach based upon a baseline model could incorporate this seasonality - probably in the form of a normalisation around a set index – but only with a high degree of scepticism with regard to the data source.

What was perhaps puzzling was how little the seasonality was affected by the falls in student numbers, suggesting that the variable activities associated with teaching are lower than one might imagine.

At this stage in my work, and with participative work starting, the annual seasonality was taken as variable and a new key issue was addressed. Seasonality is further addressed in section 10.6.4.

p values	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Jan		0.137	0.001	0.001	0.001	0.001	0.001	0.004	0.001	0.346	0.124	0.001
Feb	0.137		0.002	0.003	0.053	0.008	0.001	0.144	0.068	0.564	0.977	0.009
Mar	0.001	0.002		0.976	0.204	0.633	0.524	0.096	0.209	0.001	0.002	0.836
Apr	0.001	0.003	0.976		0.240	0.672	0.514	0.118	0.236	0.001	0.003	0.864
May	0.001	0.053	0.204	0.240		0.453	0.056	0.666	0.956	0.010	0.054	0.372
Jun	0.001	0.008	0.633	0.672	0.453		0.261	0.248	0.432	0.001	0.008	0.822
Jul	0.001	0.001	0.524	0.514	0.056	0.261		0.021	0.053	0.001	0.001	0.431
Aug	0.004	0.144	0.096	0.118	0.666	0.248	0.021		0.708	0.039	0.149	0.206
Sep	0.001	0.068	0.209	0.236	0.956	0.432	0.053	0.708		0.014	0.068	0.349
Oct	0.346	0.564	0.001	0.001	0.010	0.001	0.001	0.039	0.014		0.541	0.001
Nov	0.124	0.977	0.002	0.003	0.054	0.008	0.001	0.149	0.068	0.541		0.009
Dec	0.001	0.009	0.836	0.864	0.372	0.822	0.431	0.206	0.349	0.001	0.009	

Mann Whitney pairwise, alpha = 0.001, <0.001 rounded as 0.001

Shaded green are significant and therefore vary pairwise

Shaded amber are significant with normal alpha of 0.05

Table 37: Monthly pairwise Mann Whitney variance testing purchasing line items, fiscal periods 2010-2011

6.3.13. Lead-time for delivery

What was the normal difference between an order being placed and when the goods were expected/required? Was the University generating just-in-time demand on suppliers and, if so, at what level and quantity? It was necessary to understand this expression of demand in order to improve the understanding of purchasing and also the traffic survey data.

As discussed, the dataset from fiscal periods 2010-2011 had now been purged of all items with lead-times of less than zero, all material groups that did not usually generate freight vehicle deliveries, and weekends. To scope this new issue, the number of days between the date of the PO and the required (estimated) delivery date would be counted, effectively recording a lead-time. These data were imported into the statistics package SPSS and lead-time was thus analysed.

N Valid	47199	Line items	
Missing	0		Lead-time (days)
		Mean	7.58
		Median	1.00
		Mode	0
Range	3667		
Percentiles (IQR)		25	.00
		50	1.00
		75	4.00

Table 38: Lead-time distributions, averages and interquartile ranges, (lead-time >=zero) weekdays only FP2010-FP2011

As shown in Table 38 above, the dataset had a valid population of 47,199, with none missing (N). There was a large range of lead-time (days) of 3667 but, as could be seen from the interquartile ranges, most cases fell into a lead time range of 0 to 4 days, with a median of 1. The proportion of line items placed with a lead-time of zero (the mode) was 38.6%. The Business Warehouse reports available did not make it easy to compare the PO date, the required (estimated) delivery date, and the invoice received date, so the proportion of these that were recording posthumous data was unknown. A Kolmogorov-Smirnov test of normality clearly showed the data to be not normally distributed, hence the difference between mean and median. Given this fact, the median was the more appropriate summary statistic to use.

	Kolmogorov-Smirnov[a]		
	Statistic	df	p-value
Lead-time	.419	46464	.001
a. Lilliefors Significance Correction			

Table 39: Test of normality of lead-time fiscal periods, fiscal periods 2010-2011

The 0-4 days range was the time between the raising of a PO and the *estimated* delivery date - effectively the *requested* delivery date, given the format of the University's POs. Zero days probably indicated either a posthumous order, or an 'as soon as possible' order.

The online survey of staff in 2014 had shown that the majority of goods deliveries ordered for work purposes were expected to be received 'as soon as possible', including the top commodities purchased: 'travel tickets or documentation'; 'books, literature, etc.'; 'repair or maintenance services'; and 'ICT equipment. For 'catering', 'food and beverages' and 'furniture', the expected delivery was on a 'specified date'. The only goods that had mostly 'next day' delivery expectations were 'office stationery' and 'travel tickets and documentation', while goods with the lowest incidence of critical delivery time were 'catering' and 'repair or maintenance'. A significant number of responses had indicated that 'office stationery' and 'ICT equipment' delivery times were not actually critical - contradicting the fast delivery often stated on the PO. It could be concluded that the characteristics of goods determined the way that they were expected to be delivered; however, whatever expected delivery time characteristics could be drawn from the survey, it was notable that the University SAP-based ordering system defaulted to 'next day delivery' (Aditjandra and Zunder, 2017).

Subject to the caveats of the poor data quality, it appeared that POs following Route B were typically placed with a delivery date between next day and 4 days in the future - a fast lead-time with a median of 1. The University did appear to express a demand pattern similar to a just-in-time car plant, or a consumer on Amazon.

6.3.14. Difference in lead-times by weekdays

One clear difference in demand pattern through the weekdays, shown in Table 40, was that orders placed for Monday delivery had a lead-time median of 3; also, both Monday and Tuesday deliveries had line items raised with a longer lead-time than on Wednesday-Friday. A Kruskal-Wallis test, shown in Table 41, also confirmed that the lead-times for each weekday differed significantly one from the other. The 3-day median for orders placed for Monday suggested a tendency for Friday replenishment order activity for the following week.

Percentiles		Weekdays	5%	10%	25%	50%	75%	90%	95%
Weighted Average (Definition 1)	Lead-time	Mon	.00	.00	.00	3.00	4.00	11.00	25.00
		Tue	.00	.00	.00	1.00	5.00	12.00	29.00
		Wed	.00	.00	.00	1.00	2.00	8.00	21.00
		Thu	.00	.00	.00	1.00	2.00	8.00	22.00
		Fri	.00	.00	.00	1.00	3.00	9.00	22.00

Table 40: Percentile frequency of lead-time, fiscal periods 2010-2011 showing interquartile range

Chi-Square	725.865
df	4
p-value	.001
a. Kruskal-Wallis H Test	
b. Grouping Variable: EstimatedWeekday	

Table 41: Kruskal-Wallis test of normality, lead-time grouped by estimated weekdays

The null hypothesis was found false and as such the variance between days was significant. To understand which days were different from each other, a 5 x 5 matrix pairwise mapped days against each other and tested variance one from the other. Using a modified SPSS script to the one shown in Table 34: Pairwise SPSS script for line items weekday matrix, and using the same Bonferroni correction - thus an alpha of 0.005 - the lead-time variance by day was tested. Again, in each pairwise test the null hypothesis was that the datasets were not different; therefore, a significant result where p was equal to or less than the alpha would show they were probably different.

p values	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
Monday		**0.001**	**0.001**	**0.001**	**0.001**
Tuesday	**0.001**		0.365	**0.001**	**0.001**
Wednesday	**0.001**	0.365		0.060	**0.001**
Thursday	**0.001**	**0.001**	**0.060**		**0.001**
Friday	**0.001**	**0.001**	**0.001**	**0.001**	
Mann Whitney pairwise, alpha = 0.005, <0.001 rounded as 0.001					
Shaded green are significant and therefore vary pairwise					

Table 42: Weekdays pairwise Mann-Whitney variance testing purchasing lead-time, fiscal periods 2010-2011

The results showed a high degree of heterogeneity between Monday and Friday, from all other days and each other, with some homogeneity between Tuesday-Wednesday and Wednesday-Thursday. This suggested that the range for Mondays was significantly different and that the median of 3 (seen in Table 40: Percentile frequency of lead-time, fiscal periods 2010-2011 showing interquartile range) could be taken to suggest that these longer lead-times of around 3 days into the future were caused by Friday ordering for Monday delivery. For the rest of the week, orders created a much faster demand on the supplier base, especially Wednesday and Thursday, where 75% of all orders were for 0-2 day lead-times. All in all, given that Friday orders for Monday were effectively ‘next working day’, there was strong evidence that the University generated an almost JIT demand on its supplier base.

6.4. Traffic Survey

Following meetings with the University Estates Service and Purchasing function, traffic entrance points were identified that were associated with the most sensitive freight traffic locations. These are shown in Figure 33 below. The traffic count was carried out by paid surveyors recording vehicles in and out at five points: Sites 1 and 2, that cordoned off the main campus; Site 3, the buildings concentrated around Park Terrace; and Sites 4 and 5 that gave access to the University’s combined medical research and teaching facilities. The latter two Sites were shared with the NHS Royal Victoria Infirmary (RVI) hospital - especially Site 5, which was the main RVI Goods-In entrance (Site 4 was for University receipts only). Two other Sites were also identified, but excluded from this research as being outside of the scope and potentially unsound.

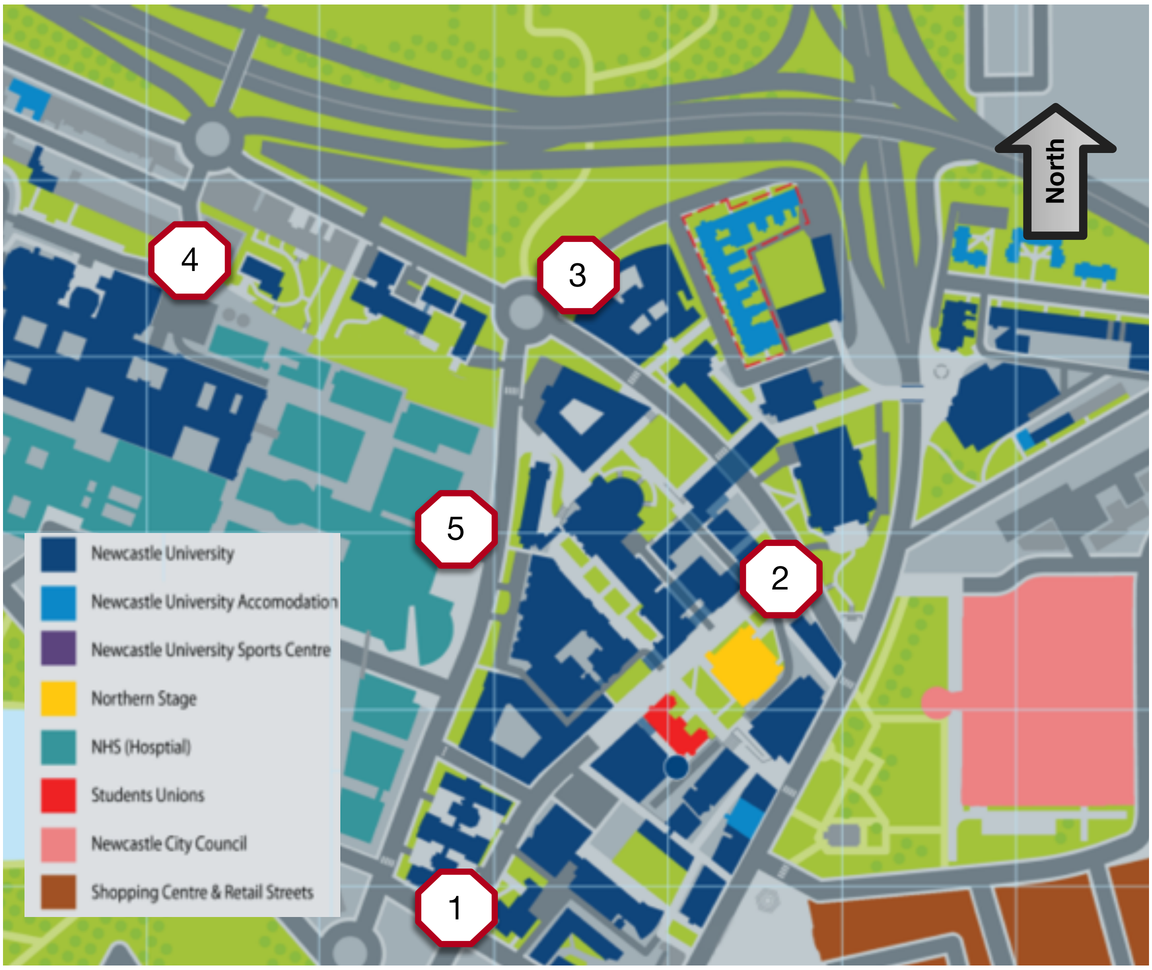


Figure 33: Main Campus of Newcastle University with numbered traffic count points 2012, adapted from University publicity materials

A tender was issued for the survey, to an agreed specification; this was awarded to an experienced company that had carried out a deal of similar work for the City Council and others. The survey was carried out from 7am to 7pm, from Monday 30th April 2012 to Friday 4th May 2012. The week was chosen to be in main term time, not in or near a major holiday, and before students started to revise or take main examinations. No major events or disruptions on the campus were expected or reported.

In order to fully inform all staff and students, the University website carried this statement in the week before and during the survey:

> *"As part of a longitudinal study over several years, researchers in NewRail are carrying out traffic surveys on the University campus each year in the first week of May. This survey was focused on freight deliveries to and from the campus, and was to assess the changes in goods deliveries as changes are made to the*

different purchasing and access policies of the University. This was to support the University Coherent Campus initiative, which looks to improve the spaces between buildings to create a sense of place that was welcoming, with well designed, well linked social spaces. The campus aims to be permeable, pedestrian and cyclist friendly, safe, clean and tidy, visually recognisable, clearly defined and environmentally sustainable. The survey was being carried out by an external traffic survey company (SMS) which has extensive expertise, and the decision to use them, as opposed to students, was based on the need for stable survey techniques over an extended period of years. All vehicles will be recorded, and although registration numbers are recorded to allow for analysis of freight vehicle movements around the campus and city, no vehicle registration numbers will be revealed and all reporting will be wholly anonymised. If you would like to discuss the research further then please contact Tom Zunder, tom.zunder@ncl.ac.uk"

One query was received, from an anonymised email address, querying why the survey was being carried out and to what use the results would be put. An email reply was sent placing the work in the wider context and assuring the questioner that the survey results would only be utilised anonymously and were indeed focused on commercial movements and not private. No further communication ensued, and the survey was completed to plan.

6.4.1. Knowledge needed from the Traffic Survey(s)

In order to begin to understand how the University campus was visited by freight vehicles, the following questions needed to be addressed - a sub-set of the full list:

- How many freight delivery vehicles visited the main campus?
- When did the freight vehicles visit?
- How long did the freight vehicles stay?
- How did those visits differ between
    - different Sites on the campus;
    - different vehicle classes; and
    - different engine types?

6.4.2. Traffic survey data processing

The data recorded were the Site, the time of a vehicle movement, the classification of the vehicle, any logo or ID name on the vehicle, and the direction of the movement, i.e. IN or OUT of the campus. The traffic classification included 7 types of freight vehicles, 4 types of commercial passenger vehicle, and 2 types of private passenger vehicle, as listed in Table 43.

Vehicle Key	Text
2	2 Axle HGV
3	3 Axle HGV
4	4 Axle HGV
3a	3 Axle Artic
4a	4 Axle Artic
5a	5+ Axle Artic
A	Ambulances
C	Coaches
L	Light Goods
M	Motor Cyclist
MB	Mini Buses
T	Taxi
	Car

Table 43: Vehicle Classifications

The surveyors' audio recorded tallies were transcribed by the survey company and provided as raw data. Table 44 shows an extracted anonymised exemplar.

Site	Time	Vehicle No. Plate	Vehicle Type/Class	Logo/ID/Name	Direction e.g. In/Out	date
Site 1	0759	[redacted]			IN	30.04.2012
Site 1	1806	[redacted]			OUT	30.04.2012
Site 1	0713	[redacted]			IN	30.04.2012
Site 1	0716	[redacted]			OUT	30.04.2012
Site 1	0928	[redacted]	2	ANONYMISED	IN	30.04.2012
Site 1	0937	[redacted]	2	ANONYMISED	OUT	30.04.2012
Site 1	1310	[redacted]	L	ANONYMISED	IN	30.04.2012
Site 1	1326	[redacted]	L	ANONYMISED	OUT	30.04.2012
Site 1	1312	[redacted]	2	ANONYMISED	IN	30.04.2012
Site 1	1313	[redacted]	2	ANONYMISED	OUT	30.04.2012
Site 1	1801	[redacted]	L	ANONYMISED	IN	30.04.2012
Site 1	1802	[redacted]	L	ANONYMISED	OUT	30.04.2012
Site 1	1551	[redacted]	L	ANONYMISED	IN	30.04.2012
Site 1	1553	[redacted]	L	ANONYMISED	OUT	30.04.2012
Site 1	0840	[redacted]	2	ANONYMISED	IN	30.04.2012
Site 1	0854	[redacted]		ANONYMISED	OUT	30.04.2012
Site 1	0723	[redacted]	4A	ANONYMISED	IN	30.04.2012
Site 1	0744	[redacted]	4		OUT	30.04.2012
Site 1	0939	[redacted]	4	ANONYMISED	IN	30.04.2012
Site 1	1007	[redacted]	4	ANONYMISED	OUT	30.04.2012
Site 1	1236	[redacted]		ANONYMISED	IN	30.04.2012
Site 1	1248	[redacted]	L	ANONYMISED	OUT	30.04.2012
Site 1	1426	[redacted]	L	ANONYMISED	IN	30.04.2012
Site 1	1429	[redacted]	L	ANONYMISED	OUT	30.04.2012
Site 1	1202	[redacted]	L	ANONYMISED	IN	30.04.2012
Site 1	1215	[redacted]			OUT	30.04.2012
Site 1	0913	[redacted]			IN	30.04.2012

Table 44: Example anonymised raw traffic data Newcastle Site 1 30.04.2012

The data contained many errors, with the logo field in particular proving of little use, due to poor recording of this detail by the survey team. A first pass was made at correcting obvious errors. The data were processed to adapt the raw time date to a useable Excel date field. This would be better addressed in 2015 and the utility of logos is explored in section 10.7.7 below.

As Ahlemeyer-Stubbe and Coleman explained: in order "to stabilise and improve data mining models, it is preferable to classify continuous variables, such as turnover, amount or purchasing days into different levels. Using such a classification, it is possible to stress more strongly differences between levels that are important from the business point of view" (2014, p. 72).

The time was 'binned[26]', using the Excel FLOOR formula to group the movements into rounded-down half-hour blocks. Finally, the engine emission type of each vehicle was identified.

To allow quantitative evaluation of vehicle emissions, in Chapter 8, it was important to know the type of engines in the vehicles that visited the campus. Since September 2001, UK number plates had followed a formula where the 4^{th} and 5^{th} characters represented half years (Sept-February; March-August); this made it possible to identify the registration period and cross match this with the dates of the EURO engine, to calculate the type of engine in the vehicle. Number plates that conformed to older numbering systems could be recorded as pre-Euro 3/III. This differed by vehicle classification, so a combination of data lookup (Excel VLOOKUP) functions, tables of classification (Table 43), and the introduction of different emission standards (Table 45) was used to derive these data.

Every 4 to 5 years a new Euro standard had ensured that vehicles sold had lower emissions: timings are given by vehicle type in Table 45 below. This provided a guide to the emission standards of each vehicle type, by date of manufacture. All dates listed referred to new type approvals. Since all vehicles had only to meet the standards within a year after the date shown (to allow sales of vehicles already produced), the relevant registration dates from the Automobile Association were used in the final spreadsheets see Table 45 and Table 47, (Automobile_Association, 2015; European Commission, 2016).

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[26] *Data binning is a statistical method to group more or less continuous values into a smaller number of "bins". For example, if you have data about a group of cars, you might want to arrange their date of registration into a smaller number of annual intervals.*

	Euro 1/I	Euro 2/II	Euro 3/III	Euro 4/IV	Euro 5/V	Euro 6/VI	Euro 6 Red Diesel
Passenger cars	July 1992	Jan 1996	Jan 2000	Jan 2005	Sept 2009	Sept 2014	Sept 2017
Light commercial vehicles (N1-I) ≤1305kg	Oct 1994	Jan 1998	Jan 2000	Jan 2005	Sept 2010	Sept 2014	Sept 2017
Light commercial vehicles (all others)	Oct 1994	Jan 1998	Jan 2001	Jan 2006	Sept 2010	Sept 2015	Sept 2017
Trucks and buses	1992	1995	1999	2005	2008	2013	Sept 2017
Motorcycles	2000	2004	2007	2016	2020		
Mopeds	2000	2002		2017	2020		

Table 45: Euro Emissions Standards (as of 2016) Source:(European Commission, 2016)

In addition, but parallel to the standards, was the term: ‘enhanced environmentally friendly vehicle’ (EEV), used in the European emission standards for the definition of a ‘clean vehicle’ > 3.5 tonne in the categories M2 and M3. The standard lay between the levels of Euro V and Euro VI.

Extracted Plate Year		Year	Engine
0		Unknown	Unknown
2		2002	Euro 3
3		2003	Euro 3
4		2004	Euro 3
5		2005	Euro 4
6		2006	Euro 4
7		2007	Euro 4
8		2008	Euro 4
9		2009	Euro 4
10		2010	Euro 4/5
11		2011	Euro 5
12		2012	Euro 5
13		2013	Euro 5
14		2014	Euro 5
15		2015	Euro 5
51		2001/02	Euro 3
52		2002/03	Euro 3
53		2003/04	Euro 3
54		2004/05	Euro 3/4
55		2005/06	Euro 4
56		2006/07	Euro 4
57		2007/08	Euro 4
58		2008/09	Euro 4
59		2009/10	Euro 4
60		2010/11	Euro 5
61		2011/12	Euro 5
62		2012/13	Euro 5
63		2013/14	Euro 5
64		2014/15	Euro 5
65		2015/16	Euro 6
99		pre 2001	pre Euro 3/III
502		2002	Euro III
503		2003	Euro III
504		2004	Euro III
505		2005	Euro III/IV
506		2006	Euro IV
507		2007	Euro IV
508		2008	Euro IV
509		2009	Euro IV/V & EEV
510		2010	Euro V & EEV
511		2011	Euro V & EEV
512		2012	Euro V & EEV
513		2013	Euro V/VI & EEV
514		2014	Euro VI
515		2015	Euro VI
551		2001/02	Euro III
552		2002/03	Euro III
553		2003/04	Euro III
554		2004/05	Euro III
555		2005/06	Euro III/IV
556		2006/07	Euro IV
557		2007/08	Euro IV
558		2008/09	Euro IV
559		2009/10	Euro IV/V & EEV
560		2010/11	Euro V & EEV
561		2011/12	Euro V & EEV
562		2012/13	Euro V & EEV
563		2013/14	Euro V/VI & EEV
564		2014/15	Euro VI
565		2015/16	Euro VI
599		pre 2001	pre Euro 3/III
1800		pre 2017	Euro 3 motorbike

Table 46: Excel Lookup table used to derive engine emission standards by extracted plate year

With these adaptations it was possible to derive a rich dataset, of 23,756 observations, that contained what vehicles entered and left the Sites when, together with vehicle classification and engine type. This dataset was a good sample for the year, being large and comprehensive through a week that was carefully chosen to be typical of the 48-week working year, in a month where the purchasing activity was close to the median shown in Figure 32: Line items per month, fiscal periods 2010-2011. An exemplar of the dataset is shown in Table 47.

date	plate	site	direction	time	30_minute	class	logo	enginetype
30.04.2012	[redacted]	Site 1	OUT	18:50:00	18:30:00	Car	[redacted]	Euro 5
30.04.2012	[redacted]	Site 1	OUT	18:53:00	18:30:00	Car	[redacted]	Euro 6
30.04.2012	[redacted]	Site 1	IN	18:49:00	18:30:00	Taxi	[redacted]	Euro 3
30.04.2012	[redacted]	Site 1	OUT	18:20:00	18:00:00	Car	[redacted]	Euro 4/5
30.04.2012	[redacted]	Site 1	OUT	18:06:00	18:00:00	Car	[redacted]	Euro 3
30.04.2012	[redacted]	Site 1	IN	18:01:00	18:00:00	Light Goods	[redacted]	Euro 4
30.04.2012	[redacted]	Site 1	OUT	18:02:00	18:00:00	Light Goods	[redacted]	Euro 4
30.04.2012	[redacted]	Site 1	OUT	18:13:00	18:00:00	Car	[redacted]	Euro 4
30.04.2012	[redacted]	Site 1	IN	18:17:00	18:00:00	Car	[redacted]	Euro 4
30.04.2012	[redacted]	Site 1	OUT	18:21:00	18:00:00	Car	[redacted]	Euro 6
30.04.2012	[redacted]	Site 1	OUT	17:45:00	17:30:00	Car	[redacted]	Euro 4
30.04.2012	[redacted]	Site 1	OUT	17:30:00	17:30:00	Car	[redacted]	Euro 4/5
30.04.2012	[redacted]	Site 1	OUT	17:52:00	17:30:00	Light Goods	[redacted]	Euro 3/4
30.04.2012	[redacted]	Site 1	OUT	17:55:00	17:30:00	Car	[redacted]	Euro 3
30.04.2012	[redacted]	Site 1	IN	17:43:00	17:30:00	Car	[redacted]	Euro 6
30.04.2012	[redacted]	Site 1	OUT	17:50:00	17:30:00	Motor Cyclis	[redacted]	Euro 3 motorbike
30.04.2012	[redacted]	Site 1	OUT	17:35:00	17:30:00	Car	[redacted]	Euro 4
30.04.2012	[redacted]	Site 1	IN	17:31:00	17:30:00	Car	[redacted]	Euro 5
30.04.2012	[redacted]	Site 1	IN	17:49:00	17:30:00	Car	[redacted]	Euro 5
30.04.2012	[redacted]	Site 1	OUT	17:53:00	17:30:00	Car	[redacted]	Euro 5
30.04.2012	[redacted]	Site 1	OUT	17:55:00	17:30:00	Car	[redacted]	Euro 4
30.04.2012	[redacted]	Site 1	OUT	17:31:00	17:30:00	Light Goods	[redacted]	Euro 3/4
30.04.2012	[redacted]	Site 1	OUT	17:02:00	17:00:00	Car	[redacted]	pre Euro 3/III
30.04.2012	[redacted]	Site 1	IN	15:37:00	15:30:00	2 Axle HGV	[redacted]	Euro IV
30.04.2012	[redacted]	Site 1	OUT	15:52:00	15:30:00	4 Axle HGV	[redacted]	Euro IV
30.04.2012	[redacted]	Site 1	IN	15:45:00	15:30:00	2 Axle HGV	[redacted]	Euro IV/V & EEV
30.04.2012	[redacted]	Site 1	OUT	15:52:00	15:30:00	2 Axle HGV	[redacted]	Euro IV/V & EEV
30.04.2012	[redacted]	Site 1	OUT	15:40:00	15:30:00	Car	[redacted]	Euro V & EEV
30.04.2012	[redacted]	Site 1	OUT	15:39:00	15:30:00	Car	[redacted]	Euro III

Table 47: Example anonymised processed traffic data Newcastle Site 1 30.04.2012

6.4.3. Comparison and separation of passenger and freight vehicles data

From these data, the University's passenger and freight traffic were separated out into class types; this follows in Table 48 and Figure 35 below.

2012		
Row Labels	**Count of plate**	**% of plate**
2 Axle HGV	800	3.37%
3 Axle Artic	10	0.04%
3 Axle HGV	88	0.37%
4 Axle Artic	17	0.07%
4 Axle HGV	158	0.67%
5+ Axle Artic	32	0.13%
Ambulances	200	0.84%
Car	15318	64.48%
Coaches	223	0.94%
Light Goods	4444	18.71%
Mini Buses	192	0.81%
Motor Cyclist	255	1.07%
Taxi	2019	8.50%
Grand Total	**23756**	
Freight total	**5549**	**23.36%**
Passenger total	**18207**	**76.64%**

Table 48: Split between passenger and freight vehicles Newcastle University 2012

A freight total of 23.36% was almost double the average for European urban freight activity, reported anecdotally and in the literature as being between 10% and 18% (Woudsma, 2001; European Commission, 2006b). It was noticeably almost double the 13% LGV and HGV traffic recorded in Newcastle City traffic surveys (Newcastle City Council, 2016), as illustrated in Figure 34. This campus traffic survey was of vehicles entering and leaving the University campus, whereas the city survey was of all moving traffic, albeit to a restricted core of the city avoiding key transit and arterial routes.

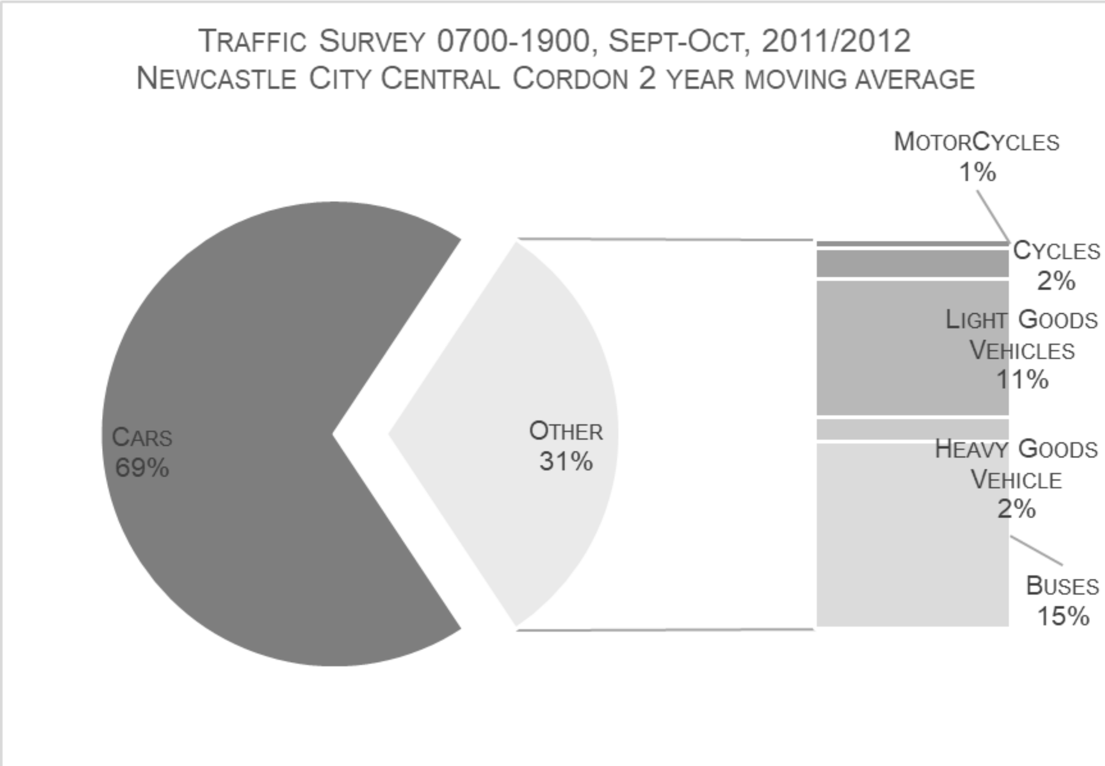

Figure 34: Traffic split by type 2011/2012, Source: Newcastle City Council (Newcastle City Council, 2016)

The split between vehicle types in the campus traffic survey also showed the predominance of light goods vehicles delivering to the campus, mirroring the trending growth in use of LGVs in urban fleets reported by many, notably Browne et al. (Browne, Allen, Nemoto, *et al.*, 2010). Taxis were viewed as passenger vehicles since (unlike in some capital cities) they did not tend to be used for document delivery to the University. It was worth noting that this relatively high proportion of freight transport may have been due in part to the University's Sustainable Travel Policy, that had reduced passenger transport by promoting subsidised public transport and progressively reducing parking spaces on campus.

6.4.4. University Travel Plan Aims

The Travel Plan, first introduced in 2004, was a collection of measures aimed at promoting sustainable travel, with an emphasis on the reduction of reliance on single occupancy car travel. Travel Plans were recommended by the Government to help employers widen travel choice – promoting greener, cleaner travel choices and reducing the reliance on cars (Newcastle University, 2015a). It included:

- Reduced congestion and lower demand for car parking spaces.

- Reduced environmental pollution and visual intrusion caused by parked vehicles.
- Increased travel choices for all staff, students and visitors of the University.
- Health benefits brought about through:
  - reduced air pollution;
  - fewer road traffic accidents; and
  - increased physical fitness through walking or cycling.
- Reduced stress originating from driving and parking.
- Lower noise levels.
- Minimised business mileage, thus reducing corporate transport costs.
- Improved environmental performance for the University.
- Planning permission for campus development.

By 2011/12, this policy had reduced parking spaces on campus by 55.58% versus 2004/5, i.e. 887 spaces reduced to 394 (Newcastle University, 2015b).

6.4.5. Engine emission standards

The split between freight vehicle classes is illustrated in Figure 35 and again confirmed the dominance of LGVs on campus.

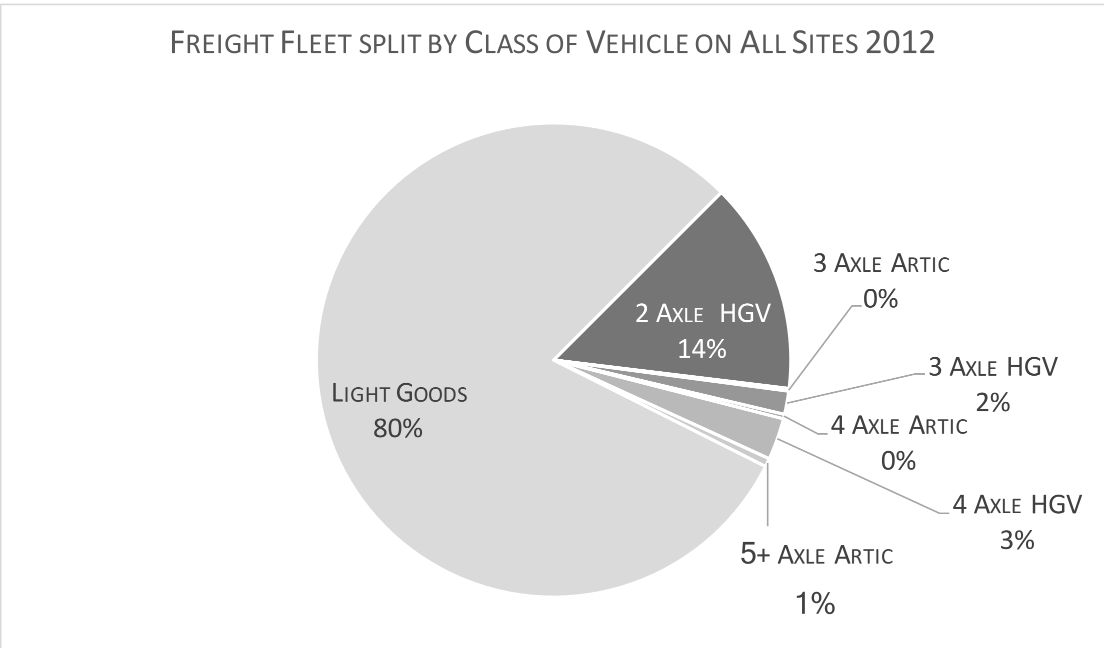

Figure 35: Split between freight vehicle classes, Newcastle University campus 2012

Vehicle class and year enabled me to evaluate the emission standards of the entire vehicle fleet on campus, as detailed in Table 49 and Figure 35.

Row Labels	Count of plate	% of plates
Euro 3	3588	15.10%
Euro 3 motorbike	243	1.02%
Euro 3/4	978	4.12%
Euro 4	9292	39.11%
Euro 4/5	1139	4.79%
Euro 5	5175	21.78%
Euro 6	536	2.26%
Euro III	328	1.38%
Euro III/IV	145	0.61%
Euro IV	578	2.43%
Euro IV/V & EEV	197	0.83%
Euro V & EEV	457	1.92%
Euro VI	215	0.91%
pre Euro 3/III	795	3.35%
Unknown	90	0.38%
Grand Total	**23756**	

Table 49: Split between engine types by emission standards, Newcastle University 2012

This was of import for later use in quantitative evaluation, in Chapter 8.

6.4.6. Movements through the day

From this dataset of all vehicles, it was appropriate to 'bin' the time of movement of vehicles into the 30-minute window in which the vehicle was observed. The absolute comparison is shown in Table 50.

	HGVs	Car	LGVs	Others	Grand Total
07:00:00	52	449	124	34	**659**
07:30:00	64	804	175	62	**1105**
08:00:00	52	898	201	92	**1243**
08:30:00	66	896	254	109	**1325**
09:00:00	78	740	309	139	**1266**
09:30:00	68	550	319	157	**1094**
10:00:00	81	486	259	167	**993**
10:30:00	73	576	212	159	**1020**
11:00:00	75	511	264	128	**978**
11:30:00	80	478	272	133	**963**
12:00:00	54	540	221	129	**944**
12:30:00	47	489	168	102	**806**
13:00:00	71	568	193	128	**960**
13:30:00	50	587	227	131	**995**
14:00:00	42	508	234	120	**904**
14:30:00	43	544	262	129	**978**
15:00:00	27	534	201	132	**894**
15:30:00	42	629	193	125	**989**
16:00:00	14	806	147	139	**1106**
16:30:00	5	1040	79	155	**1279**
17:00:00	6	1122	46	145	**1319**
17:30:00	6	604	49	109	**768**
18:00:00	6	489	30	86	**611**
18:30:00	3	470	5	79	**557**
Totals	**1105**	**15318**	**4444**	**2889**	**23756**

Table 50: Absolute split of vehicle classification aggregated by half hour (time rounded down)

In order to observe the shape of the activity, irrespective of absolute numbers, the data were plotted as columns, with a moving 2-point average trend-line added to Cars and LGVs. The results are shown in Figure 36.

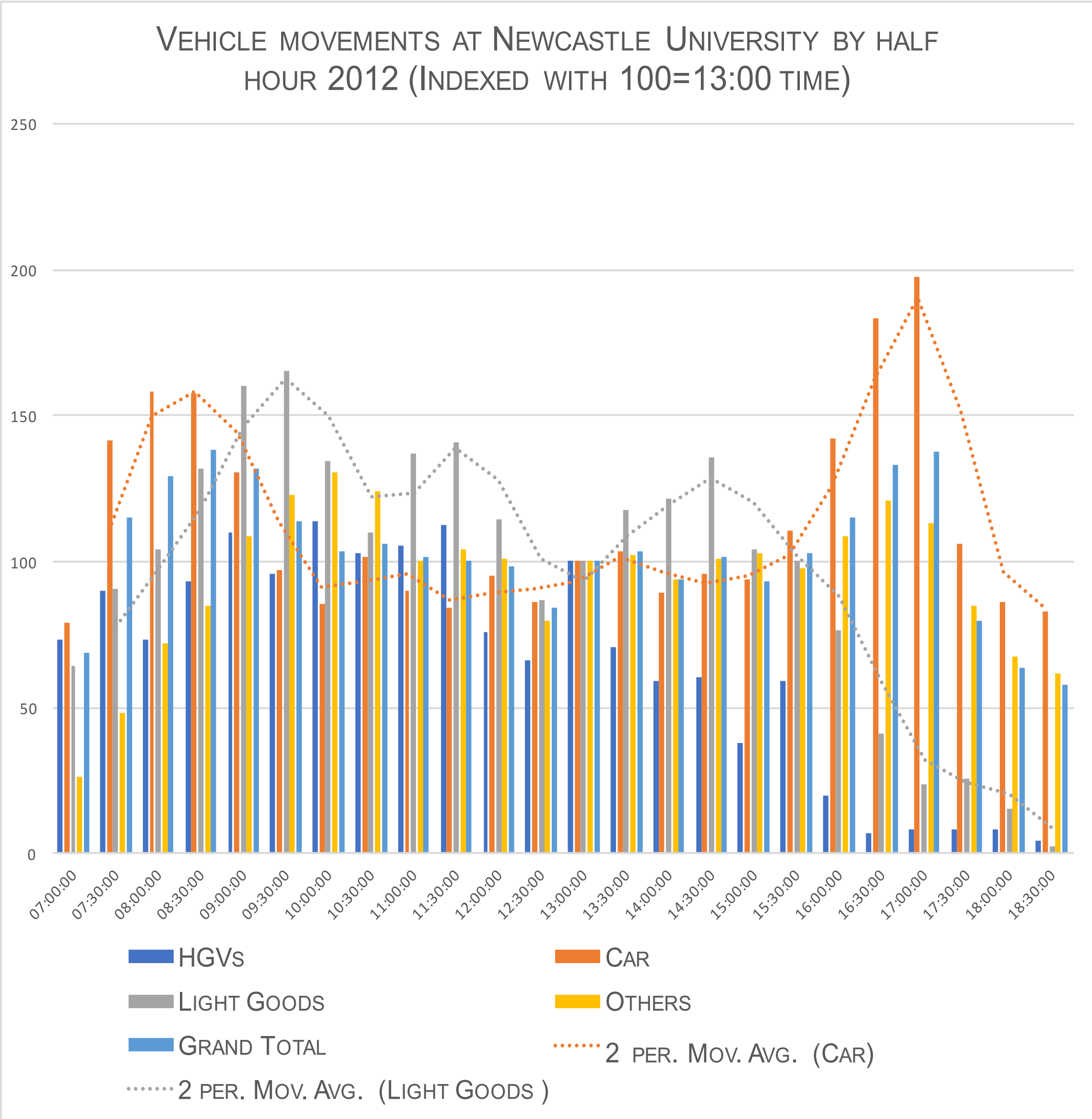

Figure 36: Vehicle Movements at Newcastle University indexed by half hour, 2012

I interpreted these data as showing the expected arrival of staff for work, between 0730-0930, and their departure between 15:30-18:00. From my experience of running vehicle fleets, and ordering goods for delivery, I recognised the LGV pattern as deliveries in the first morning drop-off (known as ‘first thing’, or ‘before 10am’), followed by the second drop off (‘before noon’). The fact that most delivery fleets operated collections and pickups in the early afternoon was borne out by the third peak, at around 14:00-15:00. Discussions with various University school and department staff also reported that some buildings still informally observed a historical ‘no deliveries after 2pm’ rule.

6.4.7. Freight vehicle dwell times

In the field of urban freight research traffic, surveys had to make assumptions from data about whether a vehicle noted at a site was making a delivery/service visit, was pausing for some minor task, or was lost. This was usually determined by 'dwell time'- the amount of time that a vehicle was observed at a location. As Cherrett et al. (Cherrett *et al.*, 2012) noted, an average High Street business could expect up to 10 core goods and 7.6 service visits per week[27]. Vans ('light goods vehicles') were the dominant mode, responsible for 42% of delivery activity, with a mean dwell time of 10 minutes. In the various studies they reviewed, Browne et al (Browne, Allen, Steele, *et al.*, 2010) reported that the average dwell time ranged from 7-34 minutes. In more recent work, looking primarily at deliveries to halls of residences at the University of Southampton, McLeod (2016) reported very short delivery times, with a median 3-4 minutes dwell time at each Site, and average dwell times between 4 and 6.5 minutes. Interestingly, the Organisation for Economic Co-operation and Development (OECD) had recommended that dwell time reduction be a public policy objective, to be addressed by consolidation (OECD, 2003); however, McLeod reported that deliveries from Amazon - with the highest volume of parcels per vehicle - had the longest dwell times. One could expect that different product types, and therefore probably different vehicle classifications suited to those product types, would have differing dwell times.

To assess dwell times in this research, further processing of the dataset was required. Since the focus was freight, the non-freight elements of the dataset were removed, reducing the dataset from 23,756 to 5,549 records. IN and OUT movements could be paired and thus dwell times calculated. Some aspects of the data were difficult to interpret, so early attempts to clean mistyped data and pair up records proved excessively time consuming and prone to further human error. Use of VLOOKUP and other spreadsheet functions were similarly unsuccessful. I therefore used my previous experience as a business analyst and quality manager in ICT to write a functional specification for a script, using the Perl programming language. I then commissioned a

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[27] *in non-peak trading periods with 25% additional activity during the build up to Christmas.*

coder to write it, refined and tested it, and used it to process the data. (The specification and resulting Perl script are listed in Appendix A.)

In short, the specification had the objective to analyse the file of vehicles entering and leaving multiple Sites, match the IN time with the OUT time, and write these to a 'good' file. Some records would not be matchable and these needed to be written to a 'bad' file, for further processing outside of the code, and then reprocessing by the script, in an iterative process.

The raw data file exampled in Table 51: Example anonymised data for pairing, Newcastle University 2012 was thus converted into processed pairs (good), as exampled in Table 52. A non-matched file (bad) was also output; this was then manually re-edited, and pairs identified where possible. Noticeably, many errors in this file proved to be due to the transposition of IN and OUT (relatively easy to spot by eye) and confusion (due to the tallies being recorded orally to tape) between the letters B,V,G, and E and also between 0 (zero) and the letter O. Some cases could not be matched because either the IN or the OUT had occurred outside of the survey hours of 7am - 7pm.

In the end, 4,404 records (out of 5,549) were paired, after 6 iterations of processing with the script, manual editing, and reprocessing; this represented 79% of all freight observations on all Sites and days.

date	plate	site	direction	time	class	logo	enginetype
30.04.2012	[redacted]	Site 1	IN	18:01:00	Light Goods	[redacted]	Euro 4
30.04.2012	[redacted]	Site 1	OUT	18:02:00	Light Goods	[redacted]	Euro 4
30.04.2012	[redacted]	Site 1	OUT	17:52:00	Light Goods	[redacted]	Euro 3/4
30.04.2012	[redacted]	Site 1	OUT	17:31:00	Light Goods	[redacted]	Euro 3/4
30.04.2012	[redacted]	Site 1	IN	16:46:00	Light Goods	[redacted]	Euro 4
30.04.2012	[redacted]	Site 1	IN	16:50:00	Light Goods	[redacted]	Euro 4
30.04.2012	[redacted]	Site 1	OUT	16:59:00	Light Goods	[redacted]	Euro 4
30.04.2012	[redacted]	Site 1	OUT	16:03:00	2 Axle HGV	[redacted]	Euro III/IV
30.04.2012	[redacted]	Site 1	OUT	16:16:00	Light Goods	[redacted]	Euro 4
30.04.2012	[redacted]	Site 1	IN	16:14:00	Light Goods	[redacted]	Euro 4
30.04.2012	[redacted]	Site 1	IN	15:51:00	Light Goods	[redacted]	Euro 4
30.04.2012	[redacted]	Site 1	OUT	15:53:00	Light Goods	[redacted]	Euro 4
30.04.2012	[redacted]	Site 1	IN	15:56:00	2 Axle HGV	[redacted]	Euro III/IV
30.04.2012	[redacted]	Site 1	OUT	15:35:00	Light Goods	[redacted]	Euro 5
30.04.2012	[redacted]	Site 1	IN	15:48:00	Light Goods	[redacted]	Euro 5
30.04.2012	[redacted]	Site 1	IN	15:36:00	Light Goods	[redacted]	Euro 4
30.04.2012	[redacted]	Site 1	OUT	15:44:00	Light Goods	[redacted]	Euro 4
30.04.2012	[redacted]	Site 1	IN	15:47:00	Light Goods	[redacted]	Euro 5
30.04.2012	[redacted]	Site 1	IN	15:33:00	Light Goods	[redacted]	Euro 4/5
30.04.2012	[redacted]	Site 1	OUT	15:43:00	Light Goods	[redacted]	Euro 4/5
30.04.2012	[redacted]	Site 1	IN	15:37:00	2 Axle HGV	[redacted]	Euro IV
30.04.2012	[redacted]	Site 1	OUT	15:52:00	4 Axle HGV	[redacted]	Euro IV
30.04.2012	[redacted]	Site 1	IN	15:45:00	2 Axle HGV	[redacted]	Euro IV/V & EEV
30.04.2012	[redacted]	Site 1	OUT	15:52:00	2 Axle HGV	[redacted]	Euro IV/V & EEV
30.04.2012	[redacted]	Site 1	OUT	15:33:00	Light Goods	[redacted]	Euro 6
30.04.2012	[redacted]	Site 1	OUT	15:16:00	Light Goods	[redacted]	Euro 5
30.04.2012	[redacted]	Site 1	IN	15:10:00	Light Goods	[redacted]	Euro 5
30.04.2012	[redacted]	Site 1	OUT	15:25:00	Light Goods	[redacted]	Euro 3
30.04.2012	[redacted]	Site 1	OUT	15:22:00	2 Axle HGV	[redacted]	Euro IV

Table 51: Example anonymised data for pairing, Newcastle University 2012

date	plate	site	directi	time_in	class_in	logo_in	enginetype_in	directic	time_out	class_out	logo_out	enginetype_out	dwell_time	class	logo	enginetype
Monday	[redacted]	Site 1	IN	07:01:00	Light Goods	[redacted]	Euro 3/4	OUT	13:56:00	Light Goods	[redacted]	Euro 3/4	06:55:00	Light Goods	[redacted]	Euro 3/4
Monday	[redacted]	Site 2	IN	07:01:00	Light Goods	[redacted]	Euro 4	OUT	07:05:00	Light Goods	[redacted]	Euro 4	00:04:00	Light Goods	[redacted]	Euro 4
Monday	[redacted]	Site 4	IN	07:01:00	2 Axle HGV	[redacted]	Euro IV	OUT	07:13:00	2 Axle HGV	[redacted]	Euro IV	00:12:00	2 Axle HGV	[redacted]	Euro IV
Monday	[redacted]	Site 4	IN	07:06:00	4 Axle HGV	[redacted]	Euro III	OUT	07:26:00	4 Axle HGV	[redacted]	Euro III	00:20:00	4 Axle HGV	[redacted]	Euro III
Monday	[redacted]	Site 4	IN	07:08:00	2 Axle HGV	[redacted]	Euro III	OUT	11:28:00	2 Axle HGV	[redacted]	Euro III	04:20:00	2 Axle HGV	[redacted]	Euro III
Monday	[redacted]	Site 3	IN	07:12:00	Light Goods	[redacted]	Euro 3/4	OUT	09:09:00	Light Goods	[redacted]	Euro 3/4	01:57:00	Light Goods	[redacted]	Euro 3/4
Monday	[redacted]	Site 1	IN	07:14:00	2 Axle HGV	[redacted]	Euro V & EEV	OUT	07:31:00	2 Axle HGV	[redacted]	Euro V & EEV	00:17:00	2 Axle HGV	[redacted]	Euro V & EEV
Monday	[redacted]	Site 4	IN	07:14:00	Light Goods	[redacted]	Euro 4	OUT	07:34:00	Light Goods	[redacted]	Euro 4	00:20:00	Light Goods	[redacted]	Euro 4
Monday	[redacted]	Site 3	IN	07:17:00	Light Goods	[redacted]	Euro 3	OUT	16:21:00	Light Goods	[redacted]	Euro 3	09:04:00	Light Goods	[redacted]	Euro 3
Monday	[redacted]	Site 4	IN	07:17:00	Light Goods	[redacted]	Euro 5	OUT	07:34:00	Light Goods	[redacted]	Euro 5	00:17:00	Light Goods	[redacted]	Euro 5
Monday	[redacted]	Site 4	IN	07:22:00	2 Axle HGV	[redacted]	Euro IV	OUT	07:46:00	2 Axle HGV	[redacted]	Euro IV	00:24:00	2 Axle HGV	[redacted]	Euro IV
Monday	[redacted]	Site 1	IN	07:23:00	4 Axle Artic	[redacted]	Euro IV/V & EEV	OUT	07:44:00	4 Axle Artic	[redacted]	Euro IV/V & EEV	00:21:00	4 Axle Artic	[redacted]	Euro IV/V & EEV
Monday	[redacted]	Site 4	IN	07:23:00	Light Goods	[redacted]	Euro 4	OUT	08:17:00	Light Goods	[redacted]	Euro 4	00:54:00	Light Goods	[redacted]	Euro 4
Monday	[redacted]	Site 3	IN	07:27:00	Light Goods	[redacted]	Euro 3	OUT	07:46:00	Light Goods	[redacted]	Euro 3	00:19:00	Light Goods	[redacted]	Euro 3
Monday	[redacted]	Site 2	IN	07:29:00	Light Goods	[redacted]	Euro 5	OUT	07:30:00	Light Goods	[redacted]	Euro 5	00:01:00	Light Goods	[redacted]	Euro 5
Monday	[redacted]	Site 4	IN	07:33:00	Light Goods	[redacted]	Euro 5	OUT	07:38:00	Light Goods	[redacted]	Euro 5	00:05:00	Light Goods	[redacted]	Euro 5
Monday	[redacted]	Site 1	IN	07:34:00	4 Axle HGV	[redacted]	Euro IV	OUT	12:19:00	4 Axle HGV	[redacted]	Euro IV	04:45:00	4 Axle HGV	[redacted]	Euro IV
Monday	[redacted]	Site 1	IN	07:35:00	Light Goods	[redacted]	Euro 4	OUT	15:44:00	Light Goods	[redacted]	Euro 4	08:09:00	Light Goods	[redacted]	Euro 4
Monday	[redacted]	Site 1	IN	07:35:00	4 Axle HGV	[redacted]	Euro IV	OUT	08:12:00	4 Axle HGV	[redacted]	Euro IV	00:37:00	4 Axle HGV	[redacted]	Euro IV
Monday	[redacted]	Site 4	IN	07:35:00	Light Goods	[redacted]	Euro 4	OUT	07:42:00	Light Goods	[redacted]	Euro 4	00:07:00	Light Goods	[redacted]	Euro 4
Monday	[redacted]	Site 1	IN	07:36:00	2 Axle HGV	[redacted]	Euro IV/V & EEV	OUT	08:10:00	2 Axle HGV	[redacted]	Euro IV/V & EEV	00:34:00	2 Axle HGV	[redacted]	Euro IV/V & EEV
Monday	[redacted]	Site 4	IN	07:42:00	Light Goods	[redacted]	Euro 4	OUT	07:53:00	Light Goods	[redacted]	Euro 4	00:11:00	Light Goods	[redacted]	Euro 4
Monday	[redacted]	Site 1	IN	07:45:00	Light Goods	[redacted]	Euro 4/5	OUT	09:41:00	Light Goods	[redacted]	Euro 4/5	01:56:00	Light Goods	[redacted]	Euro 4/5
Monday	[redacted]	Site 3	IN	07:47:00	Light Goods	[redacted]	Euro 5	OUT	16:16:00	Light Goods	[redacted]	Euro 5	08:29:00	Light Goods	[redacted]	Euro 5
Monday	[redacted]	Site 4	IN	07:47:00	4 Axle HGV	[redacted]	Euro IV	OUT	07:58:00	3 Axle HGV	[redacted]	Euro IV	00:11:00	4 Axle HGV	[redacted]	Euro IV
Monday	[redacted]	Site 3	IN	07:48:00	Light Goods	[redacted]	Euro 5	OUT	13:50:00	Light Goods	[redacted]	Euro 5	06:02:00	Light Goods	[redacted]	Euro 5
Monday	[redacted]	Site 4	IN	07:49:00	2 Axle HGV	[redacted]	Euro III	OUT	07:51:00	2 Axle HGV	[redacted]	Euro III	00:02:00	2 Axle HGV	[redacted]	Euro III

Table 52: Example anonymised data output from pairing

Using a combination of the INDEX and MATCH functions within a formula array in Excel, all observations in the original freight dataset of 5,549 were matched with the dwell time, if such a pairing had been made, and the data were prepared for and imported into the SPSS statistics software, for further analysis. Note that each observation was still separate, although the paired dwell time could be clearly seen from the examples in Table 53. Unpaired data were imported with null fields.

date	plate	site	direction	time	class	logo	enginetype	half_hour	dwelltwime
Wednesday	[redacted]	Site 4	IN	07:00:00	Light Goods	[redacted]	Euro 4	07:00:00	
Friday	[redacted]	Site 4	OUT	07:00:00	Light Goods	[redacted]	Euro 3	07:00:00	
Monday	[redacted]	Site 4	IN	07:01:00	2 Axle HGV	[redacted]	Euro IV	07:00:00	00:12:00
Thursday	[redacted]	Site 4	OUT	07:01:00	Light Goods	[redacted]	Euro 3/4	07:00:00	
Monday	[redacted]	Site 2	IN	07:01:00	Light Goods	[redacted]	Euro 4	07:00:00	00:04:00
Wednesday	[redacted]	Site 2	IN	07:01:00	Light Goods	[redacted]	Euro 4	07:00:00	00:04:00
Friday	[redacted]	Site 2	IN	07:01:00	Light Goods	[redacted]	Euro 4	07:00:00	00:04:00
Monday	[redacted]	Site 1	IN	07:01:00	Light Goods	[redacted]	Euro 3/4	07:00:00	06:55:00
Wednesday	[redacted]	Site 1	IN	07:01:00	Light Goods	[redacted]	pre Euro 3/II	07:00:00	06:42:00
Thursday	[redacted]	Site 4	OUT	07:02:00	Light Goods	[redacted]	Euro 4	07:00:00	
Friday	[redacted]	Site 4	IN	07:02:00	Light Goods	[redacted]	Euro 4	07:00:00	00:57:00
Monday	[redacted]	Site 2	OUT	07:02:00	2 Axle HGV	[redacted]	Euro III	07:00:00	
Monday	[redacted]	Site 2	OUT	07:02:00	Light Goods	[redacted]	Euro 5	07:00:00	
Friday	[redacted]	Site 1	IN	07:02:00	Light Goods	[redacted]	Euro 3/4	07:00:00	06:40:00
Thursday	[redacted]	Site 4	OUT	07:03:00	Light Goods	[redacted]	Euro 3	07:00:00	
Friday	[redacted]	Site 4	IN	07:03:00	Light Goods	[redacted]	Euro 5	07:00:00	
Wednesday	[redacted]	Site 3	IN	07:03:00	Light Goods	[redacted]	Euro 4	07:00:00	08:54:00
Thursday	[redacted]	Site 4	IN	07:04:00	Light Goods	[redacted]	Euro 5	07:00:00	00:12:00
Wednesday	[redacted]	Site 3	OUT	07:04:00	Light Goods	[redacted]	Euro 4	07:00:00	
Thursday	[redacted]	Site 3	IN	07:04:00	Light Goods	[redacted]	Euro 4	07:00:00	08:31:00
Tuesday	[redacted]	Site 1	IN	07:04:00	Light Goods	[redacted]	Euro 3/4	07:00:00	06:40:00
Thursday	[redacted]	Site 4	OUT	07:05:00	2 Axle HGV	[redacted]	Euro IV	07:00:00	
Monday	[redacted]	Site 2	OUT	07:05:00	Light Goods	[redacted]	Euro 4	07:00:00	00:04:00
Tuesday	[redacted]	Site 2	IN	07:05:00	Light Goods	[redacted]	Euro 4	07:00:00	
Wednesday	[redacted]	Site 2	IN	07:05:00	Light Goods	[redacted]	Euro 4	07:00:00	
Wednesday	[redacted]	Site 2	OUT	07:05:00	Light Goods	[redacted]	Euro 4	07:00:00	00:04:00
Wednesday	[redacted]	Site 2	OUT	07:05:00	Light Goods	[redacted]	Euro 4	07:00:00	
Friday	[redacted]	Site 2	OUT	07:05:00	Light Goods	[redacted]	Euro 4	07:00:00	00:04:00
Tuesday	[redacted]	Site 1	IN	07:05:00	Light Goods	[redacted]	Euro 4	07:00:00	00:54:00
Monday	[redacted]	Site 4	IN	07:06:00	4 Axle HGV	[redacted]	Euro III	07:00:00	00:20:00
Monday	[redacted]	Site 4	IN	07:06:00	Light Goods	[redacted]	Euro 4	07:00:00	00:06:00
Wednesday	[redacted]	Site 4	OUT	07:06:00	2 Axle HGV	[redacted]	Euro V & EEV	07:00:00	
Wednesday	[redacted]	Site 4	IN	07:06:00	Light Goods	[redacted]	Euro 4	07:00:00	00:03:00
Tuesday	[redacted]	Site 2	IN	07:06:00	2 Axle HGV	[redacted]	Euro III	07:00:00	00:08:00
Tuesday	[redacted]	Site 2	OUT	07:06:00	Light Goods	[redacted]	Euro 4	07:00:00	00:01:00
Thursday	[redacted]	Site 2	IN	07:06:00	2 Axle HGV	[redacted]	Euro III	07:00:00	00:08:00

Table 53: Freight movements anonymised data with dwell times, Newcastle University, 2012

6.4.8. Summary of filtered data set

I removed observations where the direction was miscoded as X or blank and it was not possible to assess the correct entry. Certain additional variables were recoded, or automatically indexed in SPSS, to allow certain tests to function where a scale or ordinal number was needed rather than a string. The filtering of the dataset is summarised in Table 54: Filtering of 2012 traffic survey data.

	cases	% of full dataset	% of freight dataset
full survey data	23756	100.00%	
freight data only	5501	23.16%	100.00%
non paired data	1885	7.93%	34.27%
paired data	3616	15.22%	65.73%

Table 54: Filtering of 2012 traffic survey data

6.4.9. Normality of traffic survey data

Using SPSS, I carried out Kolmogorov-Smirnov normality tests for dwell time, half hour 'bins', and the time of observation. I then repeated these for the variables grouped by the factors of: weekday, Site, direction of travel, vehicle class, engine type, and LGV versus HGV. For some of these, the sub-samples were smaller than 2000, so Shapiro-Wilk tests were also evaluated.

Dwell time, half hour 'bins', and the time of observation were not distributed normally when tested alone. Dwell time, half hour 'bins', and the time of observation were not distributed normally when tested grouped by weekday.

Dwell time was not distributed normally when assessed grouped by Site, although the box plot showed that Site 5 (RVI Hospital) was different. These findings are illustrated in Figure 37: Dwell time in minutes by Site, normality box plots, traffic survey 2012.

Dwell time was not normally distributed when grouped by the direction of travel (IN/OUT), nor by any vehicle class, engine type, or LGV versus HGV.

Half hour 'bins' were not distributed normally grouped by Site, nor by direction of travel, but did show normality for 3 Axle HGVs, 4 Axle Artics, and 5+ Axle Artics: see Table 55: Test of normality of half hour bins grouped by vehicle class, traffic survey 2012. However, these Shapiro-Wilk results were very small samples within the larger dataset, and were not seen in engine type, so the half hour bins grouped by LGV versus HGV were checked: the data were not normally distributed.

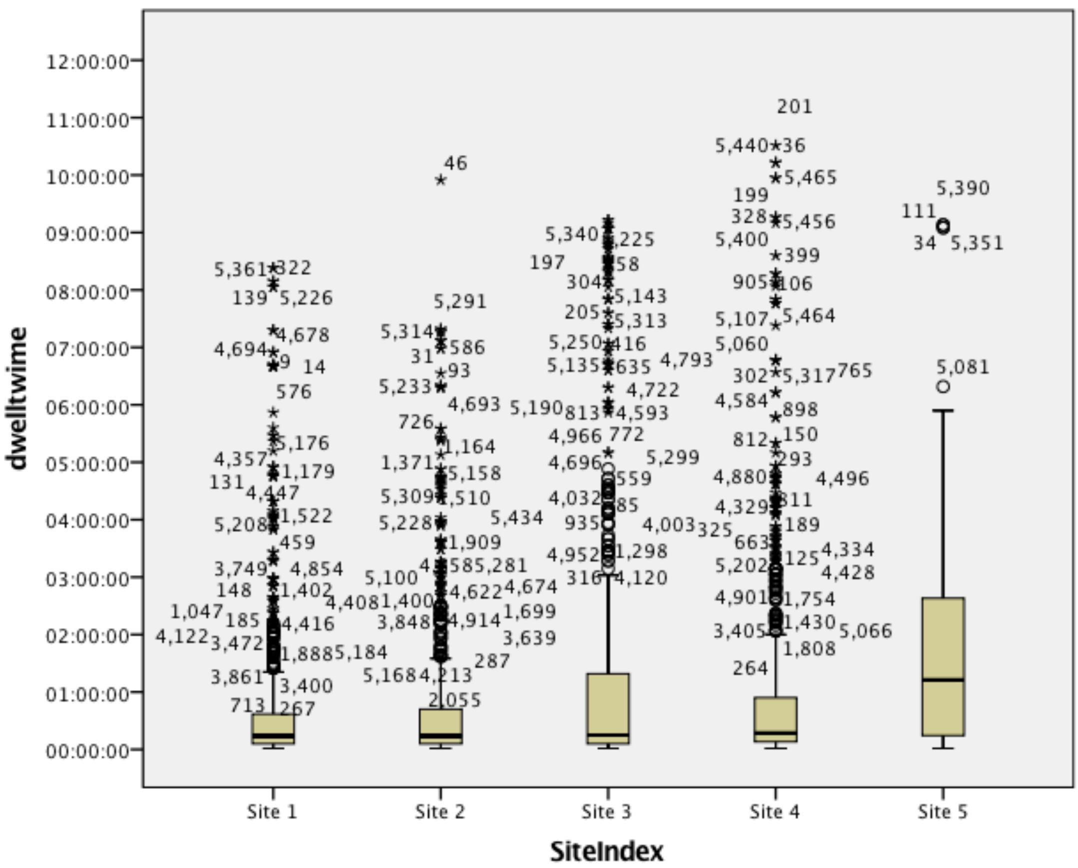


Figure 37: Dwell time in minutes by Site, normality box plots, traffic survey 2012

		Shapiro-Wilk		
		Statistic	df	Sig.
half_hour	2 Axle HGV	.973	799	.001
	3 Axle Artic	.949	10	.652
	3 Axle HGV	.933	88	.001
	4 Axle Artic	.932	17	.235
	4 Axle HGV	.943	149	.001
	5+ Axle Artic	.964	32	.351
	Light Goods	.965	4406	.001

Table 55: Test of normality of half hour bins grouped by vehicle class, traffic survey 2012

Time of observation was normally distributed, both in half hour bins and in absolute time, for some vehicle classes (3 Axle HGVs, 4 Axle Artics, and 5+ Axle Artics). When grouped by engine type, normality was observed for Euro 6, Euro VI and pre Euro3/III, though again these were small samples inside the larger dataset.

The conclusion I drew was that, unless specific questions about minority vehicles would prove to be useful, the traffic survey data would be treated as not normally distributed in all cases, and non-parametric tests would be used.

6.4.10. Frequencies and ranges of dwell times

As discussed earlier, the question of dwell times for freight deliveries was of interest in urban freight logistics research. Therefore, I analysed the freight dwell time data to attempt to determine key parameters: what was the range and median of dwell times for different freight vehicles on the campus, and at what bottom level and which upper level should a vehicle movement be viewed as a ‘drop-off’ (lower), or a ‘service visit’ (higher)? I observed the survey Sites, timed drivers entering and leaving the campus, and walked the distance from vehicle stop to the nearest delivery points. As a simple observation, I noted and could replicate deliveries as fast as 5 minutes on all the Sites. I then turned to the data for further elucidation; this is shown in Table 56. Note that although the dwell time data was stored as IN and OUT cases, the dwell time record was duplicated on each half of the pair; it was therefore inappropriate to include both halves of a visit, so only cases with direction of travel of IN were included. Any cases with no dwell time were automatically excluded from the analysis, by SPSS.

dwelltime		
N	Valid	1823
	Missing	957
Median	0:16:00	
Range	10:30:00	
Minimum	0:01:00	
Maximum	10:31:00	
Percentiles	25	0:07:00
	50	0:16:00
	75	0:52:00

Table 56: Descriptive statistics for dwell time, traffic survey 2012

As the data were not normally distributed, the median (16 minutes) was the appropriate average to use - inside the service visit window suggested by Browne et. al, (Browne, Allen, Steele, *et al.*, 2010), see section 6.3.7. The maximum of 10hrs 31min clearly showed that some vehicles were very long stay service visits; indeed, I observed many parts of the campus had parked-up LGVs operating as ‘portable workshops’ for much of most days. The interquartile ranges of 7 minutes, 16 minutes and 52 minutes were adapted based on timings I made of actual deliveries on site. A lower bottom limit cut-off of 5 minutes was adopted, with a top cut-off of 52 minutes, classifying a freight vehicle movement between these limits as a delivery. Anything below the bottom limit was a pass-by; above was a service visit. Note that a service visit still counted as a freight delivery, but a longer one, and probably of a service rather than goods alone.

I placed on hold, for later traffic surveys, a conclusion about what a freight vehicle had been doing entering and leaving the University campus in under the time needed to make a delivery - see section 10.7. One intriguing suggestion, made by an audience member when I presented the data to the University's finance staff, was that this had been van drivers dropping off their partners at work before heading on to their own workplace: also known as a 'kiss and drive'. A total of 14.9% of all LGV movements observed were less than 5 minutes but, although significant, this query had to be placed on hold pending further investigation in future traffic survey work - see section 10.7.5.

Variances in dwell time medians and ranges

Table 57 shows there was no apparent variation in the ranges of dwell time grouped by weekday.

		date	Percentiles			
			N	25	50	75
Weighted Average (Definition 1)	Dwell time	MONDAY	741	0:07:00	0:15:00	0:43:00
		TUESDAY	653	0:07:00	0:16:00	1:01:00
		WEDNESDAY	798	0:07:00	0:17:00	0:55:00
		THURSDAY	782	0:06:00	0:15:00	0:47:30
		FRIDAY	642	0:07:00	0:16:00	1:02:15

Table 57: Dwell time median and range by weekdays

Table 58 shows that Site 5 had very different dwell times, with a median of 1hr 08min and an upper interquartile range (IQR) of 2hr 17min. I noted this for later analysis - see section 10.7. This was the RVI hospital goods inwards and suggested either longer unloading, or possibly longer waiting times.

	Site Index				
		N	25	50	75
Weighted Average (Definition 1)	Site 1	503	0:06:00	0:14:00	0:37:00
	Site 2	445	0:06:00	0:14:00	0:40:30
	Site 3	414	0:06:00	0:15:00	1:19:00
	Site 4	374	0:08:00	0:17:00	0:55:30
	Site 5	87	0:14:00	1:08:00	2:17:00

Table 58: Dwell time median and range grouped by Site

Table 59 shows that LGVs and 2 Axle HGVs were similar in lower IQR and median, but quite different in upper IQR, suggesting that LGVs were used for both short deliveries and longer service visits.

	Class Index	Percentiles			
		N	25	50	75
Weighted Average (Definition 1)	2 Axle HGV	285	0:07:00	0:13:00	0:31:30
	3 Axle Artic	3	0:11:00	0:43:00	.
	3 Axle HGV	36	0:14:00	0:20:00	0:37:30
	4 Axle Artic	5	0:21:30	0:29:00	0:38:30
	4 Axle HGV	42	0:16:30	0:28:30	0:52:15
	5+ Axle Artic	14	0:15:45	0:38:00	1:27:00
	Light Goods	1438	0:06:00	0:15:00	1:07:00

Table 59: Dwell time median and range grouped by vehicle class

Grouping together all HGVs, separate from LGVs, appeared to show a loss of heterogeneity within the heavier HGV classes. Table 60 shows a very similar lower IQR and median, but a significantly different higher IQR.

	LGV or HGV	Percentiles			
		N	25	50	75
Weighted Average (Definition 1)	LGV	1438	0:06:00	0:15:00	1:07:00
	HGV	385	0:08:00	0:17:00	0:35:00

Table 60: Dwell time median and range grouped by LGV/HGV

I coded and analysed a new grouping, of LGV, 2 Axle HGV and HGVs with 3 axles or more (named 'three-way vehicle classification'). Shown in Table 61, this analysis seemed to capture the diversity, whilst keeping the samples at useful quantities.

	Three-way vehicle class	Percentiles			
		N	25	50	75
Weighted Average (Definition 1)	2 Axle HGV	285	0:07:00	0:13:00	0:31:30
	3+ Axle HGVs	100	0:15:00	0:27:00	0:48:15
	LGV	1438	0:06:00	0:15:00	1:07:00

Table 61: Dwell time median and range grouped by 3 vehicle class groups

6.4.11. Pairwise differences of dwell time by other factors.

Having noted the median and ranges for weekdays, sites, and a new three-way vehicle class split, it was appropriate to confirm to what extent dwell time varied: first with a Kruskal-Wallis H test, and then with pairwise Mann-Whitney tests, with or without

Bonferroni corrections. I did this first by weekday, secondly by Site, and thirdly by the newer, three-way vehicle classification. These tests followed the same procedure and scripts as detailed in section 6.3.11; they are repeated here only in summary.

Pairwise difference of dwell time, weekday by weekday.

Two hypotheses were formed:

> H_0 There was no difference between the freight vehicle dwell time in the data between weekdays.
>
> H_1 There was a difference between the freight vehicle dwell time in the data between weekdays.

The null hypothesis was found to be true using a Kruskal-Wallis H test of variance in dwell time between weekdays and as such there was no difference between the dwell times by weekday.

Pairwise difference of dwell time, Site by Site.

Two hypotheses were formed:

> H_0 There was no difference between the freight vehicle dwell time in the data between individual Sites (1-5).
>
> H_1 There was a difference between the freight vehicle dwell time in the data between individual Sites (1-5).

Ranks	Site Index	N	Mean Rank
Dwell time	Site 1	503	860.10
	Site 2	445	870.51
	Site 3	414	919.08
	Site 4	374	952.42
	Site 5	87	1216.87
	Total	1823	

Test Statistics a, b	
	dwelltime
Chi-Square	83.834
df	4
Asymp. Sig.	.001
a. Kruskal-Wallis H Test	
b. Grouping Variable: Site Index	

Table 62: Kruskal-Wallis H test of variance in dwell time between Sites, traffic survey 2012

The null hypothesis was found false and as such the variance between Sites was significant. To understand which days were different from each other, a 5 x 5 matrix pairwise mapped Sites against each other and tested variance one from the other. Since this was non-parametric, each comparison utilised a Mann-Whitney test, since I assumed each day to be independent. This generated a matrix grid of 10 results. A Bonferroni correction was applied for familywise errors: in this case 0.05/10 or an alpha-value of 0.005. In each pairwise test, the null hypothesis was that the datasets were not different; therefore, a significant result where p was equal to or less than the alpha, would show they were probably different.

p values	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**
Site 1		0.448	0.025	**0.001**	**0.001**
Site 2	0.448		0.119	**0.005**	**0.001**
Site 3	0.025	0.119		0.251	**0.001**
Site 4	**0.001**	**0.005**	0.251		**0.001**
Site 5	**0.001**	**0.001**	**0.001**	**0.001**	
Mann Whitney pairwise, alpha = 0.005, <0.001 rounded as 0.001					
Shaded green are significant and therefore vary pairwise					

Table 63: Sites pairwise Mann Whitney variance testing dwell time, traffic survey 2012

The results in Table 63 clearly showed that Site 5, the RVI hospital entrance, was significantly different to all other Sites, confirming that the freight activity at that goods-inwards was quite different to the rest of the University. This fitted with the fact that the RVI and University shared that goods-inwards: the demand being satisfied was an amalgam of the University and a major hospital. The pairwise analysis also showed significant variance between Site 4 - the entrance for the medical teaching departments of the University - and Site 5, but also a difference between these two Sites and Sites 1 and 2. Sites 1 and 2 were the two main entrances to the campus; the fact their results were similar fits with their role in allowing access to homogenous University buildings. Site 3 - access to the main Engineering departments and a public road that is noticeably used as an 'LGV park' - differed only with Site 5.

The analysis confirmed my induction from Table 58, that Site 5 should be viewed as wholly separate. I noted that a case could be made to exclude it from any combined analysis of traffic data and purchasing data, given its difference and the fact it represented merged purchasing demand. The clear similarity between Sites 1 and 2, and their joint difference to Site 4, was noted. I used a Kruskal-Wallis H test to analyse Sites

1-3, which confirmed that these could be viewed as having no differences pairwise, as shown in Table 64.

Ranks	Site Index	N	Mean Rank
Dwell time	Site 1	503	666.56
	Site 2	445	673.71
	Site 3	414	708.02
	Total	1362	

Test Statistics [a, b]	
	Dwell time
Chi-Square	2.785
df	2
Asymp. Sig.	.248
a. Kruskal Wallis Test	
b. Grouping Variable: Site Index	

Table 64: Kruskal-Wallis H text of variance in dwell times between Sites 1-3 only, traffic survey 2012

Pairwise difference of dwell time by 3-way vehicle classification.

Due to the small samples of some HGVs, but also the apparent different ranges and medians detailed in Table 59, Table 60, and Table 61, I had recoded the data to form a new three-way vehicle classification of LGV, 2 Axle HGV and HGVs with 3 axles or more. I now carried out a pairwise Kruskal-Wallis H test on this new grouping.

Two hypotheses were formed:

H_0 There was no difference between the freight vehicle activity in the data between a 3-way vehicle classification.

H_1 There was a difference between the freight vehicle activity in the data between a 3-way vehicle classification.

Ranks	Three-way vehicle class	N	Mean Rank
Dwell time	2 Axle HGV	285	841.47
	3+ Axle HGVs	100	1106.43
	LGV	1438	912.46
	Total	1823	

Test Statistics [a, b]	
	dwelltime
Chi-Square	18.772
df	2
Asymp. Sig.	.001
a. Kruskal Wallis Test	
b. Grouping Variable: Three-way vehicle class	

Table 65: Kruskal-Wallis H test of variance in dwell time between 3-way vehicle classification, traffic survey 2012

The null hypothesis was found false and as such the variance between the three-way vehicle classification was significant. To understand which classes were different from each other, a 3 x 3 matrix pairwise mapped classes against each other and tested variance one from the other. Since this was non-parametric, each comparison utilised a Mann-Whitney test, since each day was assumed to be independent. This generated a matrix grid of 3 results. A Bonferroni correction was applied for familywise errors: in this case 0.05/3 or an alpha-value of 0.017. In each pairwise test the null hypothesis was that the datasets were not different and therefore a significant result, where p was equal to or less than the alpha, would show they were probably different.

p values	**2 Axle HGV**	**3+ Axle HGVs**	**LGV**
2 Axle HGV		**0.001**	**0.049**
3+ Axle HGVs	**0.001**		**0.001**
LGV	**0.049**	**0.001**	
Mann Whitney pairwise, alpha = 0.017, <0.001 rounded as 0.001			
Shaded green are significant and therefore vary pairwise			

Table 66: 3-way vehicle classification pairwise Mann Whitney variance testing dwell time, traffic survey 2012

This result showed that there were no differences between LGV and 2 Axle HGV, but that they were both significantly different to 3+ Axle HGVs. The first two groups were therefore viewed as the same for dwell time, from this point forward.

These analyses suggested that a working definition of dwell times on the Newcastle University Campus in 2012 was a median of 15 mins for LGVs, 13 mins for 2 Axle HGVs, and 27 mins for HGVs with 3 axles or more.

6.4.12. Frequencies and ranges of time of arrival

The arrival time of the freight delivery was an issue for exploration. Therefore, I analysed the data to attempt to determine key parameters: what was the range and median of arrival times for different freight vehicles on the campus? Note that the observation data were stored as IN and OUT cases but, since for this purpose the vehicle arrival time was my primary interest, the SPSS dataset was limited to IN only.

N	Valid	2780
	Missing	0
Median	11:27:00	
Range	11:48:00	
Percentiles	25	9:23:00
	50	11:27:00
	75	14:01:00

Table 67: Descriptive statistics for time of arrival, traffic survey 2012

As the data were not normally distributed, as explained in section 6.4.9, the median (11:27 am) was the appropriate average to use. The interquartile ranges showed the activity falling between 9:23 and 14:01, but I was unconvinced this was a useful statistic, since the distribution and shaping of freight in Figure 36 and Figure 37 were more informative.

6.4.13. *Variances in arrival time medians and ranges*

Initial analysis of medians and range for arrival time by weekdays was carried out and summarised below:

		date	Percentiles			
			N	25	50	75
Weighted Average (Definition 1)	time	MONDAY	741	9:32:00	11:16:00	13:57:00
		TUESDAY	653	9:30:30	11:32:00	14:17:30
		WEDNESDAY	798	9:45:45	11:39:30	14:17:15
		THURSDAY	782	9:25:45	11:14:30	13:32:30
		FRIDAY	642	9:34:00	11:41:00	13:42:15

Table 68: Arrival time median and range grouped by weekday

		Site Index	Percentiles			
			N	25	50	75
Weighted Average (Definition 1)	time	Site 1	652	9:31:00	11:33:00	13:46:00
		Site 2	660	9:23:00	11:18:00	14:04:45
		Site 3	541	9:18:30	11:17:00	13:59:00
		Site 4	687	9:04:00	11:23:00	14:08:00
		Site 5	240	10:00:30	12:01:00	14:37:30

Table 69: Arrival time median and range grouped by Site

		Class Index	Percentiles			
			N	25	50	75
Weighted Average (Definition 1)	time	2 Axle HGV	399	9:16:00	10:59:00	13:05:00
		3 Axle Artic	4	8:00:30	10:30:00	11:58:00
		3 Axle HGV	47	8:48:00	10:55:00	13:15:00
		4 Axle Artic	8	7:43:15	9:25:00	11:23:15
		4 Axle HGV	63	8:17:00	10:07:00	13:09:00
		5+ Axle Artic	15	10:02:00	11:04:00	12:51:00
		Light Goods	2244	9:26:00	11:36:00	14:14:45

Table 70: Arrival time median and range grouped by vehicle class

		Three-way_vehicle_class	Percentiles			
			N	25	50	75
Weighted Average (Definition 1)	time	2 Axle HGV	399	9:16:00	10:59:00	13:05:00
		3+ Axle HGVs	137	8:45:30	10:33:00	13:04:30
		LGV	2244	9:26:00	11:36:00	14:14:45

Table 71: Arrival time median and range grouped by 3-way vehicle classification

Table 68 showed no obvious variation in arrival time, when grouped by weekday. Table 69 showed that perhaps Site 5 had different arrival times. Site 5 did close at 2pm, but it was not clear whether this was significant. Table 70 showed a range of arrival times by vehicle class; this showed variations between the smaller LGV and 2 Axle vehicles, versus the heavier HGVs. To explore this a new grouping of LGV, 2 Axle HGV and HGVs with 3 axles or more, named ‘three-way vehicle classification’, was coded and analysed and is shown in Table 71 above. This suggested from the lower IQR that heavier vehicles might be arriving earlier and lighter ones later.

6.4.14. Pairwise differences of arrival time by other factors.

Having noted the above, it was appropriate to confirm to what extent arrival time differed between groups: first with a Kruskal-Wallis H test and then with pairwise Mann-Whitney tests with or without Bonferroni corrections. These were done first by weekday, secondly by Site, and finally by the newer three-way vehicle classification. These tests followed the same procedure and scripts as detailed in Table 34; they are repeated only in summary here.

Pairwise difference of arrival time, by weekdays

Two hypotheses were formed:

> H_0 There was no difference between the freight vehicle arrival time in the data between weekdays.
>
> H_1 There was a difference between the freight vehicle arrival time in the data between weekdays.

The null hypothesis was found false using a Kruskal-Wallis H test of variance in arrival time between Sites; as such the variance between weekdays was significant. To understand which weekdays were different from each other, a 5 x 5 matrix pairwise mapped Sites against each other and tested variance, one from the other. Since this was non-parametric, each comparison utilised a Mann Whitney test, as each day was assumed to be independent. This generated a matrix grid of 10 results. A Bonferroni correction was applied for familywise errors: in this case 0.05/10 or an alpha-value of 0.005. In each pairwise test the null hypothesis was that the datasets were not different and therefore a significant result, where p was equal to or less than the alpha, would show they probably were different.

p values	Monday	Tuesday	Wednesday	Thursday	Friday	
Monday		0.004	0.193	0.800	0.496	
Tuesday	0.004		0.069	0.002	0.026	
Wednesday	0.193	0.069		0.126	0.596	
Thursday	0.800	0.002	0.126		0.343	
Friday	0.496	0.026	0.596	0.343		
Mann Whitney pairwise, alpha = 0.005, <0.001 rounded as 0.001						
Shaded green are significant and therefore vary pairwise, amber shading denotes a standard 5% significance						

Table 72: Weekdays pairwise Mann Whitney variance testing arrival time, traffic survey 2012

Monday and Tuesday showed variance to each other, as did Tuesday and Thursday. Whether this had inductive utility was not clear at this time.

Pairwise difference of arrival time, Site by Site.

Two hypotheses were formed:

> H_0 There was no difference between the freight vehicle arrival time in the data between individual Sites (1-5).
>
> H_1 There was a difference between the freight vehicle arrival time in the data between individual Sites (1-5).

Ranks	Site Index	N	Mean Rank
time	Site 1	652	1399.71
	Site 2	660	1377.12
	Site 3	541	1360.41
	Site 4	687	1362.09
	Site 5	240	1551.41
	Total	2780	

Test Statistics a, b	
	time
Chi-Square	11.535
df	4
Asymp. Sig.	.021
a. Kruskal Wallis Test	
b. Grouping Variable: Site Index	

Table 73: Kruskal-Wallis H test of variance in arrival time between Sites, traffic survey 2012

The null hypothesis was found false and as such the variance between Sites was significant. To understand which Sites were different from each other, a 5 x 5 matrix pairwise mapped Sites against each other and tested variance, one from the other. Since this was non-parametric, each comparison utilised a Mann-Whitney test, as each day was assumed to be independent. This generated a matrix grid of 10 results. A Bonferroni correction was applied for familywise errors: in this case 0.05/10 or an alpha-value of 0.005. In each pairwise test the null hypothesis was that the datasets were not different and therefore a significant result, where p was equal to or less than the alpha, would show they were probably different.

p values	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**
Site 1		0.585	0.391	0.402	0.010
Site 2	0.585		0.686	0.704	0.003
Site 3	0.391	0.686		0.991	0.002
Site 4	0.402	0.704	0.991		0.002
Site 5	0.010	0.003	0.002	0.002	
Mann Whitney pairwise, alpha = 0.005, <0.001 rounded as 0.001					
Shaded green are significant and therefore vary pairwise, amber shading denotes a standard 5% significance					

Table 74: Sites pairwise Mann Whitney variance testing arrival time, traffic survey 2012

The results in Table 63 clearly showed that Site 5, the RVI hospital entrance, was significantly different to all other Sites, confirming that the freight activity at that goods-inwards facility was quite different to the rest of the University. This fitted with the fact that the RVI and University shared that goods inwards location and therefore the demand being satisfied was an amalgam of the University and a major hospital. The results also showed that in terms of arrival time there was no significant difference between Sites 1-4.

Pairwise difference of arrival time, by 3-way vehicle classification.

Having recoded the data to form a new three-way vehicle classification, I tested whether arrival time varied, based on this new grouping.

Two hypotheses were formed:

> H_0 There was no difference between the freight vehicle arrival time in the data between a 3-way vehicle classification.
>
> H_1 There was a difference between the freight vehicle arrival time in the data between a 3-way vehicle classification.

Ranks	Three-way_vehicle_class	N	Mean Rank
time	2 Axle HGV	399	1257.53
	3+ Axle HGVs	137	1165.44
	LGV	2244	1427.88
	Total	2780	

Test Statistics a, b	
	time
Chi-Square	26.589
df	2
Asymp. Sig.	.001
a. Kruskal Wallis Test	
b. Grouping Variable: Three-way_vehicle_class	

Table 75: Kruskal-Wallis H test of variance of arrival time between 3-way vehicle classification, traffic survey 2012

The null hypothesis was found false and as such the variance between the three-way vehicle classification was significant. To understand which classes were different from each other, a 3 x 3 matrix pairwise mapped one against each other and tested variance, one from the other. Since this was non-parametric, each comparison utilised a Mann-Whitney test, as each day was assumed to be independent. This generated a matrix grid of 3 results. A Bonferroni correction was applied for familywise errors, in this case 0.05/3 or an alpha-value of 0.017. In each pairwise test the null hypothesis was that the datasets were not different and therefore a significant result, where p was equal to or less than the alpha, would show they were probably different.

p values	**2 Axle HGV**	**3+ Axle HGVs**	**LGV**
2 Axle HGV		**0.200**	**0.001**
3+ Axle HGVs	**0.200**		**0.001**
LGV	**0.001**	**0.001**	
Mann Whitney pairwise, alpha = 0.017, <0.001 rounded as 0.001			
Shaded green are significant and therefore vary pairwise			

Table 76: 3-way vehicle classification pairwise Mann Whitney variance testing arrival time, traffic survey 2012

This result showed that there were no differences between 2 Axle HGVs and 3+ Axle HGVs, but that they were both significantly different to LGVs. This was important, as it confirmed that for arrival time LGVs had a different movement pattern to HGVs. I therefore illustrated the arrival time for each group as a line chart, shown in Figure 38, indexed to 07:00[28], with 2 point moving averages to allow ready comparison between the different sample sizes. This showed graphically the differences observed in the statistical analysis.

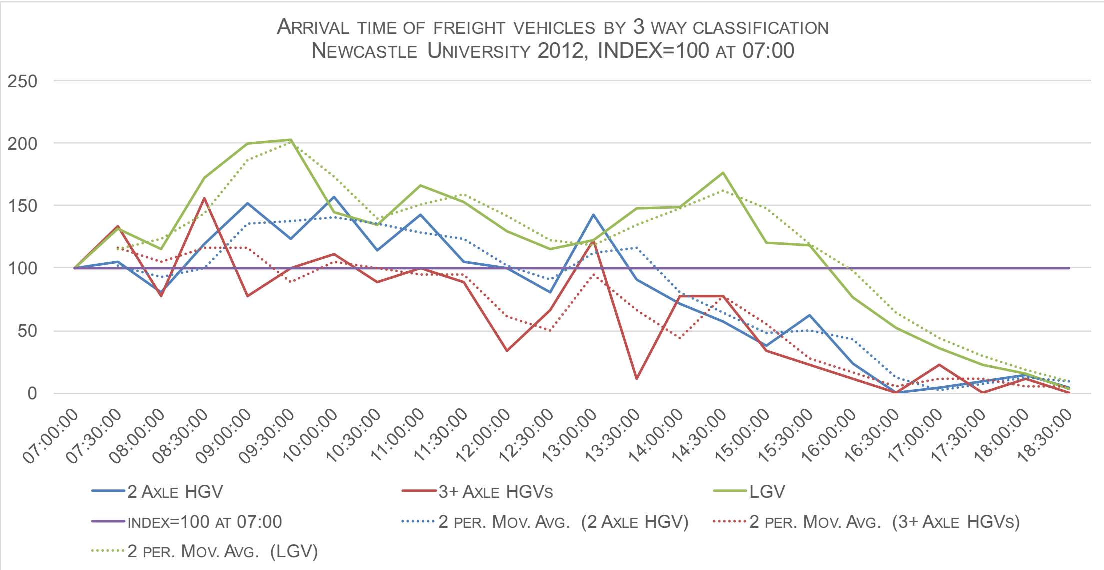


Figure 38: Arrival time of freight vehicles indexed to 07:00, traffic survey 2012

6.5. Differences between LGV and HGV by Site.

The chi-squared test was used to determine whether there was a significant difference between the expected frequencies and the observed frequencies, in one or more categories. I was interested in the distribution of nominal variables, such as vehicle class or Site, where the chi-square test could be appropriate. The one test that showed very significant difference was that of LGV or HGV and Sites, as shown in Table 77.

---

[28] Normalising the data using means and standard deviations was not appropriate given its non-normal distribution.

Count				
		LGV_or_HGV		Total
		LGV	HGV	
SiteIndex	Site 1	450	202	652
	Site 2	531	129	660
	Site 3	496	45	541
	Site 4	549	138	687
	Site 5	218	22	240
Total		2244	536	2780
Chi-Square Tests				
	Value	df	Asymptotic Significance (2-sided)	
Pearson Chi-Square	115.226[a]	4	0.000	
Likelihood Ratio	120.404	4	0.000	
Linear-by-Linear Association	53.370	1	0.000	
N of Valid Cases	2780			
a. Zero cells (0.0%) had expected count less than 5. The minimum expected count was 46.27.				

*Table 77: SiteIndex * LGV_or_HGV cross tabulation*

The bar chart (Figure 39) showed that the distribution of vehicle observations between the classes varied between Sites.

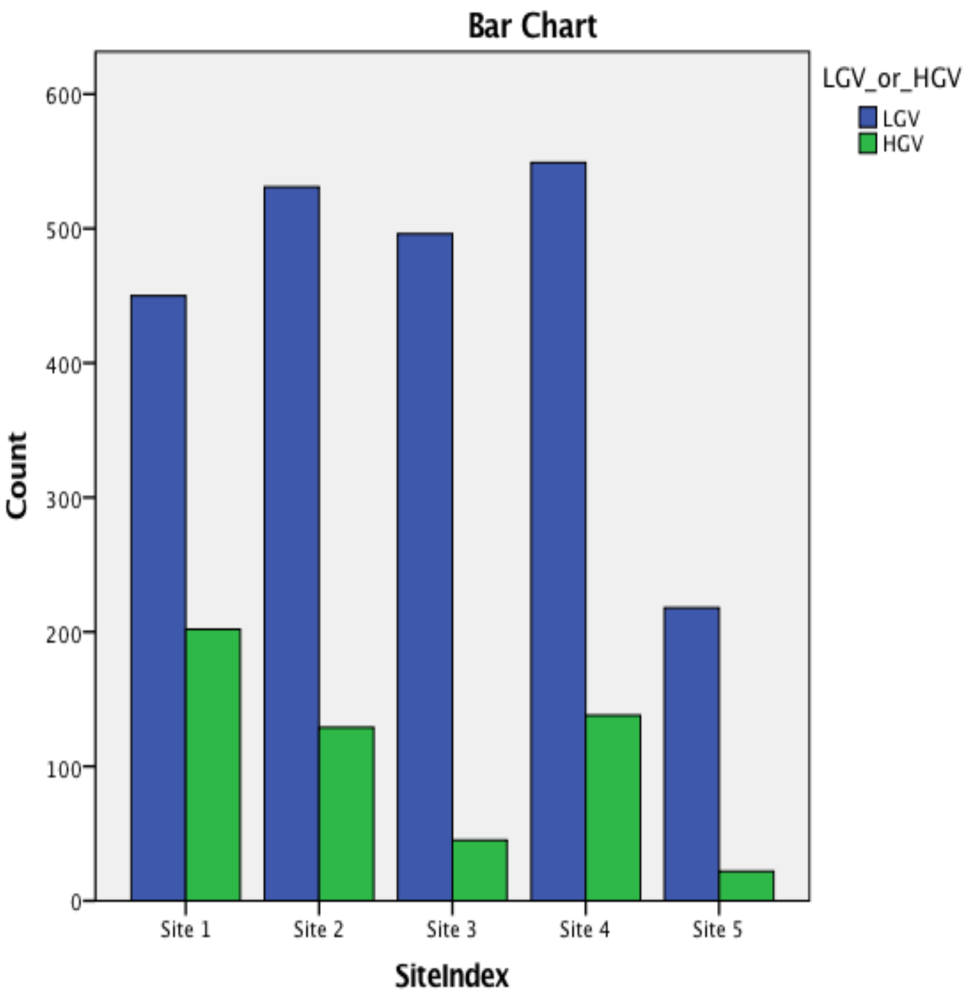


Figure 39: Frequency of observed vehicles arriving (IN) by Site

6.5.1. Other chi-squared tests

Other chi-squared tests showed few differences of note to the investigations at that time.

6.6. Correlations

It was of interest to establish if there were correlations between interval data and I had hoped to observe whether there was a correlation between purchase order line items, ordered for delivery on a weekday, and the observed traffic data. It was only possible at this point to utilise aggregated purchasing data for these tests, so I had only 5 cases: Monday-Friday - too small a sample for any statistical strength and of no great value for further exploration in this work.

6.6.1. Between traffic variables

Arrival time and dwell time seemed logical variables to judge for correlation, so I tested them with a Spearman Rho test, using SPSS Bivariate correlation analysis, as appropriate for non-normally distributed data. Arrival time showed a very weak negative correlation with dwell time; exit time showed a weak positive correlation with dwell time. Both are shown in Table 78 and Figure 40.

			dwelltime	time
Spearman Rho	Dwell time	Correlation Coefficient	1.000	-0.161
		Sig. (2-tailed)		0.000
		N	1823	1823
	Time (IN)	Correlation Coefficient	-0.161	1.000
		Sig. (2-tailed)	0.000	
		N	1823	2780
			dwelltime	time
Spearman Rho	Dwell time	Correlation Coefficient	1.000	0.274
		Sig. (2-tailed)		0.000
		N	1793	1793
	Time (OUT)	Correlation Coefficient	0.274	1.000
		Sig. (2-tailed)	0.000	
		N	1793	2721

Table 78: Correlations arrival time (IN) and dwell time; and exit time (OUT) and dwell time

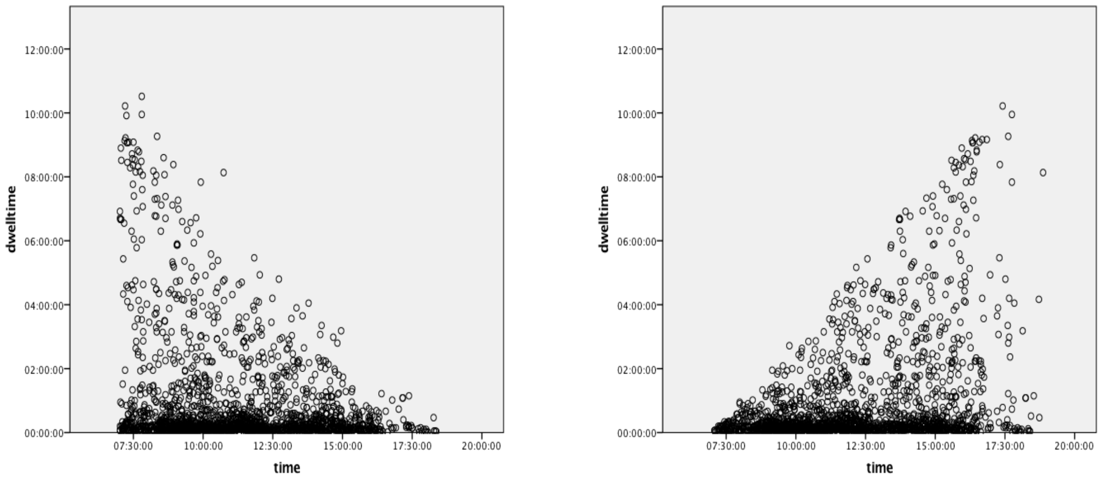


Figure 40: Scatter plots of Correlations arrival time (IN) and dwell time; and exit time (OUT) and dwell time

6.6.2. Correlations of arrival by the half hour

As a final exploration of potential correlation, I calculated whether there was a correlation between the half hour 'bins' and the number of vehicles observed arriving.

To perform these tests, I used PIVOT tables in the original spreadsheet to compile a dataset sorted by half hour 'bins', with the count of vehicles by Site, in full, shown in Table 79. This was then analysed in SPSS for bivariate correlation, using Spearman Rho, and mapped as scatter plots.

half_hour_text	Site1	Site 2	Site 3	Site 4	Site 5
7:00:00	1470	1867	2169	3914	279
7:30:00	7644	10325	10296	11487	1237
8:00:00	11611	11238	15733	20438	4166
8:30:00	37033	42127	24061	36051	8084
9:00:00	58120	51735	43952	48310	33161
9:30:00	75867	68863	81568	75660	7700
10:00:00	83854	76199	48212	69423	28703
10:30:00	78765	92154	51833	58149	33594
11:00:00	97405	125925	81193	107938	27833
11:30:00	131336	98366	78194	75403	58029
12:00:00	99019	99444	100377	70532	41717
12:30:00	90353	93377	65504	90451	58756
13:00:00	159097	96031	92593	121253	43918
13:30:00	163522	102854	95041	162006	23922
14:00:00	148411	157419	97773	153460	42139
14:30:00	140874	145197	154453	199141	86096
15:00:00	106214	124936	133898	100895	48103
15:30:00	125741	150442	85664	156901	35104
16:00:00	63000	88906	73133	88703	36593
16:30:00	69730	48160	26796	48167	32243
17:00:00	21708	48885	0	65157	37892
17:30:00	5487	16435	32954	27373	27337
18:00:00	5509	16553	27625	27624	11035
18:30:00	0	5544	11088	5548	0

Table 79: Data for half hour correlation tests

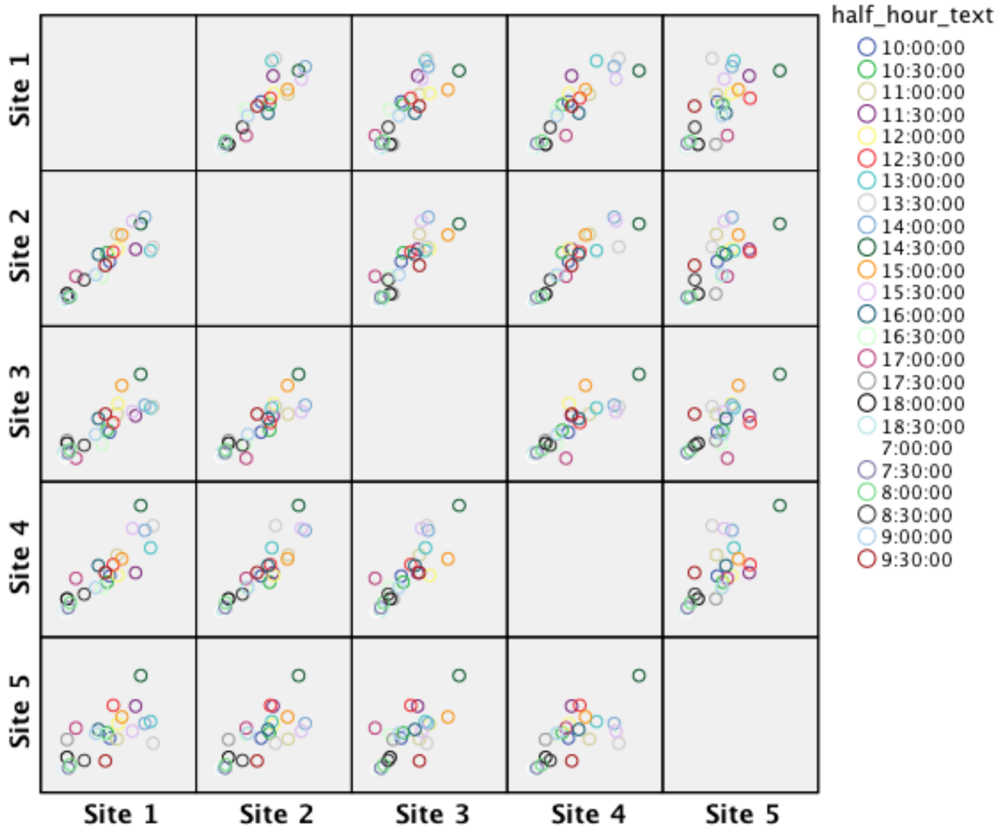


Figure 41: Matrix scatter plot, number of arriving vehicles by half hour bin

The matrix scatter plot Figure 41 showed positive correlations between Sites 1-4 and, as in other tests, much lower with Site 5. These positive correlations suggested that freight tended to rise and fall in line by half hour between Sites. This was borne out by the test results shown in Table 80 but, on reflection, correlations were very weak and added little to understanding.

Arriving vehicles by half hour		Site 1	Site 2	Site 3	Site 4	Site 5
Site 1	Correlation Coefficient	1.000	.921**	.871**	.915**	.703**
Site 2	Correlation Coefficient	.921**	1.000	.896**	.940**	.741**
Site 3	Correlation Coefficient	.871**	.896**	1.000	.870**	.645**
Site 4	Correlation Coefficient	.915**	.940**	.870**	1.000	.697**
Site 5	Correlation Coefficient	.703**	.741**	.645**	.697**	1.000

**. *Correlation was significant at the 0.01 level (2-tailed). All results were significant at 0.001 (2 -tailed)*

Table 80: Spearman Rho correlation arrival time vehicles by half hour by Site

6.7. Summary of findings from empirical observations

The key issues to explore were set out at the start of this Chapter thus:

- How did the University translate user demand to supplier demand?
- How well could I assess how that demand was expressed?
- How was that demand expressed in terms of differences between:
    - material groups;
    - day of the week;
    - month of the year; and
    - lead-time provided to suppliers?
- How many freight delivery vehicles visited the main campus?
- When did the freight vehicles visit?
- How long did the freight vehicles stay?
- How did those visit differ between:
    - different Sites on the campus;
    - different vehicle classes; and
    - different engine types?

6.7.1. Summary of findings from purchasing analysis

The University translated demand from users to suppliers using various formal and informal methods. I mapped and explained each route from A to E in section 6.2 and explained that the only route that created reliable transactional data – Route B - was not the only route that generated freight deliveries. The University used SAP R3 to record all the financial data, and some of the transactional data, associated with procurement. These data needed to be filtered, as detailed in section 6.3. The first filter was to exclude all order details that referred to material groups that would not normally lead to a physical freight vehicle delivery; then, all data were excluded that, probably for posthumous reasons, showed negative lead-times.

The purchase orders had been raised by a group of 112 people, 23% of the active buyers on the system, in line with an 80/20 pareto split. The default delivery date within the SAP system was set to be the day after the PO was released to the supplier.

The data set was large - 47,199 cases - representing 143,619 distinct purchase orders and 267,402 line items. The first result was that the purchasing data were not normally distributed. Analysing demand, I assessed that the University's weekend purchasing was significantly different to weekdays and thus I excluded weekends in section 6.3.8. Within the weekdays, demand differed significantly, with orders for delivery on Monday or Friday having fewer line items than those for delivery on the 3 midweek days. Demand varied through the year; pairwise testing in 6.3.12 showed that significant differences occurred, and an index chart of seasonality was drawn up.

A key question was the lead-time expressed to suppliers, to evaluate whether this stimulated a just-in-time response. I found that the University did exhibit a very short lead-time, with a modal average of zero lead-time (38.6% of filtered samples) and a final estimate of a range of 0-4 days, with a median of 3.

No correlation testing was considered appropriate at this time for the data in the purchasing dataset.

6.7.2. Summary of findings from traffic surveys

The traffic survey was carried out 7am – 7pm, from Monday 30th April 2012 to Friday 4th May 2012. As detailed in section 6.4.2 above, the data were transcribed from tape recordings to a spreadsheet and cleaned with the use of Excel. Vehicle plates and vehicle classification were used to derive engine types; non-freight vehicles were excluded. A Perl script was used to match arrival (IN) vehicle observations with exit (OUT), to create pairs and to derive the dwell time of a vehicle at each Site.

The first result was that the traffic survey data were not normally distributed.

In section 6.4.3 I detailed a freight total of 23.36% - almost double the average for European urban freight activity, reported anecdotally and in the literature as between 10% and 18% (Woudsma, 2001; European Commission, 2006b). It was noticeably almost double the 13% LGV and HGV traffic recorded in Newcastle City traffic surveys (Newcastle City Council, 2016), as illustrated in Figure 34. It may have been that the University campus was a major attractor of freight, and/or that the University Travel Plan had reduced car parking on campus by 55.8% between 2004/5 and 2011/12. Of the freight vehicles, 80% were LGVs. Of these vehicles, 39.11% were Euro 4 engines, 21.78% Euro 5, and 15.10% Euro 3. These data, shown in section 6.4.5, would be key to evaluation modelling in Chapter 8.

I refined the earlier aggregate mapping of traffic movements through the day (section 6.4.6) and a different pattern between cars and light goods vehicles was elaborated and analysed pairwise. In section 6.4.12 onwards, I reported that arrival time differed significantly between weekdays, with Monday and Tuesday showing variance one to the other, as did Tuesday and Thursday. Arrival time varied significantly between Site 5 and all others, Sites 1-4 being much the same as one another. Arrival time showed no differences between 2 Axle HGVs and 3+ Axle HGVs, but both were significantly different to LGVs. This importantly confirmed that, for arrival time, LGVs had a different movement pattern to HGVs. I illustrated the arrival for each group as a line chart, in Figure 38, which would also be key to evaluation modelling in Chapter 8.

Dwell time was a key metric in the literature and was of great interest in assessing how much time freight spent at a location, as opposed to on the road. In sections 6.4.10 and 6.4.11 I showed that the IQR for dwell time was 07-52 minutes and that this was amended by visual observation to 05-52 minutes, with a median of 16 minutes. The dwell time median for LGVs and HGVs was similar (15 and 17 minutes, respectively), but LGVs had a higher range (IQR 06-67 minutes), which appeared to be in line with many LGVs being observed in use on campus as portable workshops. When a three-way vehicle classification was used, it became clearer that 3+ Axle HGVs had a different median to 2 Axle HGVs and LGVs, (27 minutes - see Table 61). Pairwise analysis then revealed that all weekdays showed the same patterns of dwell time and that Site 5 differed significantly from the other 4 Sites in terms of dwell time, with a median of 68 minutes (see Table 58).

Nominal data were analysed using Spearman Rho chi-square tests of expected frequencies; these showed significant differences between Sites, in terms of frequency of LGVs versus HGVs (see section 6.5).

Correlation testing reported in section 6.6 above showed a weak negative correlation between arrival time (IN) and dwell time and, in reverse, a weak positive correlation between exit time and dwell time. Of more interest, and reported in section 6.6.2, was a strong correlation between Sites 1-4 and each other in terms of numbers of vehicles arriving every half hour, and also the very weak correlation between Site 5 and the other Sites.

I placed on hold, for later traffic surveys, a conclusion about what a freight vehicle had been doing entering and leaving the University campus in under the time needed to make a delivery.

Site 5 (RVI) differed to the other Sites in much of the analysis; its dual usage between the University and the hospital was of note.

6.8. Summary [Meta-step]

This Chapter has reported how its objectives were met, with an extensive report on the processes of purchasing that led to demand; a statistical analysis of the SAP records of that demand; and then a traffic survey of the main campus, to observe freight vehicle behaviour.

6.8.1. Reflection on Content

Core

Of importance to the knowledge gained was the decentralised nature of the purchasing system, but also the key role of a small number In FP 2010, 80% of all Purchase Orders were raised by 112 (23%) of the active buyers on the system.

The key point from the traffic survey data was that the freight vehicle total of 23.36% was almost double the average for European urban freight activity and almost double the 13% recorded in Newcastle City traffic.

Thesis

With regard to content within the thesis, the work reported in this chapter has addressed the concept of poor ex-ante and ex-post data collection from the literature review; however, it has also identified that, even when collected, data can be very poor in an operational context, where the purposes for collection are at variance with the interests of the researcher.

6.8.2. Reflection on Process

Core

With regard to process, the categorisation of survey techniques by Allen, Browne and Cherrett (listed above in Table 16) was helpful - both in formal use during the research process and informally to help inform it. Whilst the key chosen techniques were 'commodity flow survey' and 'vehicle traffic surveys', they were augmented and understood by 'walking the site', ad-hoc parking surveys with cameras, and talking to drivers as and when the opportunity arose. These insights - which stemmed from a more holistic understanding of the raw traffic counts and purchasing transactions - all came about from regular 'walking the site', or an informal version of 'establishment survey', carried out over a period of years. There was little meaningful correlation between the SAP data and the traffic survey, other than the weak correlations discussed in section 6.6 above. The very low level of potential buyers was noted, and the relevant individuals were included in the work going forward.

The datasets were very large, and SPSS handled them easily. The data were non-parametric and, as such, some functions normally useable with normally distributed data were not available, making some scripting needed. I was well supported with advice and suggestions by Dr. Simon Kometa, of the University statistics support team, and by my colleague Dr. Shirley Coleman; I am pleased to have gained enormously greater confidence as a statistician.

Thesis

With regard to theory, this could be seen as similar to Dingwall's (1997) comment that there are only two basic methods in social research: "asking questions", and "hanging out" and that logistics researchers have to gain greater relevance by spending more time in organisations - or in this case, on the kerbside.

6.8.3. Reflection on Premise

Core

The work reported here showed that the premise upon which the Purchasing systems lay was primarily about invoice clearance and had only just started, in 2010-2011, to move to a system for procurement.

Thesis

This contextual research primarily addressed the Where, When and How top-level groupings of the system outlined in *Figure 15* above. The theoretical premise of viewing the issues within a socio-technical frame was neither confirmed nor denied in this chapter.

Investigation into the existence, role, and influence of power buyers was furthered, with the identification of a very small subset of buyers placing a high volumes orders for the Faculty of Medicine, and their inclusion in the collaborative process added insight. This in itself advanced the knowledge in this area of enquiry, and lays the groundwork for further focused research in sustainable procurement.

Chapter 7. Stakeholder Engagement: Design and Monitoring Framework

This Chapter is focused on the presentation of the outcomes of the Asian Development Bank's DMF process, which formed the first two Action Research iterative cycles. Therefore, its purpose is to document the steps known as stakeholder analysis; problem analysis; the alternatives analysis; and the DMF table. In each step, concrete data from the work are evidenced as exemplars of how the process unfolded, so that the reader can follow the route from a group of semi-strangers in a room, to an agreed design for work that can be monitored in a sound framework.

7.1. Pre-step

7.1.1. Context

The DMF process asked for the inputs of actors as stakeholders, but also asked them to work with others and construct mutual understanding, meaning and potential solutions for problems, as detailed in section 5.10.3 above. This process was defined as local, and contingent on time and place; it was therefore primarily integrated into the local context, then, secondarily, into the national and international contexts. The nature of the work contracted had been formally scoped with the EU and, less formally, with the University. The preliminary analysis from the first traffic survey and the SAP data to that date had been completed, as detailed in Chapter 6 above. The process itself was to be about constructing meaning; therefore, the participants themselves brought their expert knowledge and insight, as data. The process sits within the who, where, and why elements of the *'systems approach' socio-technical framing* adopted.

7.1.2. Purpose

The DMF occupied much of the first two AR cycles, constructing meaning and planning action. Although DMF and AR had developed from different disciplines and approaches, both were pragmatist and constructionist in premise and seemed aligned. The theoretical purpose was to address Dablanc's concerns, that urban logistics was "difficult to organize, difficult to modernize" and that "all players are expecting initiatives to come from the other side" (2007). The process would bring stakeholders together to address the "… heterogeneity of the stakeholders involved. Besides the traditional logistics actors such as shippers, carriers and receivers that share consistent interests (i.e. price and quality), city logistics highly respect the interests of public administrators and citizens that care more about the social welfare. To reach an optimal balance between private and public benefit, it is necessary to understand … different groups" (Anand, Yang, *et al.*, 2012).

7.1.3. Ethical considerations

The DMF process asked for the inputs of others and constructed shared meanings and purpose. This could potentially cause individuals to adopt positions, or express opinions, they would wish to be anonymous for personal, commercial or professional reasons; as such, personal identities were anonymised in published research.

7.2. Planned Implementation of the DMF process

The Design and Monitoring Framework (DMF) process was based on the logframe method for project planning and monitoring, developed from the original logframe, further developed in ZOPP (Gasper, 2000a) and finessed by the Asian Development Bank (ADB, 2007). DMF goals included the monitoring and evaluation of the deliverables of a project, the measurement of its impacts and outcomes, and the identification – at an early stage - of risks and assumptions, for better preparation and design of mitigating actions. All these elements were documented in the DMF process and their evolution from earlier logical framework approaches has been detailed previously, in Chapter 3.

The process consisted of four main steps: Stakeholder analysis; Problem and Objectives Trees; Alternatives analysis; and the design of the Framework. To obtain a holistic view of the issues, all steps utilised a participatory approach, involving different stakeholders. Within the AR cycle for this work, the first cycle contained the first two DMF workshops, beginning with scoping and problem definition (constructing) and leading to stakeholder analysis (planning action); the creation of the Problem Tree (taking action); and the sharing and evaluation of these outputs by all engaged actors (evaluating action). The Second Cycle contained the 2nd DMF workshop (constructing action), where the Alternatives analysis was completed (planning action), converted to an Objectives Tree, and the chosen actions written up as a DMF (taking action), before distribution to all engaged actors in preparation for the next stage (evaluating action). The stakeholders were recruited from the relevant University functions; the staff of the

Tyne and Wear LTP3; members of the project staff; and invited members of the local Freight Partnership.

Since the interests, issues and objectives of transport operators, city transport planners, University estates or purchasing staff, local retailers, and wider policy makers differed, the participatory approach embraced these different stakeholder views in a mutual process that aimed to recognise the different ‘lenses’ through which the actors viewed the situation; it then created a mutual understanding and shared language. Since the DMF actions were divided into two main categories (the situational analysis - intended to analyse the present conditions; and project identification – to explore the future options) the work was mapped neatly into two AR cycles. Together, these two cycles produced the first action plan output: a DMF table. There were however some deviations from the planned process, as described below.

7.3. Workshops

To carry out the DMF process, workshops were planned as detailed in Table 81.

Workshop	Date	Newcastle
I	12-13 Nov 2012	Stakeholder analysis; Stakeholder Problem analysis
Interim session	11 Dec 2012	Workshop for more focused group of interested actors to revise the problem analysis tree development
Session with Tyneside freight operators	7 Feb 2013	This workshop was planned as an after-work session for freight operators, but was cancelled due to lack of interest - *itself an important finding*.
II	21/2/2013	Development of the objectives tree. Stakeholder consultation on alternatives; decision on interventions. Inputs to the DMF table

Table 81: DMF Workshops

In addition to the workshops, further consultations with relevant stakeholders were held to clarify outstanding issues from one step, before proceeding to the next. In between each session, paper-based documents and artefacts were converted to electronic diagrams for use at the next stages.

7.4. Workshop I

The first workshop was the first step in the AR cycle, after the initial framing, scoping, and contractual process and the setting of initial context via SAP and a traffic survey. Since the process was designed to mutually define the problem(s), the working problem for the workshop was defined very broadly as:

"Unsustainable Freight in the Centre of Newcastle."

First, several presentations were made, to demonstrate the current status in Newcastle and on the University campus. These were:

- the use of urban consolidation centres;
- freight in Newcastle;
- ITS tools for urban freight distribution;
- innovative vehicles for freight transport; and
- purchasing and traffic survey context on campus.

Following the presentations, the DMF process was explained and detailed for the attendees. The process then began, with the stakeholder analysis, see the agenda as Figure 42 below.

7.4.1. Stakeholder Analysis

The first diagnostic tool in the DMF process was to ensure that the actors present had a common, shared set of interests, problems, mandate and resources. In order to work together, the actors had to become shared stakeholders; to begin this process they needed to share their knowledge. This was 'stakeholder analysis': "[i]t helps clarify which people and organizations are directly or indirectly involved in or affected by a specific …. problem. It helps identify which groups are supportive and which groups may oppose the project strategy and subsequently obstruct project implementation. This provides a sound basis for taking appropriate actions to gain the support of opponents and to get key supporters more involved" (ADB, 2007)

Date:	13th November 2012
Host:	NewRail, Newcastle University
Venue:	Clore Suite, Great North Museum: Hancock (Map Ref: 34)
Address:	Barras Bridge, Newcastle-Upon-Tyne, NE2 4PT, United Kingdom
Chairman:	Tom Zunder, NewRail

Time	Topic	Organisation
09:00 – 09:30	Registration & Tea & Coffee	
09:30 – 10:00	Welcome to Smartfusion. Overview of Days events and Newcastle Demonstration	Tom Zunder, NewRail
10:00 – 10:20	Urban Consolidation Centres	Richard Ball, Clipper Logistics
10:20 – 10:40	The Freight City in a City - Newcastle University Case Study	Paulus Aditjandra, NewRail
11:00 – 11:30	Tea & Coffee / Networking	
11:30 – 11:50	ITS Tools for Urban Freight Distribution	Detlef.Bäuerle ,PTV AG
11:50 – 12:10	Innovative Vehicles Technologies for City Logistics	Smith Electric
12:10 – 12:40	Money & energy saving in Freght Transport	Jacques Leonardi, University of Westminster
12:40 – 13:20	Lunch / Networking	
13:20 – 13:45	Design and Monitoring Framework Approach	PANTEIA/NEA
13:45 – 14:30	Tyne & Wear - Local Stakeholder Roles	Tom Zunder, NewRail
14:30 – 14:45	Tea & Coffee / Networking	
14:45 – 15:45	Tyne & Wear – Problem Identification	Tom Zunder, NewRail
15:45 – 16:00	Tea & Coffee / Networking	
16:00 – 17:00	Development of Tyne & Wear Strategy	Tom Zunder, NewRail
17:00	Close of Days Events	

Figure 42: First workshop agenda

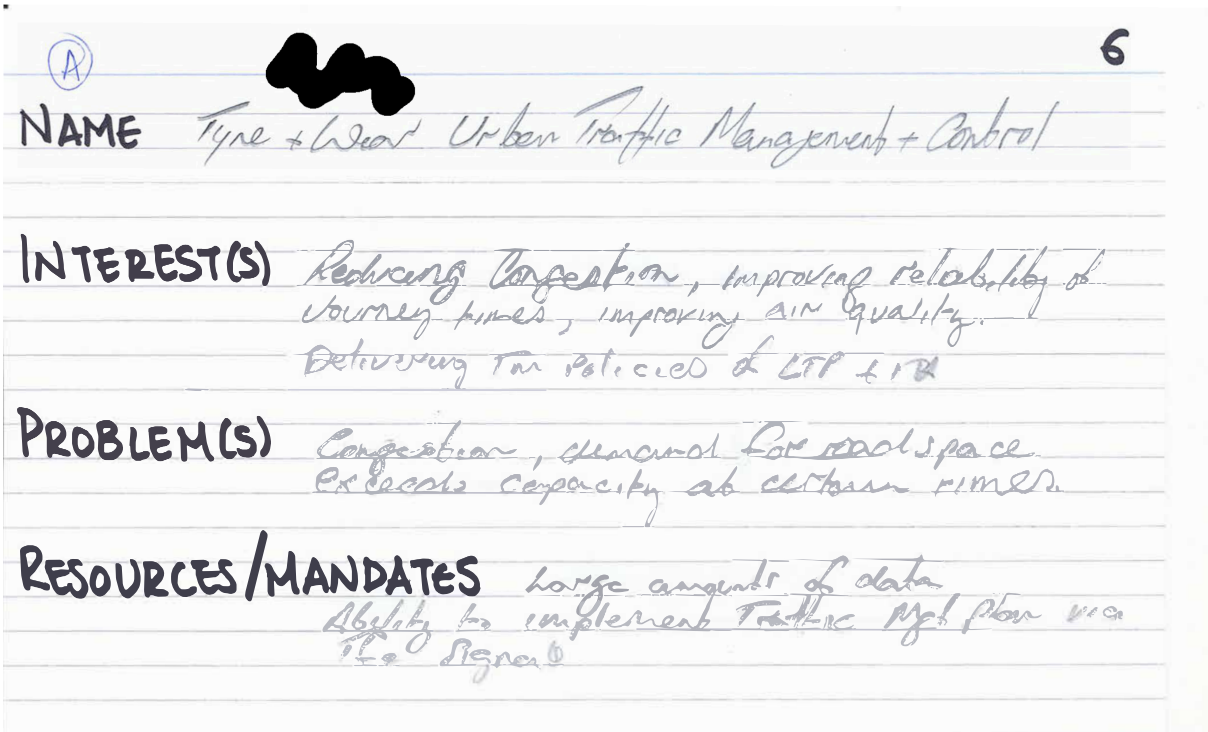
7.4.2. Stakeholder Analysis

The first diagnostic tool in the DMF process was to ensure that the actors present had a common, shared set of interests, problems, mandate and resources. In order to work together, the actors had to become shared stakeholders; to begin this process they needed to share their knowledge. This was 'stakeholder analysis': "[i]t helps clarify which people and organizations are directly or indirectly involved in or affected by a specific …. problem. It helps identify which groups are supportive and which groups may oppose the project strategy and subsequently obstruct project implementation. This provides a sound basis for taking appropriate actions to gain the support of opponents and to get key supporters more involved" (ADB, 2007).

The first workshop was intended to explore the problems of urban freight in the city of Newcastle - not just on the University campus, but also in the wider cityscape within which the University sat and interacted. The City Council had strong policy interests in air quality, freight consolidation, and electric vehicles in its LTP3, as detailed in Chapter 1, and therefore the invitation list for this first workshop was a composite of the bodies in local government, freight trade associations, sustainability, logistics providers, University staff, international researchers, vehicle manufacturers, and urban traffic management.

The attendees were allocated to small sub-groups, where they were asked to introduce themselves and then to each fill in an index card (see example in Figure 43), covering:

- their stakeholder interests;
- their perception of the problem(s);
- their possible contribution to the process (awareness, support, technology etc.);
- their mandate (public, private, regulatory, policy or commercial).


A [redacted] 6

NAME Tyne + Wear Urban Traffic Management + Control

INTEREST(S) Reducing Congestion, improving reliability of journey times, improving air quality. Delivering the policies of LTP & [illegible]

PROBLEM(S) Congestion, demand for road space exceeds capacity at certain times.

RESOURCES/MANDATES Large amounts of data. Ability to implement Traffic Mgt plan via [illegible] Signals

Figure 43: Example stakeholder analysis card (anonymised)

The index cards were immediately transcribed into tables and the output recorded, as in Table 82.

Organisation	Interest(s)	Problem(s)	Mandate/Resources
Local Sustainable Travel Fund Programme Manager	Transport Planning; Traffic Management; Development Management; Delivery Service Plans; Behavioural Change; Travel Plans	Business interests in freight operations; Understanding the actual problems; Future planning for the city	Staffing resource; LTP3 Budget; Local highway authority; Local planning authority
Smith Electric Vehicles Europe	Environmental; Financial; supply of Electric Vehicles	Environmental impact of CO_2 production; Lack of buy-in to Green Solutions by Fleet Operators	All electric solutions/alternatives to conventional IC engines
Head of Procurement - Newcastle University	Deliveries to the University Campus	Too many deliveries; Too many multiple drops from the same company; Pedestrianisation of the Campus	Approve all University supply contracts; Control access to the procurement system; Control contracts if necessary; Control supplier delivery, to a certain extent
National Contracts Manager - Clipper Logistics	Supply Chain Management; Retail Deliveries; Freight Consolidation Centres	Traffic Congestion; Too many timed (specified) deliveries	Urban Delivery; Optimum Planning to optimise the supply chain
Managing Director - Zero Carbon Futures	UCC Training; LCV Development; EV Infrastructure; Transport/Logistics	Opportunities Enrichment, driven by commercial sector; Development of a curriculum	Gateshead College facilities; Clustering opportunity on LCV & Logistics
Tyne and Wear Urban Traffic Management Centre	Reducing Congestion; Improving reliability of journey times; Improving air quality; Delivering the policies of the LTP3 & ITA	Congestion: demand for road space exceeds capacity at certain times	Large amounts of data; Ability to improve Traffic Management Plan, via traffic signals

Organisation	Interest(s)	Problem(s)	Mandate/Resources
Consultant - AECOM	Sustainable Movement of Urban Freight	Emissions; Loading Bays; No Car Lanes; Connectivity	Tyne & Wear Freight Partnership; Tyne & Wear Local Transport Planning Team
Manager of Estate Support Service - Newcastle University	Reduction in Carbon Emissions related to journeys to & from campus; Reduction in traffic movement on campus	Current lack of hard & fast data to clearly identify issues	Coherent Campus Budget; Control over access to campus; Improvement to campus infrastructure
Researcher - Newcastle University	Understand urban freight economies	Urban freight issue at Newcastle University	Historical Procurement/Traffic Data
Transport Planning Manager - Newcastle City Council	Sustainable Development - Government Legislation & Guidance; Environmental Improvements - Noise, Air Quality; Public realm improvements; Pedestrian Activity; Stimulating the economy	Congestion; Insufficient loading/unloading areas; Timing of deliveries	Funding available to mitigate problems, providing the problems are known; Staffing resource; Highways Authority Powers & responsibility
Fleet & Transport Contracts Manager - Office Depot (UK)	Making deliveries to central Newcastle locations; Reduction of distribution costs	Traffic congestion; (Un) Loading Access; Delivery time windows; Delivery access points; Delivery frequency; Customer demands on specified delivery times/points	Vehicles; Telematics; Scheduling
Product Support Manager - Smith Electric Vehicles Europe	Vehicle fleet profile & usage	Understanding & acceptance of alternative logistics solutions	Extensive performance data for EVs; Predictive simulation tool for vehicle sustainability confirmation

Organisation	Interest(s)	Problem(s)	Mandate/Resources
Policy Manager - Freight Transport Association (FTA)	Representing the interests of the industry; Road/Rail/Sea & Air Freight	Slow uptake of alternative fuels to help with emission issues; Affordability; Encouragement of alternative distribution patterns, such as 'out of hours' deliveries	The FTAs policies; FTA demographic process
Head of Business Development - Clipper Logistics	Consolidation Centres; Supply Chain Management	Non-compliance (Direct Supply); Adoption of new technology; Upfront costs; Demonstrating return on investment	Warehousing; Staff; "The Know how" - experience

Table 82: Stakeholder Analysis Table

7.4.3. 1st Problem Analysis

The purpose of problem analysis through the development of a Problem Tree - the 2nd diagnostic tool - was to "(i) analyze the existing situation surrounding a given development problem context, (ii) identify the major related problems and constraints associated with the development problem, and (iii) visualize the cause-effect relationship in a diagram—a problem tree" (ADB, 2007). This was performed next, in three mixed groups. My research team facilitated and recorded the conversations and the process itself created permanent archival records in the form of index cards and photographs that were later converted to electronic format. Top level leadership and co-ordination of the activity was managed by me. The workshop defined 3 broad topics of conversation. These were derived from: the interests of the initial problem formulation (as recorded in Chapter 1); parallel research activities; and a first pass discussion with the participants.

The topics were, provisionally:

- Group A: Consolidation Centres
- Group B: Newcastle City Freight Problems
- Group C: Customer Demand Issues

The full output was recorded in internal project reports and early progress was reported at conference (Zunder *et al.*, 2013); shorter highlights were summarised as follows:

Group A: Consolidation Centres

A University supplier, Office Depot, represented the broader views of suppliers and fleet operators, stating that many issues were not Newcastle specific and that, across the UK, there were many cities suffering from congestion, loading access, and high emissions - making these problems quite generic. It was stated that suppliers responded to customer needs and behaviour and that transport operations responded only to customer demand. A customer request for goods next day would result in next day delivery, even if such was not the true underlying need. Next day delivery was used by some companies as a tool, or selling point, to differentiate themselves to win business, providing them with a competitive advantage in the marketplace. Consumers had grown to expect this service level, driving a '24/7' environment that directly impacted on such issues as guaranteed delivery time (e.g. before 9am) in peak congestion.

The Freight Transport Association was keen to express its interest in the entire supply chain, e.g. freight movements beyond the urban (city) environment. Smith Electric was keen to promote its circa 30 years of experience in the manufacture of electric vehicles. Of note was their contention that the clean commercial fleet market was supply side driven, not customer led, with weak market demand for clean vehicles. Newcastle City Council spoke about several issues where the environment was high on the political agenda: the role of the city as a bypass, a motorway, and a historic city centre; problems of safety, unclear routing, and illegal parking; and concern about the effect of large numbers of vehicles and deliveries on city infrastructure. The City was a member of the local Freight Partnership and was thereby aware of more regional issues, not just city specific problems, and had access to additional data sources.

The whole group was very interested in how the costs and benefits of a consolidation centre were shared: who actually paid for the cost of running a Consolidation Centre and who enjoyed the potential benefits of fewer truck movements and overall trip distances? The idea of centralisation and decentralisation was strongly debated, referring to the different supply chain approaches of organisations that hold stock on-site versus those that call in goods on a 'just-in-time' basis.

Group B: Newcastle City Freight Problems

The group had limited awareness of existing problems regarding freight transport in Newcastle, in particular regarding external effects. Participants mentioned that congestion might be a problem, but were unable to speak with data. Initially one member refused to talk about '*problems'*, preferring *'opportunities* and *issues'*. However, during the problem analysis, the stakeholders' discussion opened up regarding the perception of a *problem*, mentioning for example that there was effectively a *problem* with regularly exceeding legal air quality limits. (The facilitator noted that a stakeholder from an environmental organisation could have helped to clarify this point, see section 7.10.3 below.)

During the problem analysis, at least one stakeholder had difficulty with distinguishing *causes* and *effects*. (For example, one person insisted that congestion was a cause of the development problem, rather than an effect.) It is worth noting that membership of this group was made up of city transport planners, the manager of the urban traffic management centre, and the local freight partnership - perhaps explaining why freight problems in the wider city were not seen as pressing. It was suggested that the direct involvement of local freight operators in the workshop might have been beneficial.

Group C: Customer demand

Group C focused on the customer demand effect on the supply chain. It synthesised cause and effect statements, suggesting three main causes for unsustainable freight:

- Use of mainly conventional fuels for freight transportation;
- Illegal parking on and around the university campus; and
- Highly unconsolidated freight flows.

7.4.4. Building the Problem Tree

These broad-brush discussions were then used by the groups collectively to complete cause and effect cards. A cause card detailed a cause for the core problem: 'Unsustainable Freight in the Centre of Newcastle' and also stated the data that could be captured with regard to that cause. Similarly, an effect card detailed an effect from the core problem and the data that could be captured for that effect. These were then mutually arranged and rearranged on a wall, to build, revise and agree upon a Problem Tree, as outlined in Figure 44 and evidenced in Figure 45

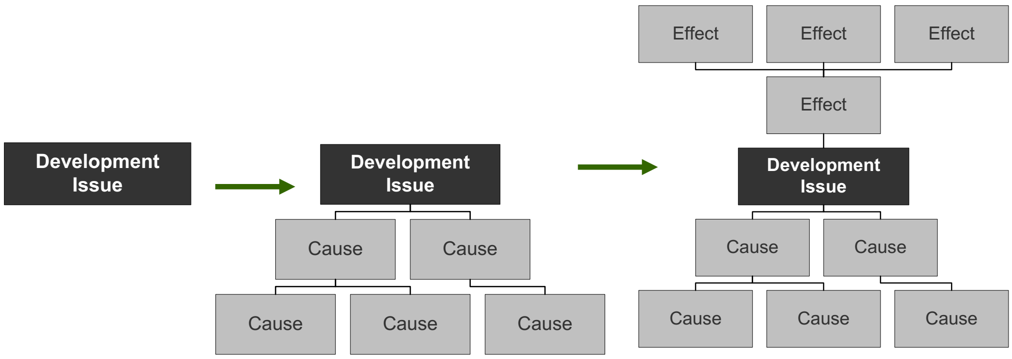


Figure 44: Problem Tree Construction Training Materials

Figure 45: Neil Addison, Newcastle University Purchasing Manager, helping to build the Tree

The participants wrote on cards the existing problems seen as the direct *causes* of the core problem and placed them in a horizontal line under the problem. Next, the participants filled in the problems that were seen as the *effects* of the core problem. These were written on cards and placed in a horizontal line above the development problem. Thus, the output was recorded in card and photograph form, as shown in Figure 46.

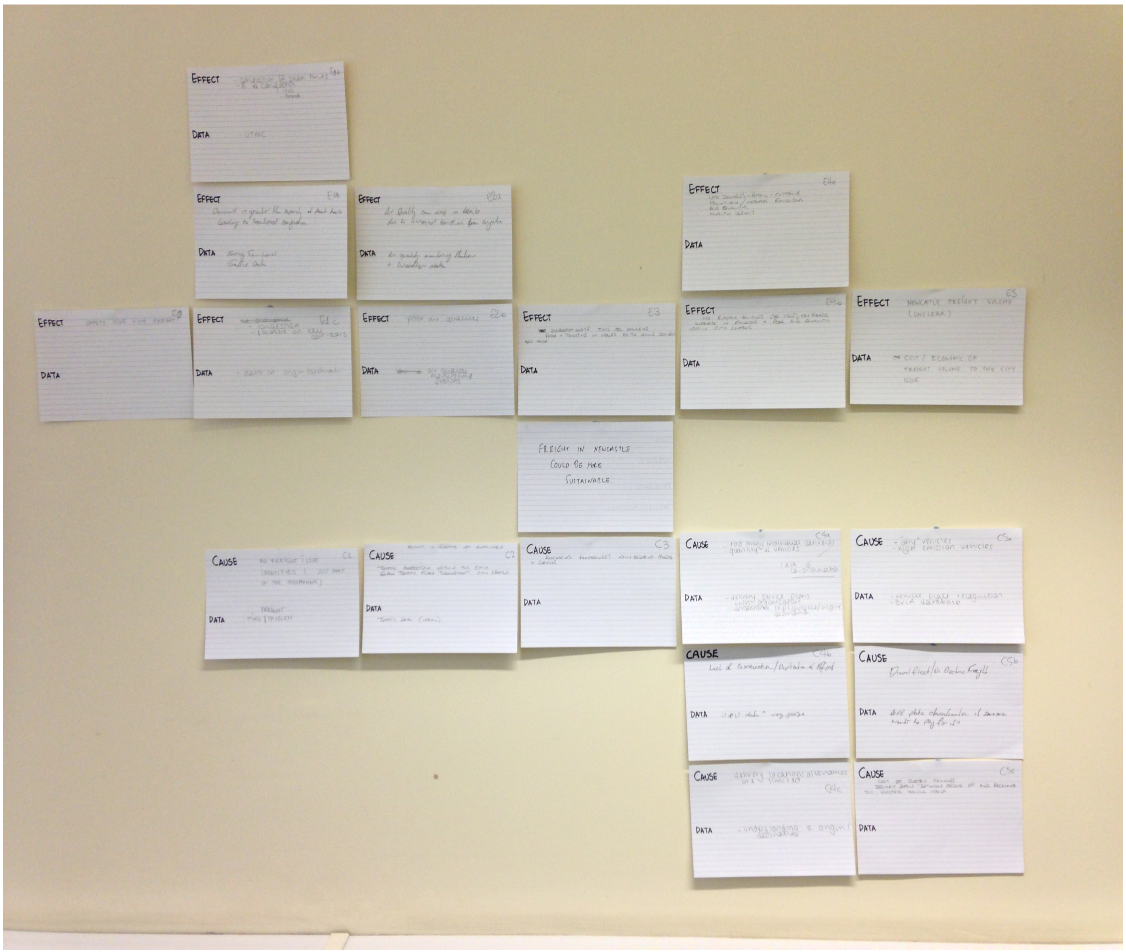


Figure 46: Newcastle Problem Tree as developed on a wall

During this step of the process, it became clear that some workshop participants did not believe Newcastle to have a sufficiently serious problem with its freight transport (limited congestion, limited emissions) and so were unable to identify sub-causes or effects. In addition, some participants did not anticipate any strong changes in the existing demand, nor its flow (from policies etc.).

The absence of certain stakeholders (e.g. transport operators and large retailers) from the participatory session, made itself felt. Other stakeholders identified and focused on some real issues around the University campus and the city. Following the building of the Problem Tree, it was decided it would be advantageous to refocus the work with the committed stakeholders and to try again to recruit transport operators, who had been unable to attend due to pressures of work.

7.5. The Cancelled Workshop

A new, open session was therefore organised and targeted at transport operators, using the Tyne & Wear Freight Partnership mailing lists. To avoid the previously reported problem in attending, the workshop was arranged after work hours, at a venue with food and drink provided. Counter to expectations, the event attracted no support. (The Tyne & Wear Freight Partnership reported a similar lack of success with evening events, despite the unpopularity of daytime meetings that clash with managing busy operations.)

I took this as indication that, following the precepts of ‘problem, interest, mandate and resources’, our work should focus first and foremost on the University campus.

7.6. Interim workshop

There was a strong core of interest from the institutional receivers of goods. As the Netherlands’ Binnenstad project had suggested (Van Rooijen and Quak, 2010), it was the receivers of goods who, consciously or unconsciously, controlled the supply chain.

Following up on this, the project organised an interim workshop, in December 2012, at which a fine-tuning of the problem analysis and the formulation of alternatives interventions were the main activities. The 18 stakeholders attending represented:

- Newcastle University Estates department;
- Newcastle University Purchasing department;
- Newcastle University Executive Board;
- Newcastle City Council Transport planners;
- Newcastle City Councillor with responsibility for the Neighbourhoods portfolio;
- National Health Service Purchasing;
- Newcastle University Students’ Union;
- Your Homes, Newcastle;
- Newcastle City Council Procurement department; and
- The Tyne & Wear Freight Partnership.

This workshop redefined the focus by concentrating on institutional receivers of goods, i.e. ‘freight attractors’. The suggested approach had been that this could eventually include Newcastle University, the City Council Civic Centre, the Newcastle Royal

Victoria Infirmary and potentially Northumbria University; however, the main campus of Newcastle University served as the lead location and demonstrator.

The Problem Tree from the first workshop was reapplied to a wall and adapted to suit this closer, tighter focus, with the problem now defined as: “Unsustainable freight transport on the University Campus”. The significant change was the addition of a section detailing the causes and effects associated with “Illegal Parking on and around the University Campus”, which was added at the centre of the diagram. A wider range of Estates personnel attended this interim workshop, which increased the ownership and buy-in within the University. The revised Problem Tree was converted to an electronic diagram, as shown in Figure 47: Newcastle Campus Problem Tree. Note: this should be read from top to bottom, with causes building up in a hierarchy to the main problem, which then expands out into the various effects.

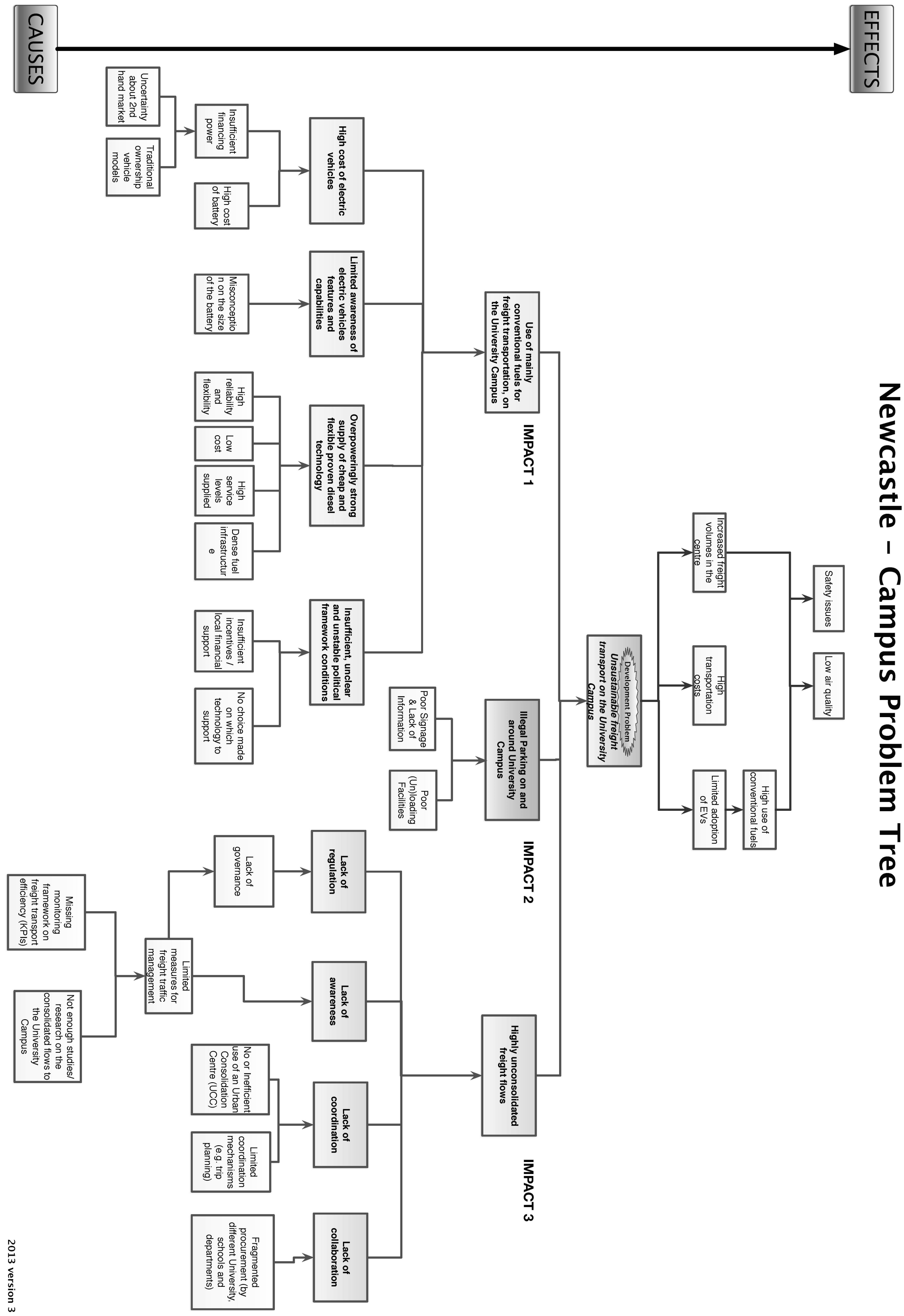


Figure 47: Newcastle Campus Problem Tree

7.7. Workshop II

The second main workshop was held in February 2013.

The analysis of the current situation had identified and refined the problem, using stakeholder analysis and problem analysis to develop a Problem Tree. The purpose now was to specify the desired future situation and this step was based upon two analytical tools: objectives analysis and alternatives analysis. Once completed, this would then be used to fill in the Design and Monitoring Framework (DMF). Following the refocusing on the campus, this workshop only involved selected stakeholders: the Newcastle University Procurement department; the Newcastle University Estates department; Newcastle University researchers; and local government transport planners.

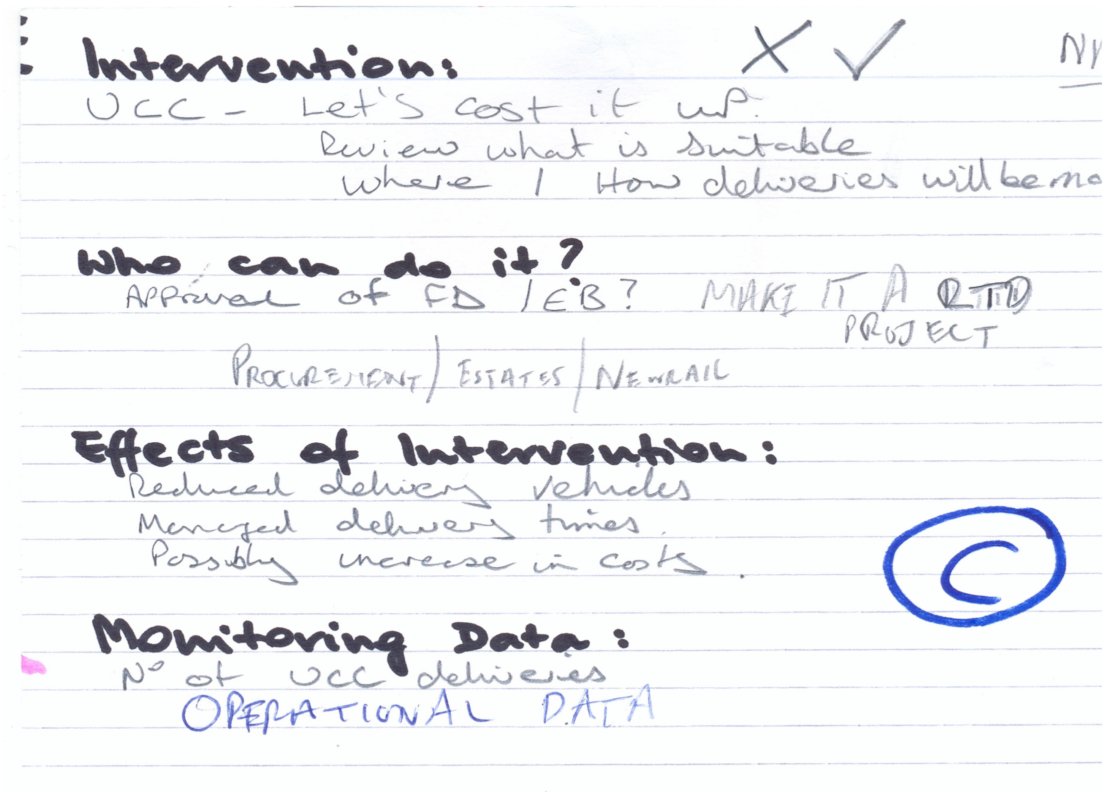
7.7.1. Alternatives Analysis.

The first task was to identify potential alternatives or interventions.

After a round table discussion of potential actions, all attendees filled in cards, both singly and jointly, with:

- the nature of an intervention;
- who could do it;
- the effects of intervention; and
- the monitoring data.

An example card is shown in Figure 48, below.



Intervention:
UCC - Let's cost it up.
Review what is suitable
where / How deliveries will be ma

Who can do it?
Approval of FD / EB? MAKE IT A RTD PROJECT
PROCUREMENT / ESTATES / NEWRAIL

Effects of Intervention:
Reduced delivery vehicles
Managed delivery times.
Possibly increase in costs.
C

Monitoring Data:
No of UCC deliveries
OPERATIONAL DATA

Figure 48: Example Intervention Card

Formulation of alternatives

The following alternatives were developed by the stakeholders as potential interventions:

Low Emission Zones (LEZ);
Urban Consolidation Centre (UCC);
Supplier (Self) consolidation of deliveries;
Joint working public private partnership (PPP);
Vehicle access weight/ size/ time restrictions;
'Out of hours' delivery;
Locker banks and designated delivery/collection points, for personal freight;
Vehicle-routing schemes and access maps;
Use of environmentally friendly goods vehicles e.g. cargo-cycle, Electric LGV;
Road pricing systems (Entry onto Site); and
Delivery and Servicing Plans (DSPs).

Table 83: Potential campus interventions

The stakeholders then ranked the alternatives positively or negatively and came up with a final list of five recommended options for the University campus, transcribed from the original index cards:

A: Better signage and Delivery Maps

Brief description: this intervention was raised to overcome the illegal parking adopted by a number of regular suppliers (including UPS, TNT, Parcel Force, Catering delivery etc.) within the main university campus.

Stakeholders: Health & Safety Department (to issue the regulation), Estates (ESS) (to enforce the new rule), Thomas Zunder (to design the measures and monitor the implementation).

Support: Procurement (to distribute the new rule to suppliers), Newcastle City Council (NCC) (to give examples of how signage and delivery maps, used in Freight Partnership, could be used in the Coherent Campus initiative).

Data and monitoring: Extra survey on illegal parking, during the next traffic count survey; Estates members to help patrol for illegal parking and subsequently distribute a delivery Map to offenders.

Data gaps: Illegal parking data.

B: Self-consolidation via Supplier

Brief description: this intervention was raised to increase the awareness of regular suppliers of efficient delivery trips that reduced excess freight traffic within the main university campus.

Stakeholders: University Suppliers.

Support: Procurement (to raise the issue to suppliers), Office Depot (to pilot efficient delivery via Office Depot consolidation centre), Clipper Logistics (to share knowledge on efficient logistics operation), Thomas Zunder (to design the measures and monitor the implementation).

Data and monitoring: Supplier delivery data – to lead to emission and cost savings.

Data Gaps: Supplier delivery data (Office Depot or any other large University supplier).

C: Consolidation Centre

Brief description: this intervention was the original Urban Consolidation Centre (UCC) intervention technique to reduce multiple random trips to the final destinations in an urban setting. The idea was to filter long distance freight traffic to the end destination that caused urban traffic congestion and pollution.

Stakeholders: Procurement (to inform supplier who used long distance delivery, facilitated by a UCC), Your Homes Newcastle, Clipper Logistics (UCC expert operator), NCC (Local authority), Suppliers, Thomas Zunder (to design the measures and monitor the implementation).

Support: Volvo; PTV (technology expert).

Data and monitoring: Identify suppliers with fewer/more deliveries.

Data Gaps: Supplier interested in UCC within its supply chain to Newcastle.

D: University Coherent Campus Consolidation Centre

Brief description: this intervention adopted the UCC intervention technique, to reduce multiple random trips to the final destinations in an urban setting, but focused in on one (internal) organisation only. While the internal consolidation centre was meant to add extra storage capacity, the idea here was to make use of the extra space as a temporary stop for long-distance and trip-intensive deliveries to the University.

Stakeholders: ESS (University logistics operator), Energy (University energy monitoring manager), Thomas Zunder (to design the measures and monitor the implementation).

Support: Smith Electric; PTV (technology expert).

Data and monitoring: internal university data of logistics operation; energy data; interview with library vehicle operator.

Data Gaps: other University vehicle operators re: fleet fuel, trip route.

E: Sustainable Catering Initiatives

Brief description: this intervention was to regulate a particular delivery pattern, based on sector. It had been identified that Catering deliveries generated regular freight traffic around the University campus, that could potentially be regulated to conform to non-peak hours delivery.

Stakeholders: Procurement, University Catering dept., Students' Union, Thomas Zunder (to design the measures and monitor the implementation).

Support: NCC (to introduce national Freight Operators Recognition Scheme (FORS)).

Data and monitoring: internal university data of logistics operation.

Data Gaps: Catering delivery data; interview with Catering delivery operator.

Selection of the preferred solution

Newcastle University agreed to proceed with all five interventions, some of which fell outside the scope of this research. The potential interventions were seen as well designed and developed; all involved stakeholders highly committed to the interventions.

A: Better signage and Delivery Maps
B: Self-consolidation via Supplier
C: Consolidation Centre
D: University Coherent Campus Consolidation Centre (CCCC)
E: Sustainable Catering Initiatives

Table 84: Selected interventions for Newcastle

7.7.2. Conversion into Objectives Tree

The second task of the Alternatives Analysis was to combine the interventions with the Problem Tree and invert it into an Objectives Tree. This was again done with the use of cards and mutual discussion and participation around a wall. The synthesised Problem Tree from Workshop I (Figure 47) was presented as an A3 poster and was used to map the completed cards (Figure 48) onto the revised Problem Tree (Figure 49).

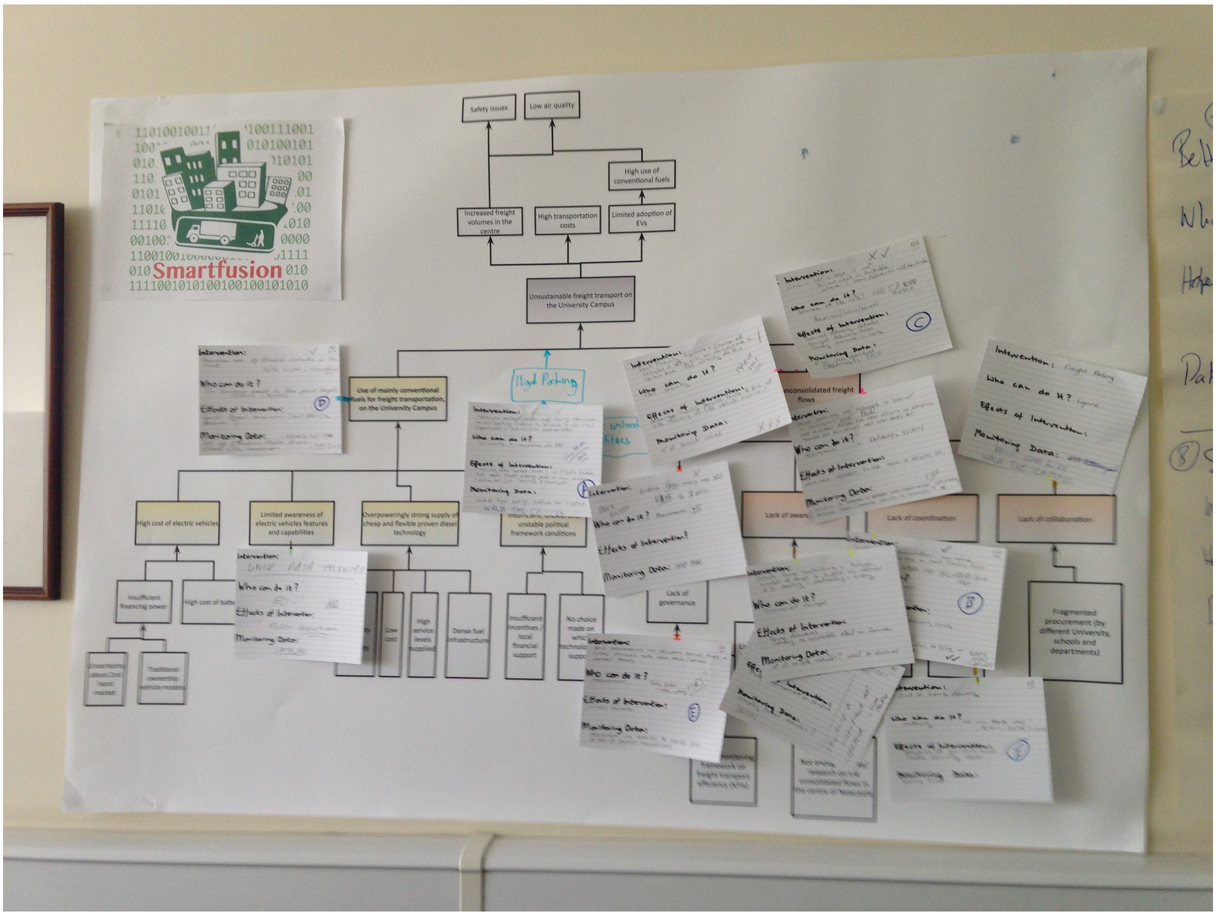


Figure 49: Alternatives (Interventions) mapped onto revised Problem Tree

This agreed structure of interventions was then converted to an electronic diagram, essentially substituting interventions for causes, and reversing effects into desired goals and outcomes. Note: this Objectives Tree should be read from top to bottom, thus building up in a hierarchy to the main objective, which then expands out into the various ends to be achieved.

This was subsequently converted to electronic format for later use in the various interventions and activities that followed; the final version is Figure 50.

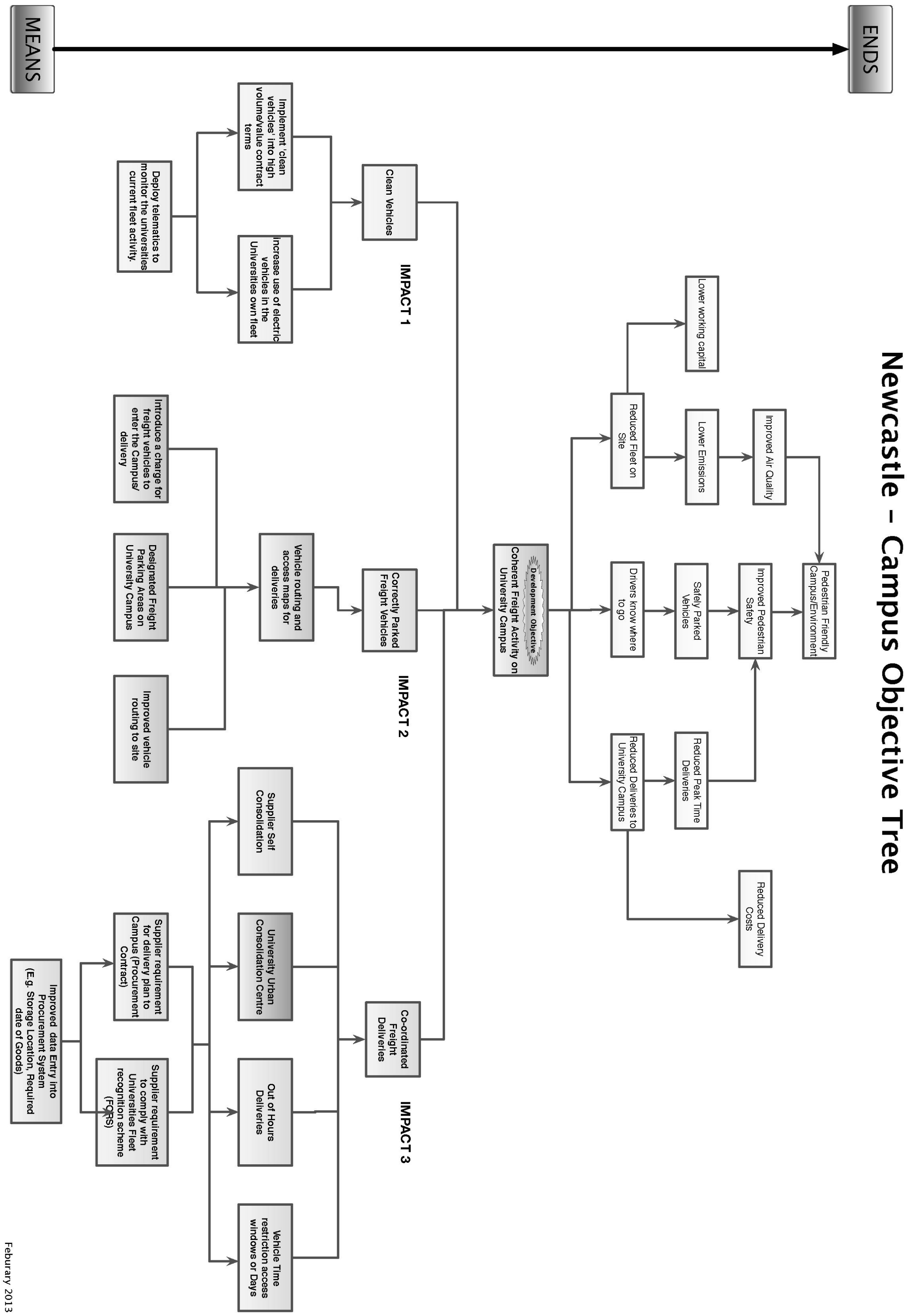


Figure 50: Newcastle campus Objectives Tree

7.8. DMF table

The DMF table was intended to follow a clearly objective approach, based on quantitative measurement and management. The guidelines, which echoed those of 1970, stated that: “If we can measure it, we can manage it” and that “[a]ll measures have to be measurable and expressible in numeric terms”(ADB, 2007). Whilst there were valid criticisms of such a non-holistic viewpoint being a ‘straitjacket’ (Dale, 2003) and ‘as often abused as effectively used’ (Bakewell and Garbutt, 2005), our reflections (see Chapter 9) led me to follow the process as defined.

7.8.1. Migration from Objectives Tree to DMF

The DMF was defined as a synthesis of the previous steps: Problem Tree, Alternatives Analysis, and Objectives Tree, that transformed the participatory processes into a clear project plan, with measurable indicators.

The Asian Development Bank process for migrating the objectives tree to the DMF involved mapping the final Impacts - the top line of the tree just before the objective - to the top line of the DMF. The second level was mapped as Outcomes, the next level was defined as the Outputs, and all work thereafter was defined as Activities. This is shown in Figure 51, where the relevant sections of the Objectives Tree have been mapped across to the DMF sections. This migration did not need to be a literal, word for word replication of the Tree text - and indeed they were rewritten for clarity, in some cases adding work implied in the Tree - in accordance with the ADB guidelines. It should be noted that this work was not done during Workshop II but afterward, as part of evaluating action, but also iteratively throughout the work as it proceeded.

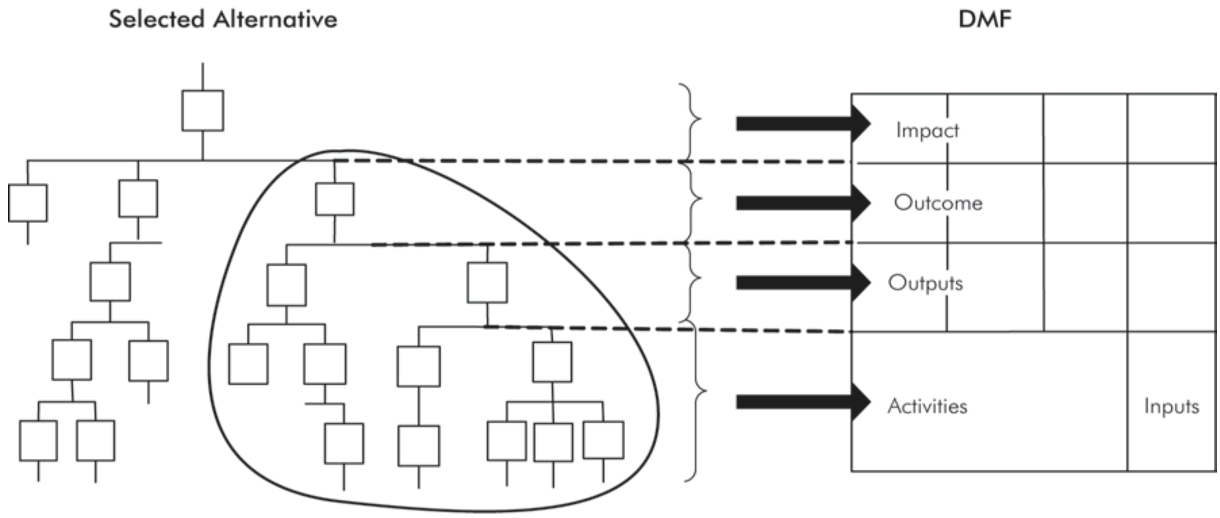


Figure 51: Linkages between the Objectives Tree and the DMF (Source: ADB, 2007)

To demonstrate how Impacts were transferred from the Objectives Tree to the DMF Table, the example of Impact 3: Co-ordinated Freight Deliveries (see Figure 50) is used below.

The Impact in this case was a longer-term objective, achievable over a 3 to10-year timeframe. The Outcomes were the key anchors of the design achievable by project end - in this case recorded as Supplier Self Consolidation, a University Urban Consolidation Centre, Out of Hours Deliveries, and Vehicle Times restriction access window (days). The first two Outcomes mapped onto Interventions B and D (see Table 84), but the final two Outcomes would not be pursued. Outputs were the physical tangible goods or services delivered by the work – in this case a procurement policy for new delivery plans to be integrated into contracts, and a requirement for suppliers to comply with a scheme, such as FORS, originated by TfL (Thompson, 2015). Activities were a group of tasks to be carried out in order to achieve the desired Outputs – here the primary one was the improvement of data in the University "SAP" ICT based Procurement system.

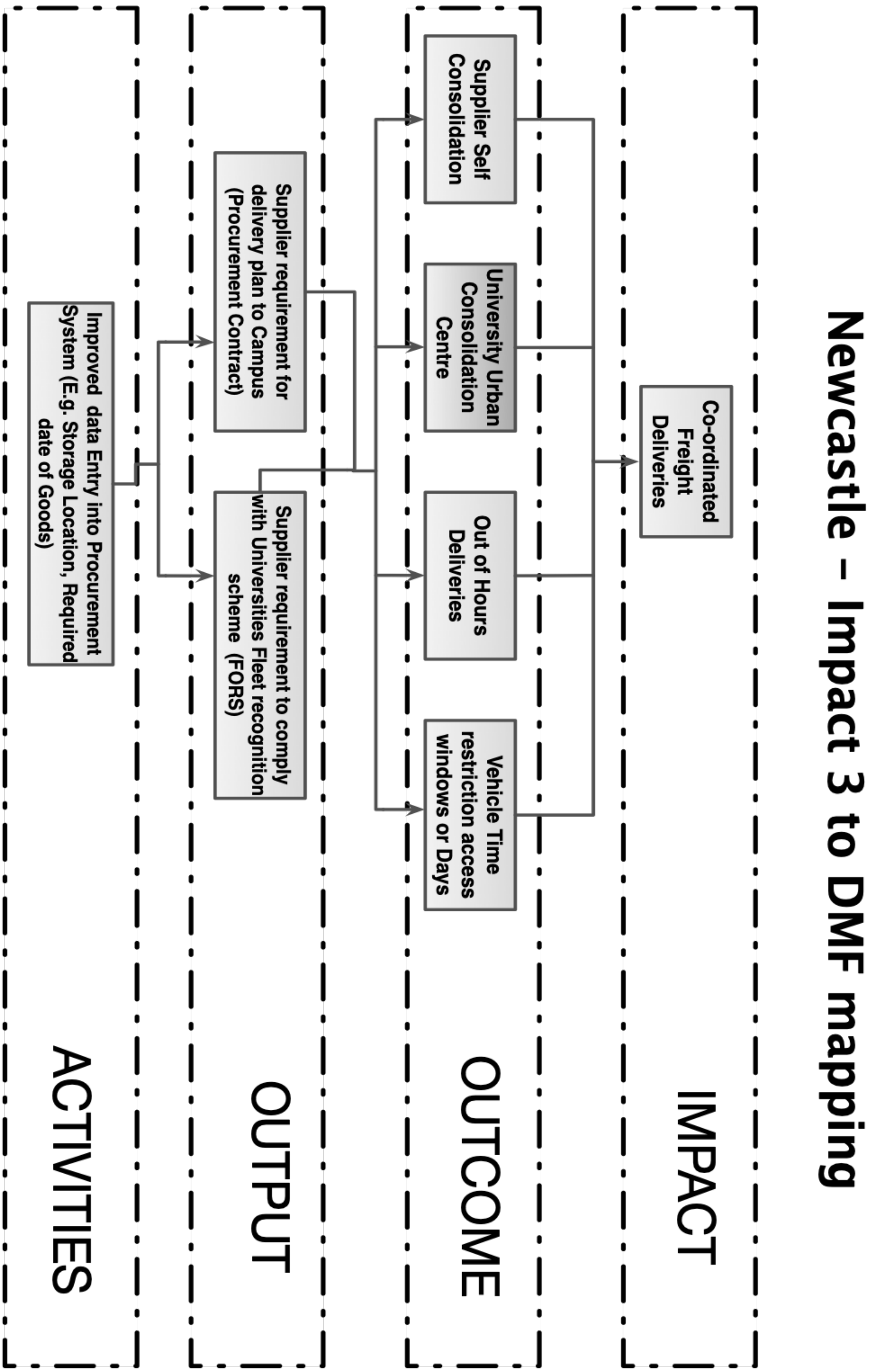


Figure 52: Newcastle: Impact 3 to DMF mapping

The required inputs were: “the main resources required to undertake the activities and to produce the results. These include consulting services, personnel, civil works, equipment, materials, and operational funds” (ADB, 2007). In this case, the Inputs were identified as: EU project funding; research partner co-funding; internal research budgets; external stakeholders; local and regional political support; University Executive Board support; and associated resourcing for Purchasing and Estates departments. They did not map to the Objectives Tree and were derived from all the records of the workshops, wider discussion, and backfilled from later AR cycles.

7.8.2. Indicators

Having completed the first column, the need was to define Performance Targets/Indicators for the different levels of the DMF - the qualitative and quantitative specifications for the desired results. The ADB guidelines suggested two schemas for ‘well-defined’ indicators: SMART and CREAM, as well as an additional category: ‘practical criteria’.

> *SMART was defined by ADB as **S**pecific – relate to the results the project seeks to achieve, **M**easurable – stated in quantifiable terms, **A**chievable – realistic in what is to be achieved, **R**elevant – useful for management information purposes and **T**ime-bound – stated with target dates.*
>
> *CREAM was defined by ADB as **C**lear – precise and unambiguous, **R**elevant – appropriate and timely, **E**conomic – available at reasonable cost, **A**dequate – sufficient to assess performance, and **M**onitorable – can be independently verified.*
>
> *Practical was defined as “Measure only what is important; limit the number of indicators to the minimum necessary to ensure the respective results level; and ensure their means of measuring is cost effective”* (ADB, 2007).

SMART and CREAM were widely used principles for selecting performance indicators in development evaluation. The CREAM criteria were introduced by Schiavo-Campo (1999) and it is worth noting that he added caveats, especially to ‘Clear’, where he added “…not necessarily quantitative...”. SMART was promoted by the United Nations Development Programme and various other international bodies.

The steps in determining performance indicators are illustrated in Table 85 using examples from the Newcastle work.

Process	Outcome: The take up of external/internal consolidation centre as a hub and 'out of hours' delivery to reduce freight traffic around campus, in a coordinated way, via procurement contract – decongesting the Campus
Step 1: Determine the basic indicator—what is to be measured?	Increased number of CCCC deliveries [versus direct deliveries] & [absolute target] Decreased total freight transportation costs (cost/kg, cost/day)
Step 2: Decide on the quantity—how much (increase/decrease)?	Increased number of CCCC deliveries [60% via CCCC] versus direct deliveries & absolute target [of 80 parcels a day] Decreased total freight transportation costs (~~cost/kg~~[29], [-5%] cost/day)
Step 3: Describe the quality—what kind of change?	Increased number of CCCC deliveries 60% via CCCC versus direct deliveries & absolute target of 80 parcels a day [of those goods or suppliers suitable for the pilot] Decreased total freight transportation costs (-5% cost/day) [expressed as the cost of the transport operation and also as the purchase cost]
Step 4: Add the time frame—by when?	Increased number of CCCC deliveries 60% via CCCC versus direct deliveries & absolute target of 80 parcels a day of those goods or suppliers suitable for the pilot [by end 2015] Decreased total freight transportation costs (-5% cost/day) expressed as the cost of the transport operation, and also as the purchase cost [by 2019]

Table 85: Example of Steps in Determining Performance Indicators: following ADB process [adapted from (ADB, 2007)*]*

This table also shows the removal and addition of indicators as the DMF developed over time; additions are [in square brackets], deletions are ~~struck through~~. Following this process and with iterative amendments in later AR cycles - as data, people, or research allowed or demanded - the DMF indicator column for Newcastle was populated as follows in Table 86. This evolution of the working document was supported by the guidelines: "If necessary and appropriate, indicators may be changed during project implementation. Indicators are linked to their respective level of the

[29] *Very few goods suitable for this service would be costed in mass/weight.*

design summary. When changing an indicator, check if the respective results statement is still adequate” (ADB, 2007).

7.8.3. Data Sources and Reporting Mechanisms

The third column of the DMF detailed the data sources and reporting mechanisms. The data sources column was a record of where the status of each indicator could be obtained, as well as who would provide the information and how it would be collected, e.g. reports. The Reporting mechanisms column recorded where the information was documented (ADB, 2007).

The ADB guidelines were very specific to the work required by the bank, but the principle of having clear and agreed data sources and reporting mechanisms was a primary feature of all logframes. Here, these sources and risks were derived from the Alternatives Analysis and, in particular, the intervention index cards used in Workshop II (see Figure 48). These were the primary data used to populate this column of the DMF.

7.8.4. Assumptions and Risks

A project at a particular place in space and time can never be isolated from externalities; these can include political, economic, social, personnel or even climatic factors. The DMF explicitly excluded all assumptions and risks within the control of the project management. The ADB considered it the responsibility of project management to handle such internal assumptions or risks and that only factors in the hands of decision makers external to the project, or so far away from the work as to be considered completely uncontrollable (albeit not limited to so-called acts of god, or *force majeure)* should appear in the DMF. I however did not subscribe to this limited view; not only was the boundary between internal and external not entirely clear, but many participants had expressed doubt about the project management detailed in the ADB guidelines. I decided to use a project management technique more closely aligned to PRINCE 2 (Bentley, 2010), wherein internal project risk management was a key feature. In completing the table, the definition of assumptions and risks was relaxed accordingly.

7.9. Newcastle University Campus DMF

With these steps, and in the manner described, a DMF was populated for Newcastle University campus for all 3 Impacts detailed in the Objectives Tree (Figure 50 above).

It is important to note and understand the vertical logic of a logframe, such as a DMF, since it can appear inverted and counter-intuitive. The table begins with the Impacts and then steps back through the process; it should therefore be read starting from the bottom, then left to right, until the top is reached, as shown in Figure 53.

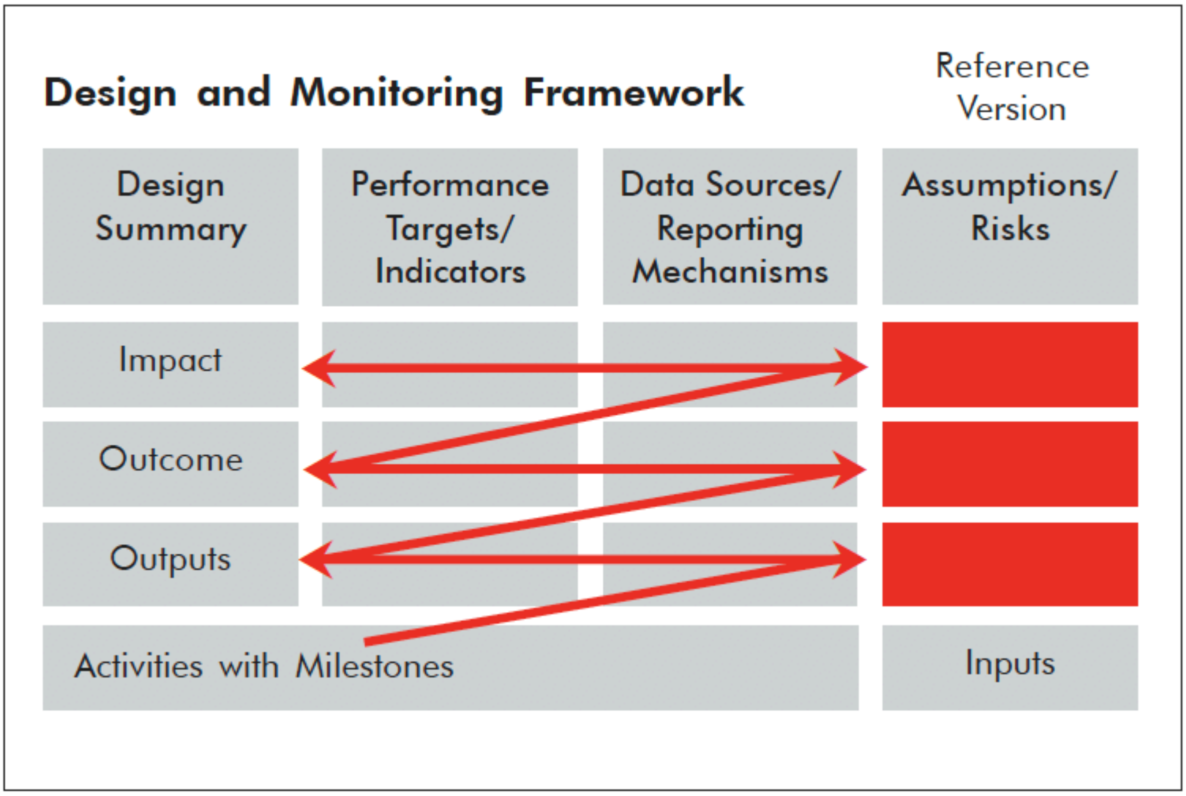


Figure 53: Vertical Logic of the DMF [(Source: ADB, 2007)*]*

At the end of the first two AR cycles, and the completion of the Design and Monitoring Framework process, the full DMF table was populated. This was begun at the end of the second workshop, converted to an electronic document, and then revised through the following AR cycles where it became input to business model generation, pilot design and, later, evaluation. It follows as Table 86.

Design summary	Performance targets/indicators	Data sources/reporting mechanisms	Assumptions and risks
Impacts			
Improved urban freight at Newcastle University contributing to sustainable economic development of the wider Newcastle region by making the city more attractive to residents and local businesses as well as allowing Newcastle to be a hub for regional traffic without bearing any negative externalities.	Increased stakeholder satisfaction by University Executive Board by a reduction of freight vehicles on campus by 25% by end 2019.	Traffic surveys. Interviews and reviews with University Exec Board.	A: The freight delivery system will be improved through the new measures and technologies. A: Continuing support for urban freight policy at Newcastle City level and other big organisations level and acceptance by cargo receivers. R: Lower impact from the measures. R: Failure to efficiently use the measures.

Outcomes			
Comprehensive University campus strategy embedding a delivery and servicing plan strategy – Delivery Strategy.	One detailed policy action of new purchasing strategy implemented as pilot by 2014, one implemented as a working service by 2019.	Official publications of procurement team of the Campus.	A: The University Strategy will be well received by stakeholders.
Procurement of electric vehicles as part of the University fleet.	One new EV added to University own fleet by end of 2015.	Official publications of campus procurement team.	A: Incentives will be enough to engage the procurement of EVs.
The take up of external/internal consolidation centre as a hub and out of hours' delivery to reduce freight traffic around campus, in a coordinated way, via procurement contract – decongesting the Campus.	Increased number of CCCC deliveries, 60% via CCCC versus direct deliveries & absolute target of 80 parcels a day, of those goods or suppliers suitable for the pilot by end 2015. Decreased total freight transportation costs (-5% cost/day) expressed as the cost of the transport operation, and as the purchase cost, by 2019.	Consolidation Centre productivity and vehicle use data.	A: The measures for the CCCC (time restrictions) will be effective. R: Failure to accept the changes in delivery services. R: The EVs will not be a commercially viable solution.

Outputs			
The uptake of clean vehicles to demonstrate the commercial viability and environmental benefits of (hybrid-) electric freight vehicles.	Increased number of EVs on campus, one by end 2015. Decrease of emissions levels (CO_2, PM_x, NO_x) -25% of CO2e by 2019.	Smartfusion project outputs (deliverables). Estimates on emissions based on fleet activity reports and factors for vehicles. Fleet activity reports.	A: The users will successfully take up the solutions. A: The demonstrations will successfully confirm the commercial viability and environmental benefits of the project. R: Technical, Financial, Planning risks for the demonstration. R: Expected impact from demonstrations not reached.
Correctly parked freight vehicles via dedicated IT-solutions for planning and driver support with access maps for deliveries.	Decreased number of illegally parked vehicles on campus, noticeable reduction by walking the campus.	Questionnaire among campus users. University staff measuring strategy violations.	R: Limited compliance to the Campus strategy.
Co-ordinated freight deliveries including the revitalisation of an urban consolidation centre and the effects of the procurement policy (in delivery times and transport costs and loading factors).	Recruitment of 20 suppliers to a pilot trial by end 2015. Negotiation of a contract with a provider of the centre by end 2013.	Consolidation Centre (CCCC) performance data. Fleet activity reports. Smartfusion project outputs (deliverables).	R: Low consolidation of cargo reached despite the procurement policy.

Activities	Inputs
Output 1: Clean vehicles. Activity 1.1: deploy telematics to monitor the university current fleet activity. Activity 1.2: achieve agreement between the university and the technology provider. **Output 2**: Correctly parked freight vehicles. Activity 2.1: introduce a charge for freight vehicles to enter the university campus. Activity 2.2: design and implement designated freight parking areas on campus. Activity 2.3: improve vehicle routing to campus. **Output 3**: Co-ordinated freight deliveries. Activity 3.1: assess supplier self-consolidation feasibility via delivery plan. Activity 3.2: assess University Coherent Campus Consolidation Centre feasibility via delivery plan. Activity 3.3: assess out of hours' deliveries for catering department. Activity 3.4: assess vehicle time restriction access windows or days.	European Commission: Smartfusion project financing; Green Cars Initiatives. Project partners co-financing: Research budgets. External stakeholder: Local and regional political support; University Executive Board support; Purchasing Manager support and resources; Estates Manager support and resources.

Table 86: Newcastle campus DMF adapted from project records

7.10. Summary [Meta-step]

In this chapter, I have detailed the implementation of the DMF process through participatory workshops: first, cancelled, interim, and second. The way that the workshops fitted into the AR cycles is explained, as is the way the workshops followed the DMF version of the logical framework approach: creating a Problem Tree, revising it, carrying out an Alternatives Analysis, building an Objectives Tree, and converting the potential solutions into a DMF. This DMF formed a mixed quantitative and quantitative evaluative framework, as well as a structure from which to build a quasi-experimental model, in section 10.10 below. In each step, the chapter has used concrete data from the work as exemplars of how the process unfolded, so that the reader can follow the route, from a group of semi-strangers in a room, to an agreed design for work that could be monitored in a sound framework.

7.10.1. Reflection on Content

Core

After briefing on the SAP and traffic survey data, the actors mutually developed data, identifying problems, and organising them into hierarchies of cause and effect. This content developed a rich problem tree (Figure 47 above), unique to the campus, from which a coherent set of potential interventions were developed. These data were equally as valid as the archival SAP data, or the empirical traffic survey data, and were used to develop a mutually agreed objectives tree, mapping the interventions into a schematic that enabled clarity on aspirations, interests, mandates, responsibilities, and the beginnings of a plan. The plan was then codified into a logframe, according to DMF. All interventions were selected, although a single one forms the body of this thesis from here onwards.

Thesis

The isolation of catering into a separate intervention - due to quite different goods profiles - and the emergent need for better signage on campus, were novel. The opportunity to test a demand-driven, receiver-led consolidation scheme was novel, compared to the literature review at this point. The relationship between the interventions and concepts from the literature review is detailed in Table 87 below.

Intervention	Key related concepts
A: Better signage and Delivery Maps	Novel in 2010/11
B: Self-consolidation via Supplier	Urban consolidation centres (1978); Delivery and servicing plans (DSP) (2010); Non-traditional approaches to consolidation (2012)
C: Consolidation Centre	Urban consolidation centres (1978)
D: University Coherent Campus Consolidation Centre (CCCC)	Urban consolidation centres (1978); novel as receiver-led
E: Sustainable Catering Initiatives	Novel

Table 87: Selected interventions mapped to Concepts

The DMF logframe created clear targets and goals that would allow for ex-ante and ex-post evaluation and hoped for avoidance of "Poor ex-ante and ex-post data collection".

7.10.2. Reflection on Process

Core

With regard to process, I was doubtful about using data, from one of several procurement processes, to identify stakeholders. The actual stakeholders could well have differed from the names recorded as having processed the transactions. This could be addressed in future work by further investigation into the degree to which formal hierarchies and transactional history in organisations are in line with practice: a field often explored by organisational science (Seidl, 2009).

The ongoing and emergent analysis was presented to all workshops and used by participants in their collaboration and development of the Trees. The DMF methodology was not data driven, but people driven, and was based on a recognition of their expertise, mutual development of definition, and Tree construction. This was in alignment with the AR concept of mutual co-creation. Many of the data and associated analyses were also emergent and, at this stage, only addressed certain aspects of known data. At this stage, the work could have addressed (and in fact did in parallel) multiple interventions. The work was not to be justified by data analysis, but by the perceived mutual needs of the stakeholders, which I believe to be in line with the core concepts of AR.

The workshop attendees were allocated to groups in a way that ensured a mix of backgrounds and interests; this generated some variant dynamics and record keeping. Group A had several participants who were keen to begin with an explanation of their respective background, expertise and views - a valid part of the exercise - before discussing and exploring the particulars of consolidation and drawing up causes and effects cards. Group B was heavily dominated by an individual with a strong background in regional development and proposal writing, whose strong aversion to discussing 'problems' threatened the underlying methodology, as they tried to apply their own approach. Some members of this group also had difficulty separating cause and effect. Group C worked very harmoniously and moved directly onto the work of card writing, with few explanatory monologues, an acceptance of the process as defined, and no need to leave an extensive transcript of their discussion.

Thesis

The DMF workshop attendees were allocated to a fixed group and this generated some variant dynamics and record keeping. This suggested a need to be very careful about pre-work training, the need for a recording device for later transcription, the need for strong facilitation, and a rotating group process such as the 'World Café' approach, whereby groups recirculate and reform throughout the process to allow all to hear about, and talk to, all and any topics (Steier, Brown and Silva, 2015).

The outcomes from the first workshop had mixed value for the process. This was due to the fact that some voluble participants did not agree with the definition of the problem and in fact militated against the underlying methodology. Based on the DMF methodology, participants are expected to analyse the causes and effects of a 'problem', but the word 'problem' was negatively interpreted by some of the workshop participants. The response, which was to iteratively re-address and re-group, fitted with the AR approach and generated a dynamic process that generated excellent interventions. What is noticeable about the Newcastle DMF process is that it was more dynamic than a parallel DMF process carried out in Como, Italy, as detailed by Oesterle et. al. (Österle *et al.*, 2015). The approach responded to the different levels of stakeholder interest and the process was refocused to those that had experienced actual problems with urban freight, rather than the original list of participants, or assumed problems. A much wider range of interventions was developed, some of which were in the originally constructed scope, and some of which (e.g. self-consolidation or freight operator recognition) emerged from the interactive process.

In future I would avoid using a logical framework approach. The stakeholder workshops were highly productive, and the development of stakeholder interests, resources and mandates was an excellent opening approach to developing a team with clear roles and goals. The follow-up process of mutually developing the Problem Trees, and then converting them to Objective Trees using the mutually shared language and definitions of the stakeholders, was highly productive. Indeed, the process generated five viable interventions for the Newcastle University campus alone, each one of which was a highly viable piece of Action Research. However, this workshop process is not the core LFA, it is the addition of later work derived from the ZOPP process (Gasper, 2000b) - the German acronym for objectives-oriented project planning. In my considered opinion, based on our experience in Newcastle, and also in parallel work in Como, the ZOPP workshops stand alone as excellent project development activities, with highly useable and mutually-owned outcomes. The process of converting these into the formal straitjacket of the logframe - the DMF in this case - was constraining, inaccessible to the stakeholders, provided little internal dynamic to create a project plan, and failed to address the ability to develop a sustainable business model for the work. To that end, I would take the ZOPP workshops, stakeholder interests, Problem/Objective Trees, and the output of interventions and then use other approaches for taking that work forward.

With regard to the thesis, this involved the mutual co-researching of all the 5W+H elements of the framing socio-technical system, and also gave insight into how the concepts of “Multi-stakeholder”, “Need for co-operation and collaboration”, and “Freight quality partnerships” might be addressed in practice. It also started to example “Engagement with Action Research in purchasing and supply chain management”, as well as being one of the first examples of research into “Higher education institutions (HEI) and freight”.

At this stage, as a group in 2012/2013, we had not seen the issue of power buyers as important - nor did we ever come to view it as core. The Purchasing and Estates functions were key actors, with the full purchasing team - from manager, to the five full time buyers - engaged from before the first workshops, to beyond the end of the pilot (see Figure 45: Neil Addison, Newcastle University Purchasing Manager, helping to build the Tree). AR supports emergent knowledge creation and also emergent methodology and objectives. The 8 individuals that the data recognised potential power buyers, see SAP analysis in section were *present and/or represented* at the workshops.

7.10.3. Reflection on Premise

Core

The work reported here showed that the premise of addressing the city as a whole would not be appropriate; however, a focus on the campus, where the actors with interest, mandate and resources were located, proved viable. Transport operators, from their absence at the first workshop, and their disinterest in the second, proved not to be actors with a key interest in voluntary engagement in this issue.

Thesis

This research activity confirmed the premise of addressing the topic via the actors, and that there were clear problems - with definable solutions - that could be mutually planned for. The theoretical premise of viewing the issues within a socio-technical frame was supported by the process and the content outputs in this chapter.

It was quickly apparent that the actors represented the city, region, and University well. The freight industry was represented at trade association level, but not by individual operators. What was less obvious at this stage was that, apart from Office Depot, the suppliers to the University were under-represented at the events; this issue became important later in the research - in the fourth AR cycle: the Pilot. The non-attendance of transport operators and the non-attendance of citizen groups, such as the local North East Combined Transport Activists Roundtable (NECTAR), was both a weakness but also an insight. These actors were invited, more than once, and yet clearly had no enthusiasm for urban freight logistics: were they simply not interested, or did they feel disempowered?

Chapter 8. Business Model Generation and Pilot Planning

This chapter is a reporting of the business model generation, using the Business Model CANVAS (BMC) method, followed by the pilot planning that followed from that proto business model and the previous DMF work, all as part of the iterative AR cycles. The chapter summarises the role of a business model, for differing value creation, capture, and reward configurations. The CANVAS population and pilot planning is reported. This is a breakpoint in the work, as only Intervention D: Coherent Campus Consolidation Centre (CCCC) is reported from this point forward.

8.1. Pre-step

8.1.1. Context

The process of Action Research Cycle 3 was set within the iterative cycles that preceded it, and is illustrated in Figure 54 below. It consisted of constructing the base understanding of the cycle - much of which was inherited from DMF cycles 1&2, detailed in detailed in Chapter 7 above.

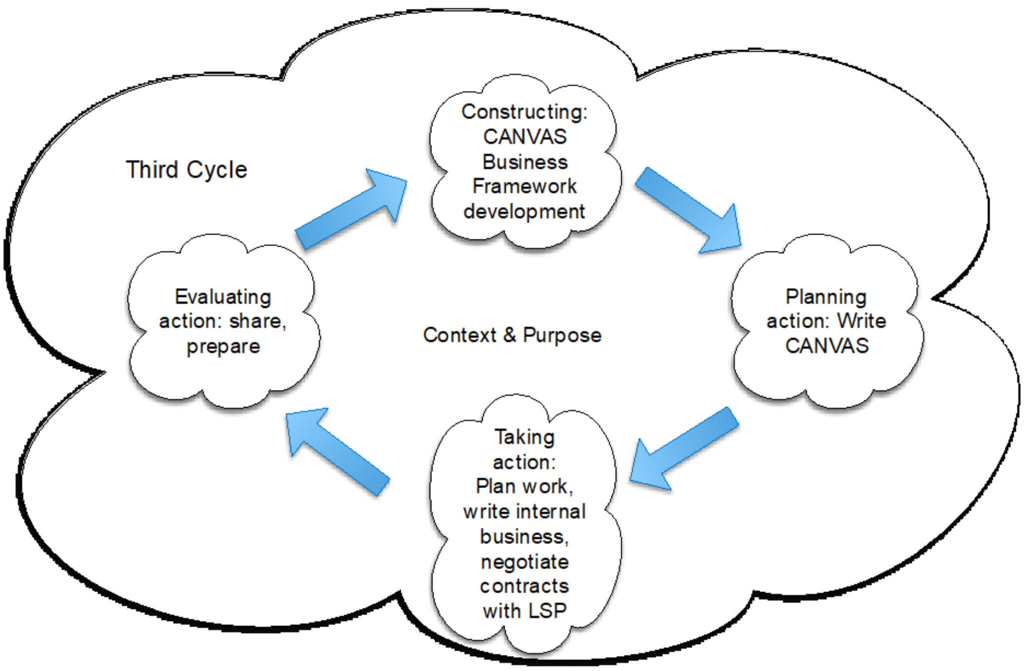


Figure 54: Coherent Campus Consolidation Centre (CCCC) Action Research Cycle 3

The process of business model generation touched upon the 'who, where, with what and how' parts of the *'systems approach' socio-technical framing* adopted. It would be developed from the constructed meanings co-created in the DMF, and would address the longer term viability issues - which are not strongly addressed in the project development focus of logframe approaches.

From this point on, this thesis focuses solely on Intervention D: the University Consolidation Centre referred to as the Coherent Campus Consolidation Centre (CCCC). This was a clear and dominant concept from the literature review and framing (see section 3.4.3 above) and was a named policy in the LTP3 and so requested by the City and the Freight Partnership. Interventions A, B and E were pursued separately, by purchasing or estates staff, and are not reported further here; Intervention C was subsumed into the CCCC.

8.1.2. Purpose

The literature review showed that a key problem in urban logistics interventions was the longer term viability of demonstration pilots and schemes and their failure to become stand-alone. Three key issues were seen: [lack of] long-term financial viability; Poor selection of location; and controlled environments (Martinez, Gadsby and Vargas, 2018). This had led to a recognition of the need for viable business models - first evidenced in the literature from 2011 onwards - and a growing interest in business frameworks, variations of the CANVAS business model generation approach, and variants thereof such as the Urban Logistics Business Model Canvas (ULBMC) (Macário, Rodrigues and Gama, 2011; Quak, Balm and Posthumus, 2014).

The issue of value creation, capture and reward was crucial to urban logistics since, as has been reported, very few urban consolidation schemes had succeeded beyond subsidised set-up (Zunder and Marinov, 2011; Quak, Balm and Posthumus, 2014). Most urban logistics was carried out by private bodies, usually on commercial grounds, so one might expect long- or short-term commercial return to be a significant goal. In a liberal economy such as the EU, this was usually also required to be completed with best value for money. This was a legal requirement on the directors and purchasing professionals in the public sector, under EU Public Contracts Directive 2014/24/EU (European Union, 2014) and subsidiary member state implementation. In many public sector and large institutions, this was supplemented by a commitment to sustainability standards, e.g. SA8000 (Baily, 2005, pp. 112–124, 484–503).

It is worth noting that in the urban environment there could be significant numbers of commercial vehicles, owned by small retailers, tradespeople, and institutions, where the commercial imperative might be mixed with travel to work, domestic service trips, or social activities affected by a different assessment of cost versus utility. There were rational and nuanced commercial interpretations of best value, in that the definition of the desired outcomes (e.g. varieties of product, different levels of service, external effects in line with objectives) and the life cycle costs of one solution over another could mitigate a solitary focus on the invoice price.

Notwithstanding all of these caveats, the primary goal of an urban logistics company was to make a return on investment for its shareholders. This was usually achieved by providing a logistics service and, often, ancillary value-added services - such as warehousing, ICT support and coordination - that ensured goods and services moved from point of origin to destination on-time and in-full, while meeting sustainability standards, e.g. SA8000 (Baily, 2005, pp. 112–124, 484–503).

Financial sustainability was just as key to any urban logistics intervention as to any other distribution firm - particularly for consolidation centres; for the Newcastle CCCC, this required a business model.

8.1.3. Ethical considerations

The key concern for the business model generation process was the wish from all commercial actors, including the University, to not prejudice commercial confidentiality for future negotiations.

8.2. What is a business model?

There was no agreed universal definition of a business model, nor was there consensus on its components (Zott, Amit and Massa, 2011; Arend, 2013). I adopted the definition from Osterwalder & Pigneur which stated: “a business model describes the rationale of how an organisation creates, delivers, and captures value” (2010). It could be said “that value proposition, value architecture, value finance, and value network articulate the primary constructs or dimensions of business models” (Al-Debei and Avison, 2010). Zott et al. (2011), went further:

Second, we found that four important themes are forming, primarily around the notions of the business model as a new unit of analysis, offering a systemic perspective on how to “do business,” encompassing boundary-spanning activities (performed by a focal firm or others), and focusing on value creation as well as on value capture. These *themes are interconnecting and mutually reinforcing. This all suggests that the field is moving toward conceptual consolidation, which we believe is necessary to pave the way for more cumulative research on business models.*

Of great value to this work, business models served as an "integrative term for reducing complexity" simplifying "networks of sophisticated interdependencies into coherent stories" and were "a cognitive tool for making the components real and explicit, allowing better business decisions to be made" (Arend, 2013).

8.3. Value configuration

The principal concepts of value in marketing were developed by Michael Porter. His value chain framework was the accepted language for representing and analysing the process of value creation at the level of the firm (1985). This process of analysing a business organisation was a method for decomposing the firm into strategically important sub-processes and understanding their impact on cost and value. The task of the value chain analyst was to reduce cost and maximise added value. It was from this long-linked view of operations that Martin Christopher (1992) was to develop the related and inverse concept of supply chain management (SCM) which, rather than viewing the chain within a firm from start to end, began instead with the final customer and looked at all firms in a single supply chain from point of origin to end customer. SCM had a greater emphasis on time as the resource to be saved, as well as cost and adding value (Christopher, 1992). Porter stated that the logic of value-creating chains was generic to all industries and enterprises (Porter, 1990), but widespread use had shown this to be problematic.

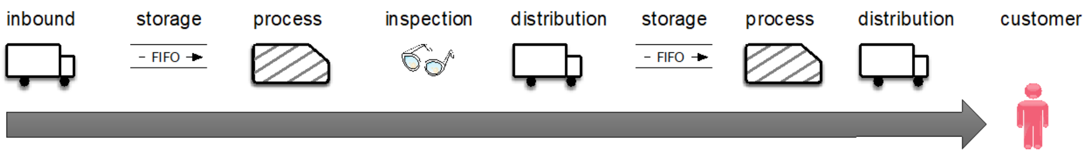


Figure 55: Simple value chain, after (Porter, 1990)

To overcome this, Stabell and Fjeldstad (1998) suggested a new approach, by configuring 'value' through three archetypes: value 'chains' (as in Porter); value 'shops' (e.g. consultancy, University, repair shop); and value 'networks' (banking, crowd sourcing/funding). These were each linked with an earlier concept of technology types: 'long-linked', 'intensive', and 'mediating', adopted from the encyclopaedic list of administrative concepts developed by James D Thompson in the late 60s (1967). Combining them in this way meant that one could envisage three quite different value configurations, better suited to the wider range of business organisations, as shown below in Table 88:

Value Configuration	**Technology type**	**Prime interactivity logic**	**Examples**
Value chain	Long-linked	Sequential	Steel manufacturing; automotive manufacture
Value shop	Intensive	Cyclical, spiralling	University; consultancy; car repair garage
Value network	Mediating	Simultaneous, parallel	Banking; ICT network providers; brokers

Table 88: Value Configurations (adapted from (Stabell & Fjeldstad, 1998))

For the Newcastle CCCC it was important to understand the applicable value configuration. Urban logistics, due to the traditional 'lens' of either transport chain planners or supply chain management practitioners, had tended to be viewed as a 'chain' activity, using long-linked technology and sequential processes. Indeed, the role of logistics as a connecting sequential activity in a manufacturing or distribution chain was key. However, that was the perspective of the chain and was consequently the approach typically taken by an in-house logistics operation and fleet manager. The perspective of a third-party logistics manager was quite different. A 3PL in fact built a business on value networks, meshing customers and resources, and mediating flows, costs and revenues. A 3PL required interconnectivity to attract customers and increased customer numbers generated network externalities, in terms of competitive advantage, value creation, cost reduction, and so on. Note also that scale could have deleterious effects: over-utilisation of trucks could reduce service levels, which could have negative impacts on customer retention. At the same time, a 3PL was providing a support activity to each chain of goods that flowed through the network.

This idea of networks that support chains was further developed and synergised by Lazzarini, Chaddad and Cook as 'netchains'. This combined the long-linked sequential logic of chains with the mediating simultaneous network approach of networks, and showed how both could integrate as three dimensional chains of networks, delivering product offerings to customers with mediation within and between levels (2001). In this approach, the chains of Porter/Christopher co-existed and created value alongside the additional value configurations of ‘shop’ and ‘network’ from Stabell and Fjelstad. A schema, suggestive of urban logistics and possibly the CCCC, was conceptualised and drawn as in Figure 56, with the arrows showing the physical flow of goods.

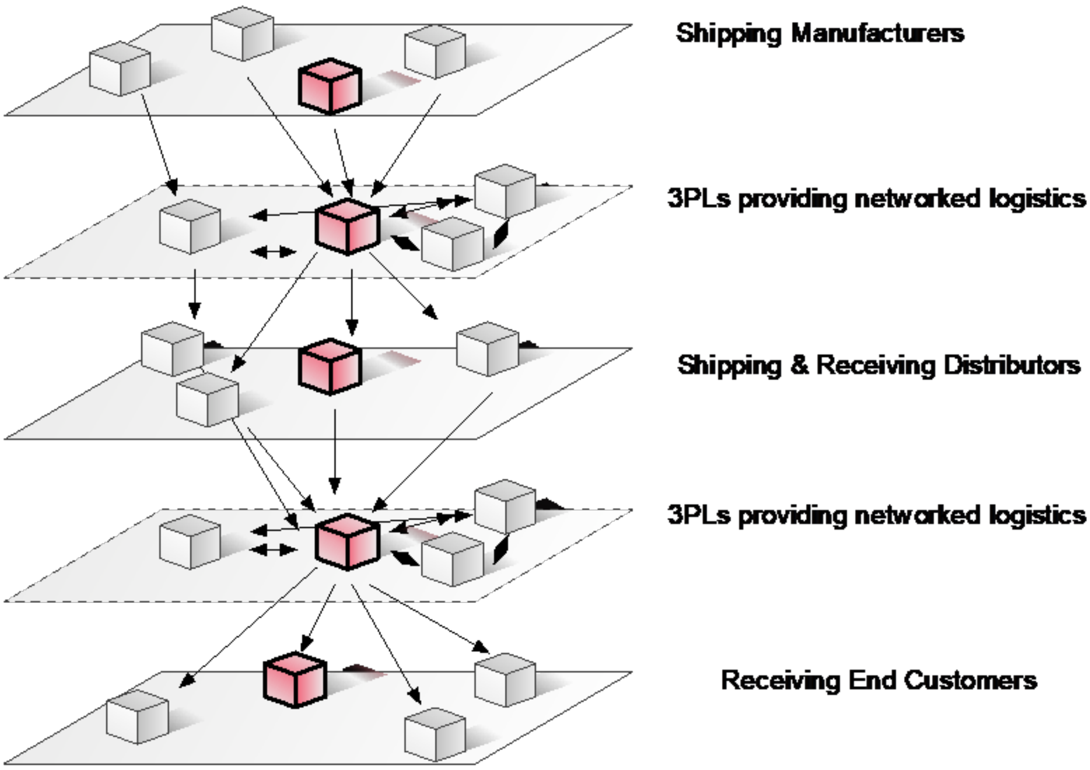


Figure 56: Author’s Netchain concept for 3PLs for the CCCC: after (Lazzarini, Chaddad and Cook, 2001)

The netchain concept allowed the plotting of a chain, value and/or supply, from originator through intermediaries, mediated more than once as part of a wider logistics network, before final delivery to the end customer - as illustrated in the layers of tiles and boxes in Figure 56. At the same time, it allowed an acceptance of the different ways value was configured. Value chain analysis had tended to focus on cost reduction; supply chain analysis had tended to focus on time reduction; value networks had been analysed so as to balance the need to add value through mediation and scale. Given the key EU policy focus on increasing truck utilisation (European Commission, 2013), it was important to note that, in a network, over-utilisation of capacity could reduce service levels.

The Newcastle CCCC was to be defined in one sense as a value/supply chain delivering the University's required goods and services. This suggested looking at cost reduction, management of the use of time, and a long-linked sequential view of operations. However, it could also be viewed as part of a process with a value network layer, in that the logistics would be provided by a 3PL with an existing role in mediating access to a network, and also potentially due to a network layer of co-operation between receivers.

8.3.1. Non-monetary value

Value, in Porter (1985) and early business model literature, was focused on monetary value and indeed profit generation. Combined with a value chain focus on cost reduction, this limited any focus on value that was not inherently monetary, or where the capture and reward to value was complex. Arend (2013) addressed this, clearly identifying that business models needed to address more than simple monetary outcomes, consider the gains and losses of all affected parties, and that better business models should be not be a contest but instead a collaboration. This holistic view, that control may be more likely shared among participants, had already been incorporated into the BMC by Osterwalder and Pigneur (2010). It fitted well with the accumulated wisdom in the city logistics community - and nearly all previous urban consolidation centre research - that the unequal distribution of costs/benefits/revenues/dis-benefits had prevented ongoing sustainability (Zunder and Ibanez, 2004; Dablanc, 2007; Munuzuri *et al.*, 2012).

This holistic view was therefore incorporated in the very basis of the Action Research strategy and the membership of this group was extended from the core of the University to include:

- local government, at city and regional level;
- suppliers to the University;
- different departments and functions within the University;
- co-located organisations, such as the Students' Union, or Northern Stage;
- city government administration departments;
- Northumbria University; and
- the neighbouring hospital.

To identify value configurations that would achieve sustainability for the Newcastle CCCC it was necessary to look, not just the bottom line, but also at non-monetary value and the different approaches to value configuration appropriate to both value chains and value networks.

The process of business model design had been seen as part of business strategy. Hence, an operationally viable and feasible business model required lateral alignment with the firm's underlying strategic plans and operational tactics. To that end it was important to follow the core procurement policy and the explicit or implied service levels expected by internal end users. It was also necessary to follow the University policy and operations on sustainability, that were in line with the core contract and access for this piece of Action Research - the core policy being the Coherent Campus policy of 2008, which had committed the organisation to a pedestrian friendly, vehicle-reduced campus. It was within this commitment that non-monetary value was to be found.

8.4. Populating the CANVAS

Having prepared the ground with additional understanding of value configuration, the probable structure of a Newcastle CCCC in a netchain, and the factor of non-monetary value, the constructing phase of the third AR cycle was complete. Continuing now with the planning action, the writing of the Business Model CANVAS was commenced.

8.4.1. Layout of CANVAS

Osterwalder's CANVAS, shown in Figure 57 below, contains nine building blocks – the different elements that could be used to define a proposed operations and value configuration. The demand side is shown on the right: customer segments, relationships and channels, and the supply side on the left: key partners, activities and resources. The revenue streams generated from the business are found in the bottom right, with the cost structure to the bottom left. The value proposition - the accrued goods, services and benefits - sits in the centre, being the meeting point of the ongoing transaction between supply and demand.

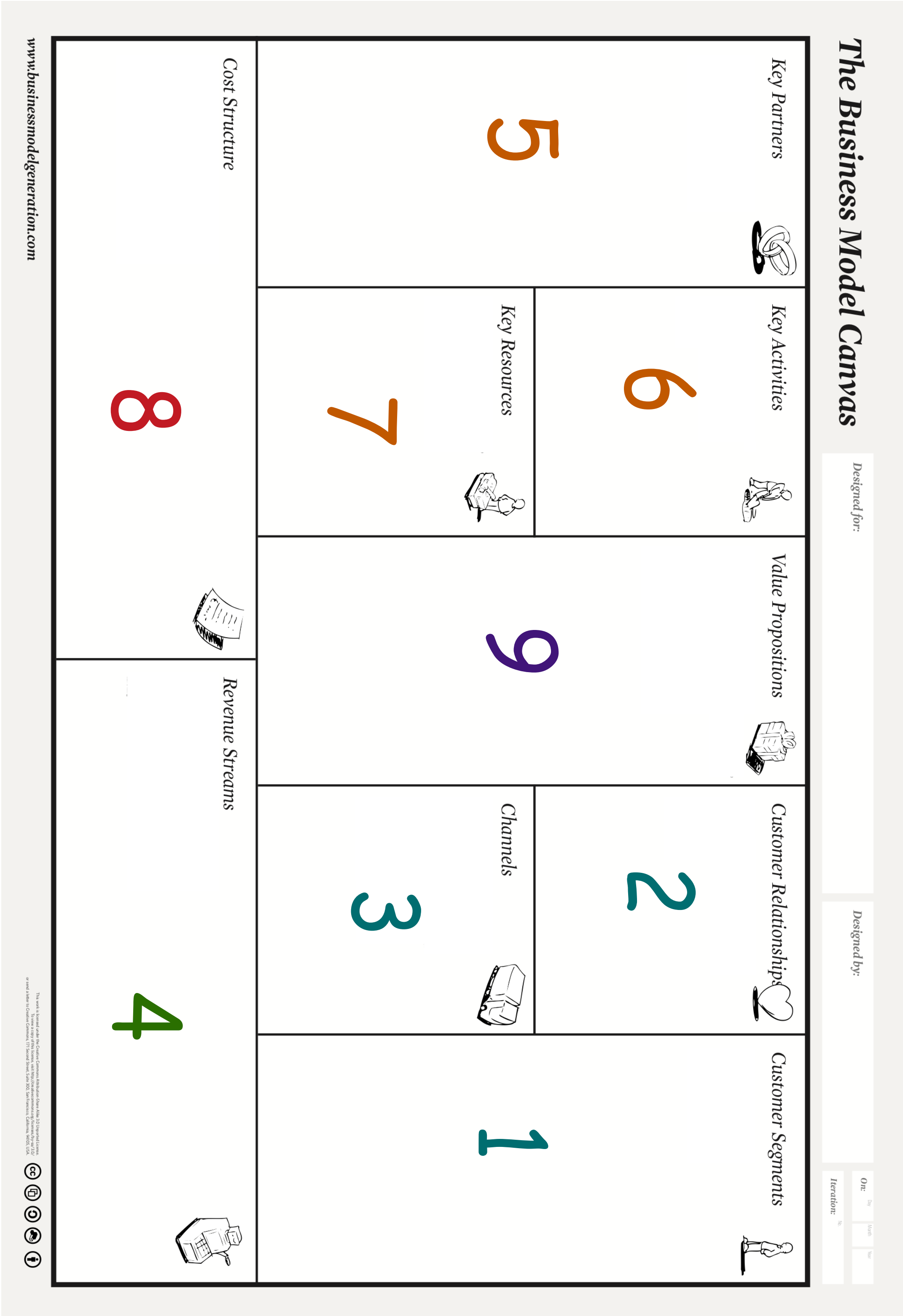


Figure 57: Business Model CANVAS: (Source: businessmodelgeneration.com)

8.4.2. Participants

The generation of the CANVAS for the Newcastle CCCC was carried out in the first 9 months of 2014. The process for completing it was by email, face to face meetings, and update meetings, through to the commencement of the pilot in Autumn 2014. Whilst the first versions of the CANVAS were fairly complete, minor variations and adjustments were made up until 2015. The organisations involved were:

- Thomas Zunder with research assistant Bruce Carnaby;
- Newcastle University purchasing staff, primarily Neil Addison, Purchasing Manager;
- Newcastle University Estates Department staff, primarily Lynn Edis and Shed Coulthard;
- Clipper Logistics staff;
- Office Depot, Freddie Watts;
- The Tyne & Wear Freight Partnership, John Bourn; and
- One-to-one discussions with buyers in the University's SAgE Faculty and Medical School.

8.5. Migration from DMF to Business Model CANVAS (BMC)

The primary goals of the Newcastle CCCC demonstration were as defined in the DMF. As stated in section 5.10.4 above, a process to convert from DMF to BMC was needed and the initial BMC drafts were prepared, using the approach described in Figure 58.

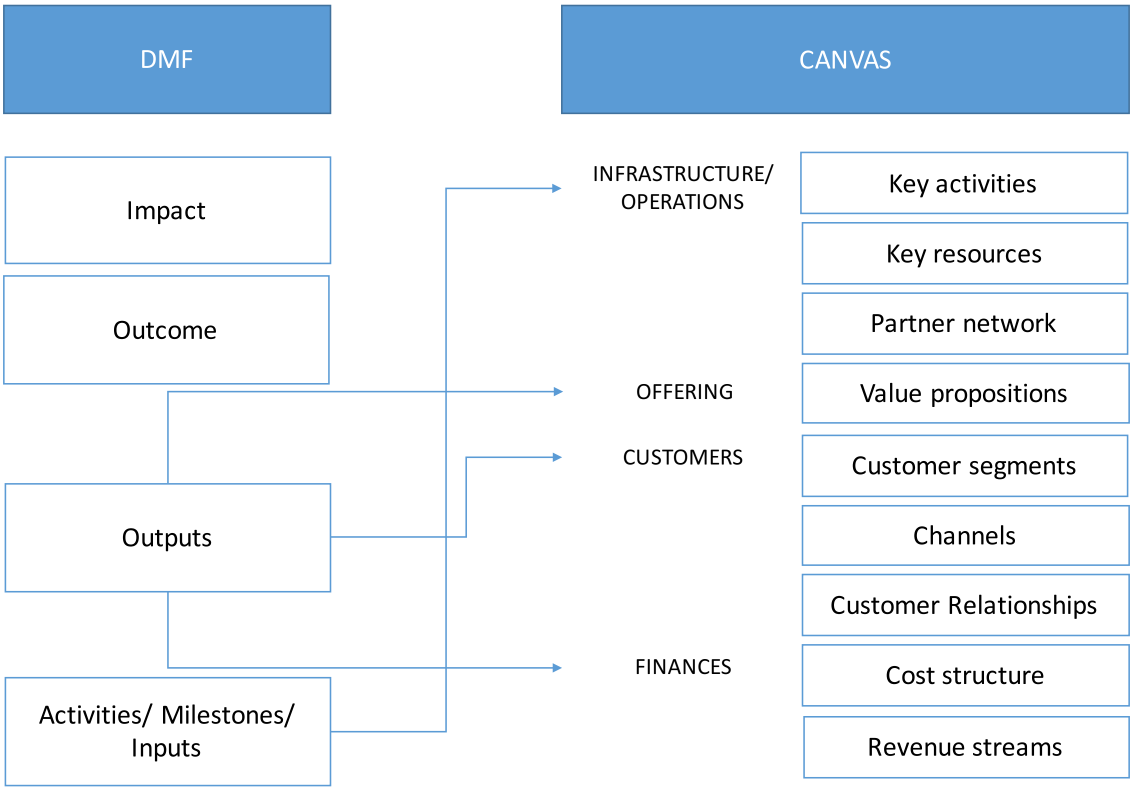


Figure 58: DMF to CANVAS translation approach (Grea, 2015)

This process required additional discussion and agreement over the elements of the socio-technical system envisaged and how this mapped onto CANVAS. The process was iterative throughout this piece of work and beyond. Although this work reports the process as sequential, in reality it was ad-hoc at first, with the sequential logic following after the initial broad-brush approach based on the DMF.

As an artefact of the work, the BMC contains grammatical and spelling errors. Rather than edit the primary source, I have made a conscious decision to present the original, errors and all.

8.5.1. Demand Side

Building a business required identification of the customers to be served; these were mapped as shown in Figure 59. The choice was apparently simple - University staff and students, in the departments and schools - but needed clarity. The customers were the actual end users, not ‘The University’ or ‘The Purchasing Department’, even though the relationships would be managed at the procurement and senior management level, on behalf of those end users. The channel - the means of delivery - would be simple: an electric vehicle; implementation of that delivery would be more complex.

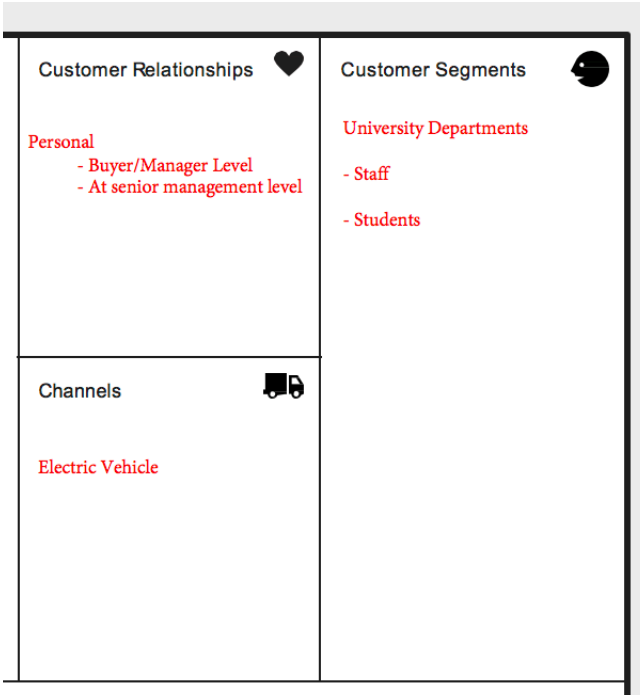


Figure 59: Newcastle CCCC Demand Side BMC

This in turn raised simple questions to test, shown in Figure 60; these form part of the evaluation and are answered in Chapter 10 of this work.

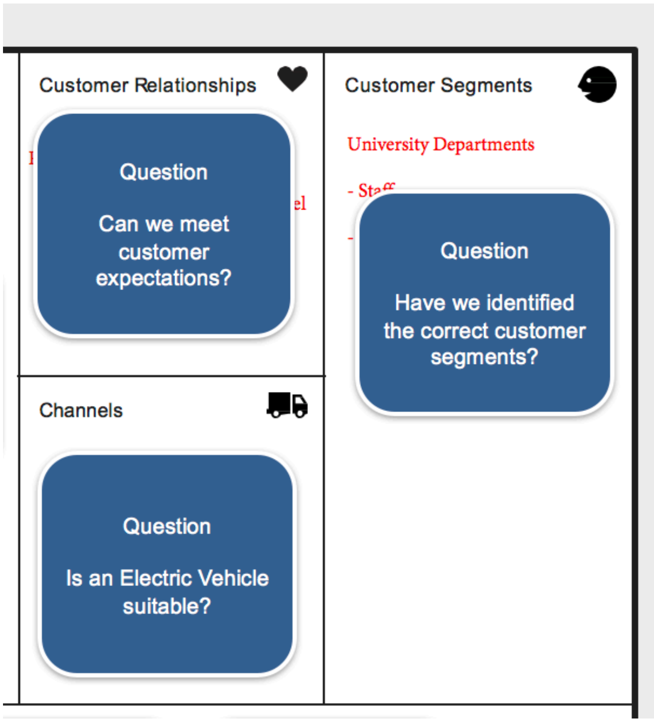


Figure 60: Newcastle CCCC Demand Side BMC Questions

8.5.2. Supply Side

Having detailed the demand side, the business needed various partners to support it. Since the process was receiver-led, many University personnel had roles on the supply side, as well as on the demand side. To achieve this organisation, key partners included Purchasing, Estates, senior management, the distributed buyers, and semi-autonomous organisations - such as the Students' Union. It was anticipated that a logistics provider would be required, as well as an electric vehicle manufacturer/supplier. Later on, after commencing dialogue with, and gaining feedback from, goods suppliers on some of the operational effects of such a scheme on certain deliveries, their role as partners was recognised. This side of the BMC is recorded below in Figure 61.

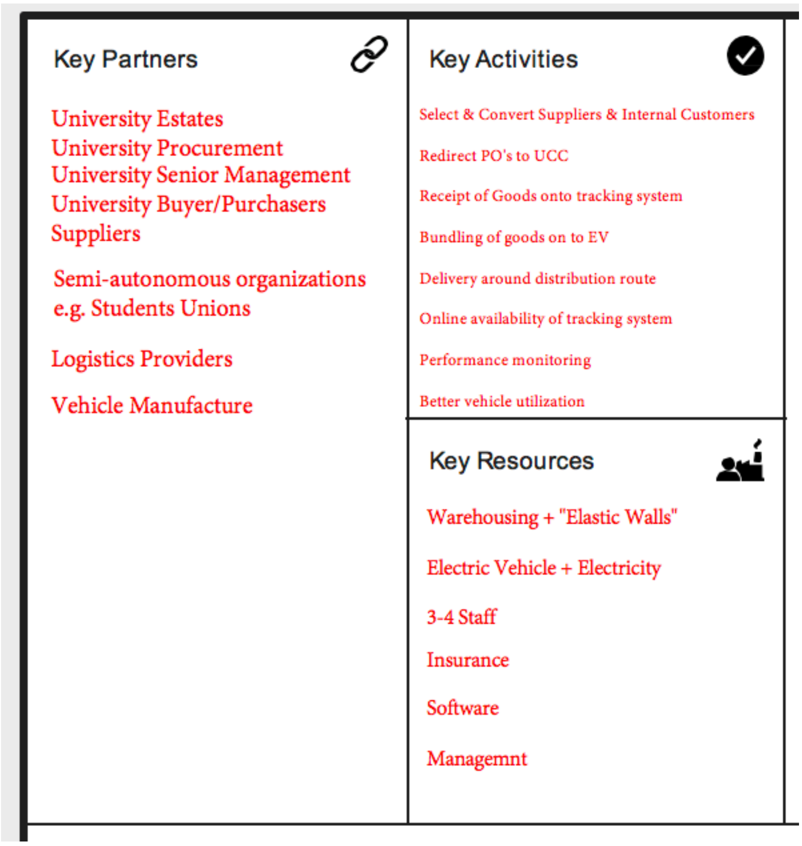


Figure 61: Newcastle CCCC Supply Side BMC

As detailed in Figure 61, key activities summarised the key steps of supplier selection, redirection of goods, bundling, distribution, tracking and monitoring. Key resources included warehousing - which generated the phrase 'elastic walls', coined by Gary Walker, Managing Director of Clipper Logistics, referring to the use of marginal space in an existing facility, thus allowing marginal costing and a high degree of scalability. This then led to the creation of another series of questions, as shown in Figure 62.

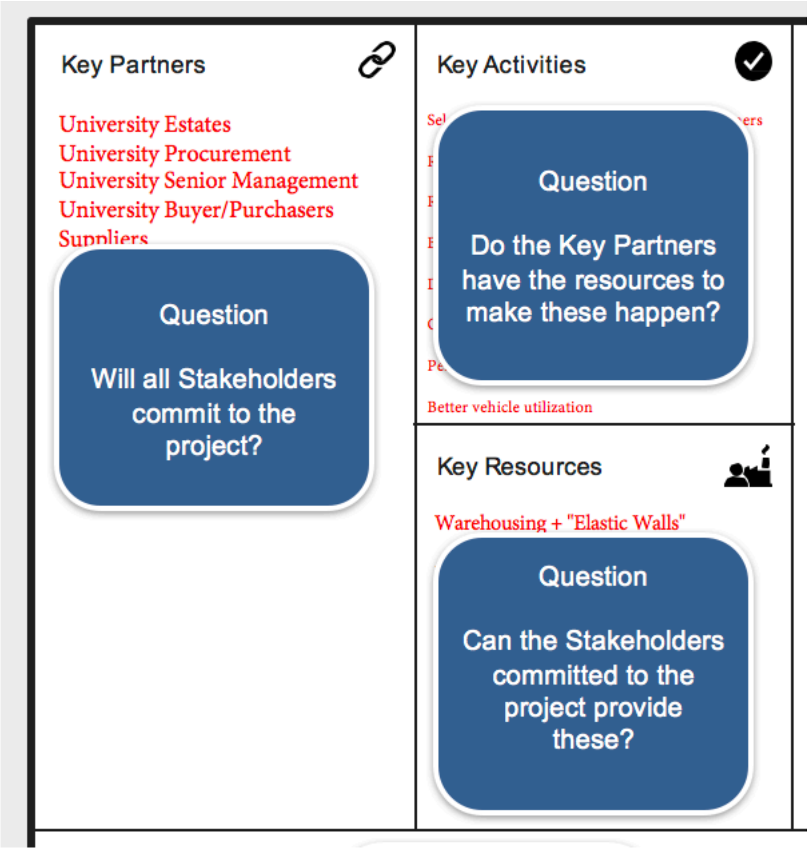


Figure 62: Newcastle CCCC Supply Side Questions

8.5.3. Costs

Cost details were kept minimal on the public BMC shown in Figure 63 below. Our partner, Clipper Logistics, was committed to the work: clean urban logistics was a potential market niche Clipper wanted to develop, to gain a differential advantage over their competitors. They needed to be mindful of their future negotiating position and, as yet, did not fully understand the costs on their side. This was a business development decision and was handled in line with the ethical considerations elaborated in section 8.1.3 above.

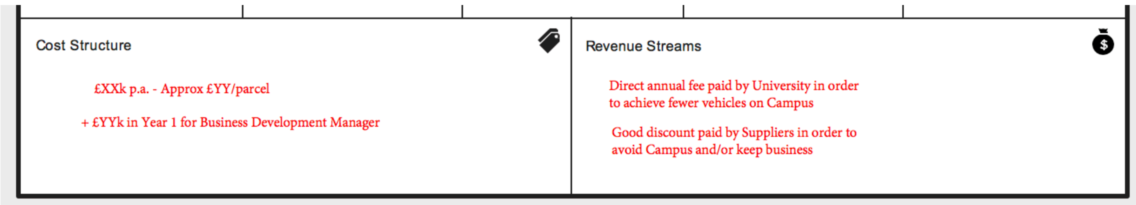


Figure 63: Newcastle CCCC BMC Costs

The questions raised on the costs were anodyne - a reflection of the commercial sensibilities within the group - but the questions on revenue streams were highly pertinent, as seen in Figure 64. The University policy stated an objective to reduce freight vehicle numbers on campus, but just how much money was it willing to pay to achieve it? At the same time, the possibility of suppliers discounting prices in exchange for avoiding a delivery to campus was raised. Parallel initiatives in Camden, London (Clausen, Geiger and Pöting, 2016) had posited this a potential source of funding; as such there was interest as to whether it would be viable in Newcastle.

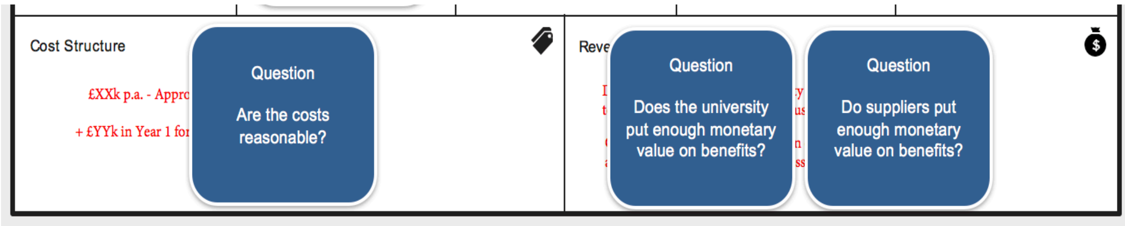


Figure 64: Newcastle CCCC BMC Costs Questions

8.6. Value Proposition

The value proposition (see Figure 65 below) was a combination of the key issues from the DMF and additional issues raised in the iterative discussion in 2014. Of note was the call for improved service levels for some, including a way to track goods once delivered to the CCCC but not yet delivered to the University proper.

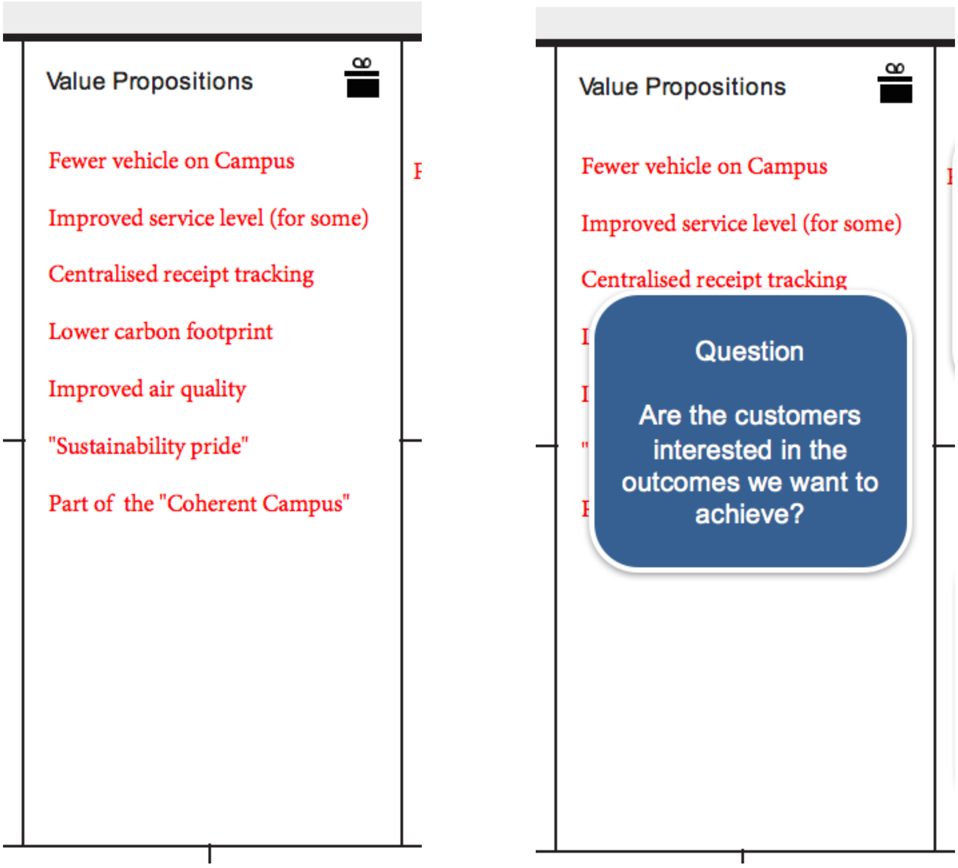


Figure 65: Newcastle CCCC BMC Value Propositions and Questions

8.7. Final CANVAS

The final BMC for the Newcastle CCCC was an institutional receiver-led model that placed value over bottom line cost savings, as can be seen in the value propositions. This created the key question of whether the University, and/ or the supplier base, placed sufficient value on the scheme to justify funding it directly, or via price discounts. As shown in Figure 66 below, it raised multiple questions in line with abductive reasoning, most of which would be addressed in the pilot design and trial, or through later evaluation.

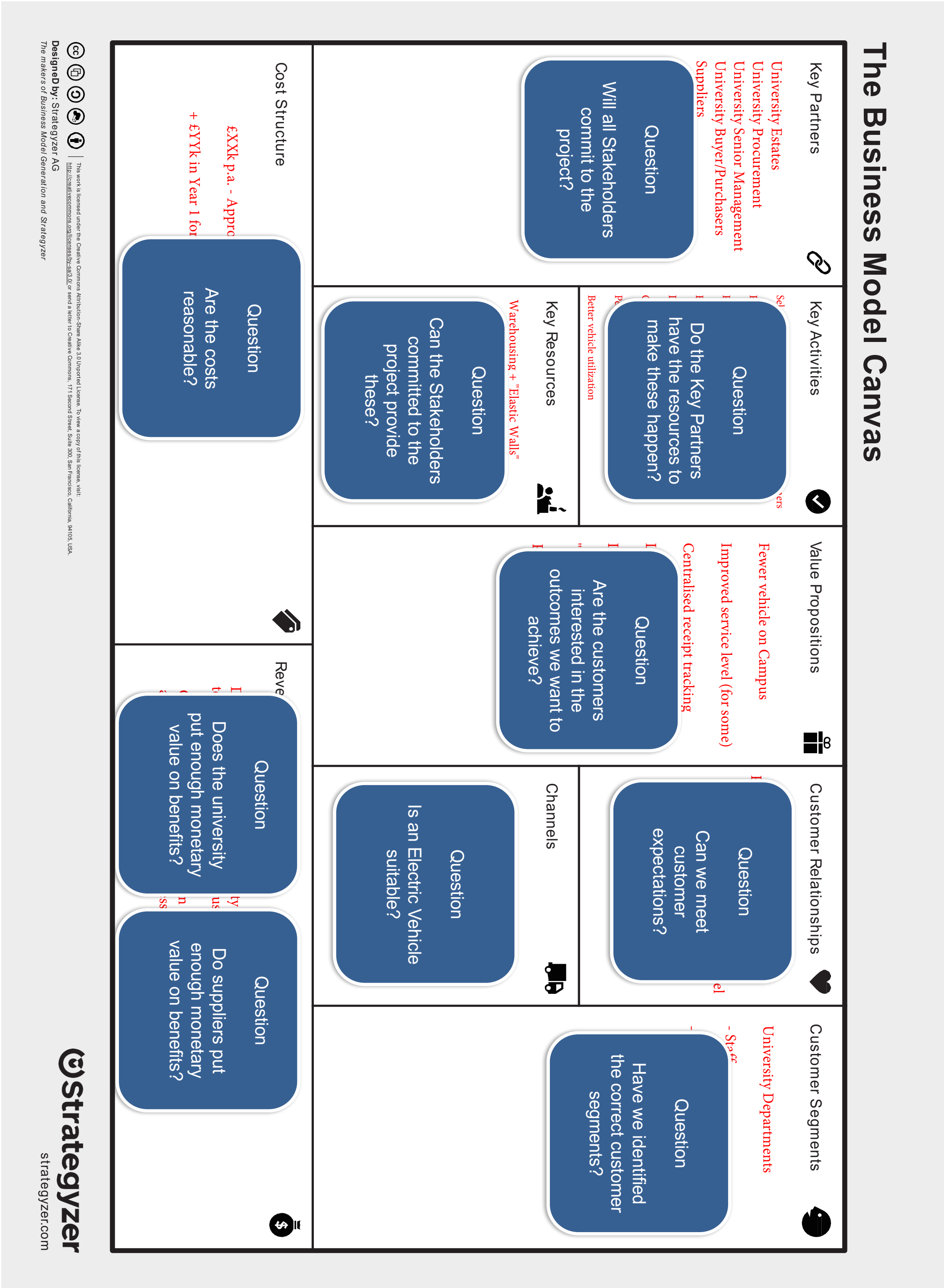


Figure 66: Newcastle CCCC BMC Questions, Source: working documents

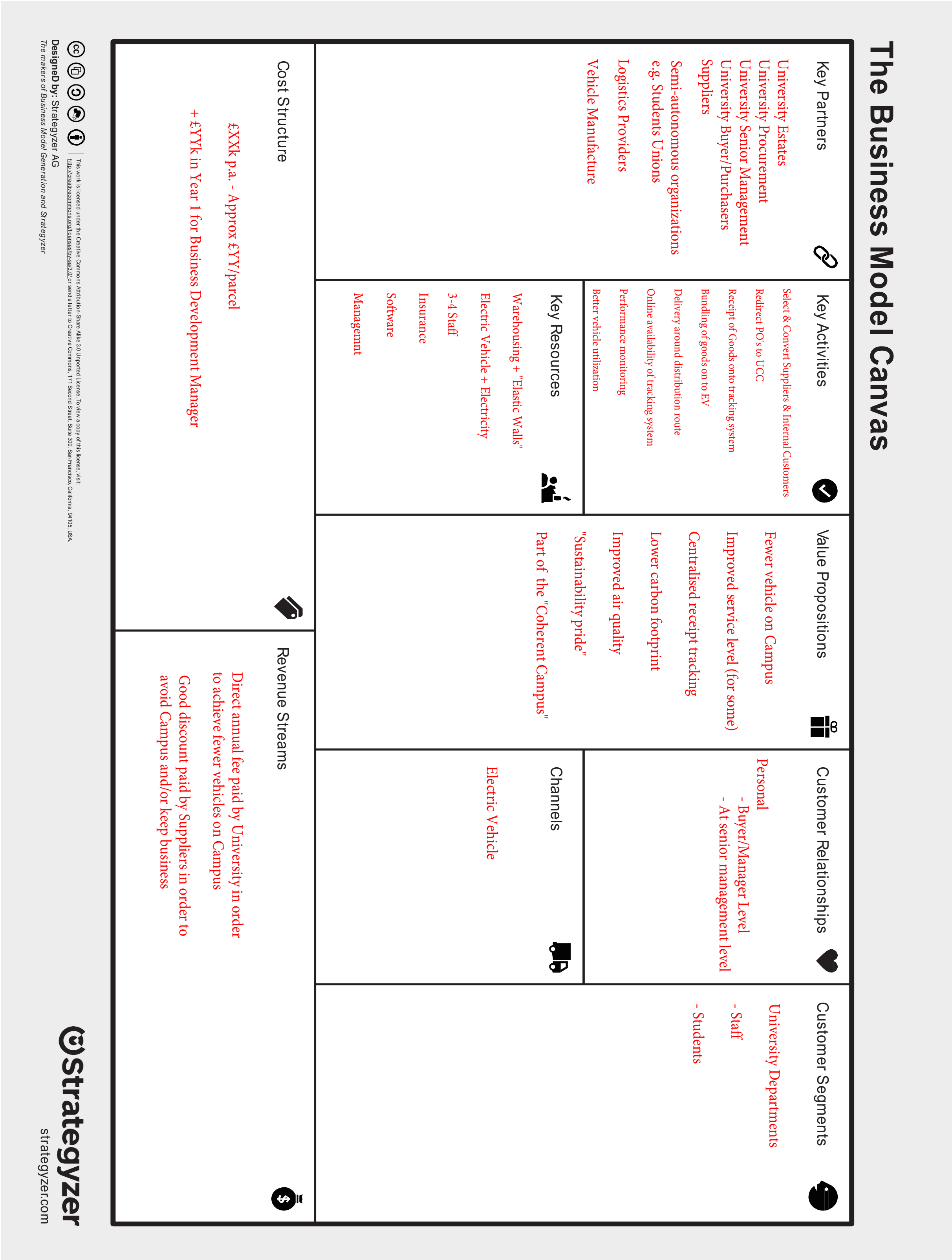


Figure 67: Newcastle CCCC BMC, Source: working documents

8.8. London Borough Consolidation Centre (LBCC)

At this point it needs to be noted that a parallel inbound logistics scheme was being developed in Camden, London, independently from the work in Newcastle upon Tyne. There was some early discussion when the project manager, Nigel Symonds, asked for details of our plans and I visited the site after both pilots had commenced. Although there was some exchange of early surveys from the older Newcastle project to LBCC, the design and execution of both schemes was independent. The LBCC scheme ran a pilot from 2014 to 2015 (Clausen, Geiger and Pöting, 2016) and has operationalised since. There is a lack of data, evaluation and results from the scheme in the literature; the project downloads have not worked since early 2017; and the key staff now work for other organisations.

8.9. Design of Pilot

From the BMC, the pilot was designed. Osterwalder and Pigneur (2010, pp. 248–249) had a highly suitable and useful checklist for the design phase of any business model generation:

- **Prevent taming of bold ideas**. This was most obvious in the natural tendency of purchasing staff to move the focus from the awkward, small volume suppliers back to the large, easily identifiable - but very few - suppliers with whom they had good relationships. This was resisted, since the logic of addressing the volume of deliveries, rather than spend, had been accepted by the Purchasing Manager.
- **Participatory design**. This was a given: the pilot was a collaborative effort by the author, University Procurement and Estates staff, logistics provider Clipper Logistics, and an electric vehicle rebuilder: Smith Electric.
- **Old versus new**. Given the nature of a pilot, and the possible need to exit the strategy at a later date, integrating the old with the new was a conscious decision, as was the avoidance of radical changes to the procurement system.
- **Avoid short-term focus**. The University's approach was long-term and, given that the potential of the proposed system was both added value and potential added cost, all planning was necessarily for the long term.

The design then followed the structure of the BMC and an operational process was designed accordingly. This would also provide answers to the stated questions, whether quantitative, qualitative, statistical, binary, or opinion. To this end, the design of the pilot was delineated following the BMC heading structure, as follows next.

8.9.1. Customer segments

There were two customer segments: staff and students.

Students resident on campus - as opposed to in off-campus halls - formed a new and growing population. This customer segment had purchasing autonomy for personal purchases. Anecdotal evidence from the University mailroom had revealed 'headline' tales of motorbikes being delivered to the mailroom, part by part, and deliveries of whole, dried fowl. None of the research to date had focused on building up any good understanding of students' personal purchasing, nor was it under the purview of any University policy or procedure; therefore the personal aspects of student demand were placed to one side[30]. Mindful that the institution placed the learning experience of students first, which must not be jeopardised, students as users of University resources would be represented in the forthcoming workshops by University staff.

The other customer segment was the circa 5000 University staff. Their fragmented and often ad-hoc purchasing demand was analysed in section 6.2 above.

8.9.2. Customer relationships

In order to develop good working customer relationships with these segments, the author met with purchasing staff and colleagues to discuss the realities of the procurement system; representatives of both segments were present. Both the system analysis and the statistical analysis in Chapter 4 backed up the view that staff demand could not just be assessed through the formal systems. To that end, an ongoing series of regular customer drop-in sessions would run during the pilot.

In addition, it was recognised that, given the high level of informality and unique relationships not always obvious, the pilot would proceed by increments. Each week, 5 new suppliers would be chosen for adoption into the scheme but, before starting, a

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[30] *Later empirical survey work with student halls of residence was carried out at the University of Southampton and can inform future work in this area* (McLeod *et al.*, 2016)

member of the purchasing team would make contact with each faculty to discuss the likely effects of the change on its staff. If a particular staff member or department would be affected, then the follow up would continue there. Only when a viable plan that maintained service levels was agreed, would the supplier be introduced to the scheme. This process also made a clear, first decision about the whole approach: it would be incremental and not a single universal implementation.

Communication to the wider staff and student segments would be carried out using the University website 'message of the day' feature, as well as through a dedicated webpage on the procurement pages - see Figure 68. The communication expressed aspirational goals from earlier versions of the DMF targets and monitoring indices (see Table 86 above), which are refined and discussed further in Chapter 10 below.

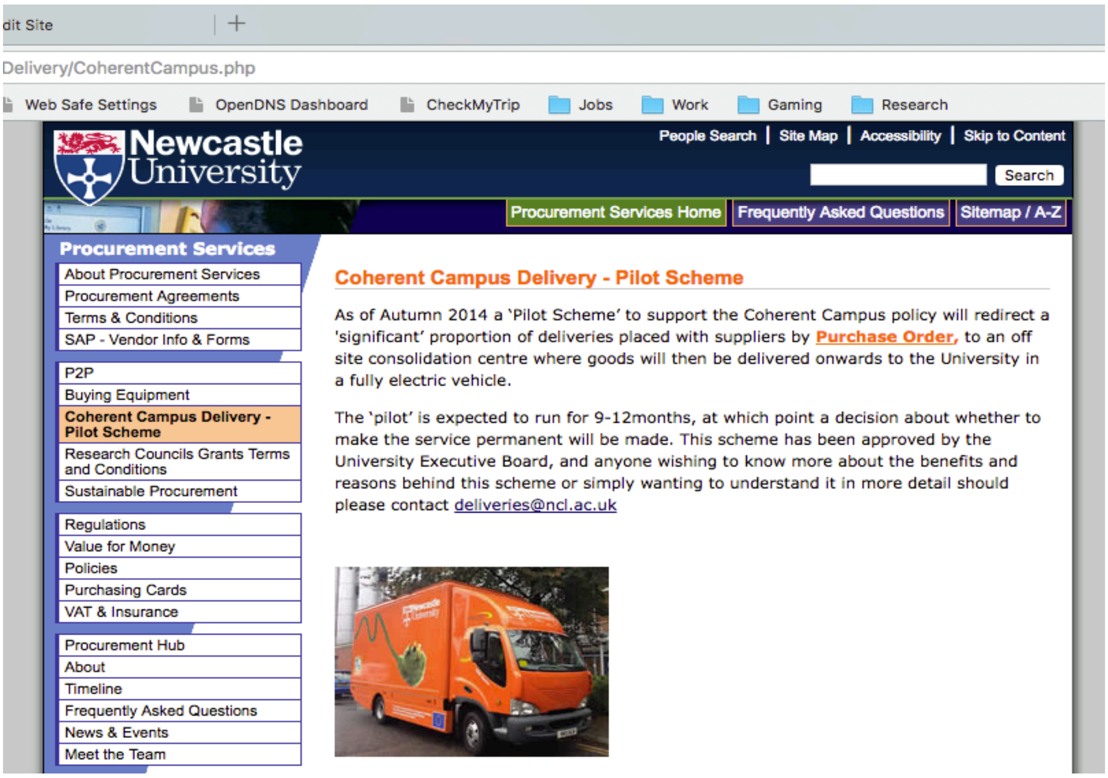


Figure 68: Coherent Campus pages on Newcastle University Purchasing Hub website

8.9.3. Channels

The default BMC asked several questions:

- Through which channels are our customer segments reached?
    - By freight deliveries onto campus - almost always by van or truck and then walked to a customer's desk.

- How do customers want to be reached?
    - Most feedback from early and ongoing sessions was that the current level of service was the minimum requirement.
    - Some segments, when represented by managers, expressed a willingness for collective deliveries to buildings. It was not clear how much this was a true customer wish or a managerial opinion.
    - Customers, or their representatives, stated repeatedly that they wanted to know where their goods were and when they would be received. A demand to track and trace goods was clearly evident.
- How are our channels integrated?
    - At first no integration between any channels was noted: each supplier operated individually and often tailored to each customer. However, once discussions with suppliers and customers began, examples of some integration emerged.
        - Bunzl, a supplier of cleaning products for the office cleaning staff, always made a consolidated monthly delivery of materials to restock cupboards and cleaning stores, supplementing this with ad hoc top-ups during the month.
        - For each of their main customers in the city, Office Depot made efforts to consolidate deliveries into 2 large deliveries per week. This was not possible for orders marked as 'next day', but was effective for slower leadtimes.
        - The University's King's Gate administration block had a self-organised stationery consolidation in effect. Staff assembled all stationery needs and released them as a single order, each Friday.
- Which ones worked best and/or were most cost efficient?
    - From the perspective of the user, simply getting their goods to their desk seemed to work.
    - For perishable, radioactive, biological reagents, and volatile products, arrival at a specific time was critical.

- For suppliers, and almost certainly for sustainability, the channels that consolidated goods into fully laden large trucks were the most efficient. Less so internally since, although Office Depot did offer discounts for slower deliveries, the internal consolidation at King's Gate did not take advantage of this discount.

The team had started to develop an understanding that there were some channels that worked well and should not be disrupted. The channel of physical delivery to desk using a vehicle was clearly required and needed to be replicated. Addressing the triple bottom line of cleaner emissions and lower carbon footprint suggested the demonstration of a clean, commercial freight vehicle.

8.9.4. Revenue Streams

The BMC asked a series of questions about revenue streams. Before detailing those answers, let us consider the state of the art at the time (2012-2014) with regard to revenue and urban consolidation.

The generation of revenue from urban consolidation schemes had been problematic for decades. This had been widely documented in the reports, cases, and best practices recorded by such projects as BESTUFS and others. The primary problem was that most interventions had been top-down and subsidised by city governments, or often by external national, regional or EU funding - all of which had been short-lived. This had led to crisis when funding ended and revenue and costs led to the closure or decline of the initial activities (Anderson, Allen and Browne, 2005; Marinov, Islam and Zunder, 2010).

At this time, logistics operators in urban freight forums and workshops had suggested a fee for the handling of goods; this was in the region of €2.50-€5.00 per parcel, across Europe. The ELCIDIS platform in La Rochelle had reported a cost of €3.75 per parcel in 2002 (Mollard, 2002) and later SUGAR reported a charge of between €1.7 and €3 per parcel (SUGAR, 2011). There were exceptions: the Binnenstad service in Nijmegen, NL was an outlier that priced €8 to €20 per parcel, depending on the service chosen. However, the statement that "the charges appear to range between £2-5 for a large box / parcel and £5-10 for a larger delivery unit such as a roll cage or pallet" (Lewis, Fell and Maclean, 2012, pp. 26–28), fitted well with the verbal (rarely written down) range of numbers from logistics providers at the time.

The problem had been who would pay this fee. Again stated well by Lewis et al, previous schemes "had found it hard to quantify a financial benefit to offset the clearly stated cost of participation which comes from the scheme operator" (Lewis, Fell and Maclean, 2012, p. 26). These problems were summarised as:

- A perception that freight consolidation was inherently expensive.
- Identification of the activity cost of logistics was not always easy, particularly as cost-per-mile underestimated the much higher cost of low speed 'last mile' urban logistics.
- Commercial sensitivities meant that there was sometimes a reluctance to reveal the transport cost element.
- The cost centre approach to accounting meant the use of a consolidation centre was often charged as an additional cost, whilst the benefits accrued elsewhere.

Many of these issues had been recently researched and analysed further and in depth. Work by Janjevic and Ndiaye (2017) bore out many of the accumulated expert knowledge used in our original discussions. This recent work confirmed the average price per parcel falling within a range of €2.50–€5.00 and, moreover, a price range of €10 to €20 per pallet - indicating an average price for pallets four times higher than for parcels.

Charging for such a service was rare and usually supplemented by a top-down subsidy - either a short-term intervention by local government, or a research fund. Lewis et. al, (2012) reported an annual charge of circa £230,000 at start-up, noting that the Bristol freight consolidation centre had been subsidised since start-up at a similar level, with no user fees, but also that the Norwich scheme had charged from day one, with associated difficulties in recruiting users. The Heathrow consolidation centre, run by Heathrow Airport Holdings, was mandatory for all tenants of the airport, with a subsidy of 50%, from the landlord who saw it as added-value to both tenants and its security obligations. Of note here is that the definition of 'customer' varied by scheme, or report. In Norwich and Binnenstad, the customer was seen to be the transport operator carrying the goods. At Heathrow, the customer was the receiver of the goods. In Newcastle, the identified customer was the University - albeit sub-divided into management, buyers, and the actual end users in the schools and departments. Using a business model generation approach focused attention on identifying the actual customer(s).

Since this work was co-funded by the EU, through grants, as co-ordinator I was privy to the actual costs claimed. However, these included a wide range of activities that would fall under research and development, or marketing, and these must necessarily remain confidential. The questions raised about revenue streams and the original answers are shown in Table 89.

BMC question	Original answer	Issues raised
For what value were our customers really willing to pay?	Delivery to desk. Some cases, such as medical reagents, radio-actives or electrical parts for student projects, required a fast-defined delivery date/time, otherwise, time was not of the essence, according to SAP analysis and discussions with buyers and Faculty Co-ordinators. Catering services had a highly time-sensitive requirement for the delivery of fresh and perishable goods on a short delivery leadtime with a well-defined next day delivery slot. The University Executive and Vice-Chancellor, the Head of Estates (and, as their proxy, the Purchasing Manager) wanted something else: fewer vehicles on campus, less intrusion, and a provable reduction in the University's carbon footprint.	The current offering did not differentiate between the value that different customer segments required. It was clear that the only customer segment that wanted – and therefore valued - reduced freight vehicles was the senior management and associated support services.
For what did they really pay?	Within the delivered price was a 'delivery to desk' service. In many cases, suppliers met the PO required delivery date with a next-day service.	As analysed in Chapter 4, the delivery dates on POs were suspect and ad-hoc interviews with buyers and Faculty Co-ordinators suggested that the field was often allowed to simply default to next day.

BMC question	Original answer	Issues raised
How were they currently paying?	Delivery was included in the total price and not quoted or itemised separately. The invoice was processed by the University. A small proportion of 2.35% of expenditure in FP 2011-2012 (Newcastle University, 2016b) was transacted using corporate purchasing cards.	What is of note is that the separation of goods/service price and delivery price was not revealed to any customer. The payment systems, whilst not perfect in terms of financial accountability, were relatively pain-free for the end customers on the desk.
How would they have preferred to pay?	Discussions with the active buyers and Faculty co-ordinators reported current systems as acceptable; in fact the main complaint was end-users causing admin problems by avoiding the laid-down systems. The response from non-admin staff was generically hostile to being involved in any payment process.	The professional administrators of the system were content with the formal use of the system and frustrated by non-compliance.
How much does each revenue stream contribute to overall revenues?	The background research had shown that a per parcel charge to users, or an annual service charge, were the two models of charging used.	

Table 89: BMC Questions re Revenue Streams

The investigation showed that end users placed value on painless delivery of their goods, to their desk. Most segments did not actively require, or even consciously request, next-day delivery, although a significant minority did have highly time-sensitive requirements. The customer segment that placed value on the reduction of freight vehicles on campus was the senior management and leadership of the University and the revenue stream would be direct funding; the EU-funded pilot then, if continued beyond the pilot stage, would need to do so as either a tendered outsourced service by a logistics provider, or possibly as an in-house service. The Purchasing Manager, previous head of Central Stores before their closure in the 1980s, had a clear wish to in-house the service.

Having identified the primary customer that placed value on the consolidation scheme, another potential revenue stream was identified - asking suppliers for a price discount in exchange for the delivery of goods to a warehouse, rather than to desk. Whilst it might be argued that this was actually a cost saving, on a purchasing spend of £100-120 million[31], a relatively small overall discount could theoretically significantly impact the bottom line.

8.9.5. Key Partners

The key partners to deliver the CCCC had been selected and self-selected through the AR cycles leading to this step. Some of those invited to the earlier stages, such as transport operators, trade associations, and sustainability lobbyists, had fallen by the wayside. Some had become secondary to the pilot, e.g. the City Council, Northumbria University, and the NHS hospitals, but were still involved as potential future partners in a shared service. Others, deeper in the University staff body, such as Faculty Co-ordinators, or sub-contractors to Clipper Logistics, or the vehicle supplier Smith Electric, had been drawn in. The core of researchers, purchasing and estates staff, and our logistics operator partner, continued with the work. The final roster of key partners is shown below in Table 90, with headings from the key BMC questions re Key Partners.

Name of key partner	**Was this an external supplier of a good or service?**	**What key resource did they provide?**	**Which key activity did they perform?**	**Was this partner also a customer?**
University Estates	No	Campus knowledge; security and safety personnel and information; details on, and access to, buildings.	Support; guidance; permission.	Partially Yes, in that Estates had an objective to reduce vehicles on campus. Yes, in that Estates bought goods and services.

[31] *For commercial confidentiality the exact spend is not reported here.*

Name of key partner	Was this an external supplier of a good or service?	What key resource did they provide?	Which key activity did they perform?	Was this partner also a customer?
University Purchasing / Procurement	No	Control and knowledge of purchasing policy; management of supplier base; control of buyers and shoppers, via policy.	Control of suppliers; control of buyers; permission.	Partially Yes, in that buyers performed tasks on behalf of Purchasing.
University Senior Management / Executive	No	Permission and funding.	Ultimate control of all University policy and staff.	Yes, in that the Coherent Campus Policy was set and monitored by the Senior Management.
Buyers/Shoppers	No	Administration.	Processing of requisitions and demand into purchase orders.	Yes, as proxies for the ultimate end user.
Faculty Co-ordinators	No	Administration; management; and liaison.	Liaison between Faculty end users and the scheme.	Yes, as the closest we could functionally get to the end customers.
Suppliers	Yes	Supply of goods and services.	Redirection of goods to consolidation scheme, whilst continuing to meet end user needs.	No
Students' Union	No	A semi-autonomous customer sharing the same campus.	Demand goods.	Yes

Name of key partner	Was this an external supplier of a good or service?	What key resource did they provide?	Which key activity did they perform?	Was this partner also a customer?
Clipper Logistics	Yes	Logistics operation.	Warehousing; driving; human resources; scheduling; goods handling; delivery to desk.	No
Smith Electric	Yes	Electric vehicle expertise and refurbishment.	Provision of electric vehicle, batteries and maintenance.	No
VIGO Software Ltd.	Yes, sub-contractor to Clipper Logistics	ICT systems.	Receipt, tracking; querying of deliveries via a web portal.	No
Brigade Electronics	Yes, supplier to Clipper Logistics	Vehicle Safety Solutions.	360° Backeye camera system.	No
Researcher.	No	Research; expert knowledge; analysis; funding; project Management.	Research; analysis; project management; facilitation.	No

Table 90: BMC Summary of Key Partners

8.9.6. Key Activities

In Chapter 3, I summarised the opening steps of Action Research. It is worth repeating them before detailing the activities agreed upon. The first is to *frame* the issue: “How to improve the sustainability of logistics on the Coherent Campus at Newcastle University?” The next step is *scoping,* which by this stage was tightly defined as a Coherent Campus Consolidation Scheme ‘local in practice to the city campus’ and ‘internationally in the context of EU policy’. The next requirement was to gain *access*; this was done top-down at the University and outward from the wider EU project, as shown in Table 90. With this the partners in the pilot needed to agree a *contract* between ourselves, as to which ‘key activities’ would be performed and by whom.

Select and convert suppliers and internal customers

Advice from Clipper Logistics and Office Depot suggested that the suppliers most in need of consolidation and greater efficiency were not the major volume suppliers, but those from whom smaller ad-hoc deliveries were received. These were also the most difficult to identify. In early 2014, data were recovered from the SAP BW for August 2012 to 2013, identifying all suppliers that made more than an average of 4 deliveries per month. This ‘top vendors’ list of 251 suppliers (exampled as Table 91 below), generating 32,235 parcels across a standard 48-week year, was then reviewed by purchasing staff to exclude any suppliers that were based closer to campus than the CCCC; were based North of the campus and would require extra travel distance to reach the CCCC; had peculiar characteristics to be avoided for a pilot; were contractually sensitive; had such high and regular volumes that consolidation was likely to make their supply chains less efficient; or delivered unsuitable goods, such as food, drink, radio-actives, biological reagents, gases, liquids, very bulky goods like steel, or otherwise dangerous or fragile items.

Volume a year/ a supplier (2012 - 2013 Financial Year)		Volume	Approved for Pilot Scheme	Potential for Pilot Scheme	umulative Total	umulative %
Vendor ID	**Vendor Name**					
124277	CPC/Farnell (Onecall)	2756	Y		2756	16%
103036	XMA Ltd	999	Y		3755	22%
100089	Bunzl Cleaning and Hygiene Supplies	713	Y		4468	26%
116298	Insight Direct (UK) Ltd	582	Y		5050	29%
100702	Getech Ltd	468	Y		5518	32%
122383	Apple Sales International	448	N	Y	5966	34%
100833	Kelway Ltd	410	Y		6376	37%
101162	Rexel UK Ltd	352	Y		6728	39%
116340	Lawsons Timber Ltd	331	N	Y	7059	41%
139433	Commercial Group Ltd	329	Y		7388	42%
102120	Rocom Group Limited	301	Y		7689	44%
100276	Buck & Hickman Ltd	240	Y		7929	46%
				Sub Totals	7929	46%
126047	Makeport 2001 Ltd	219	N	Y	8148	47%
102294	Axminster Power Tool Centre Ltd	202	Y		8350	48%
101088	Systemax Europe Ltd t/a MISCO	172	Y		8522	49%
101247	Supplies Team Ltd	172	Y		8694	50%
101393	RM Education Plc	147	N		8841	51%
116823	MAE Ltd t/a Primo IT	136	Y		8977	52%
122800	Titan Fluid Technologies Ltd	129			9106	52%
124144	Camfil Ltd	123			9229	53%
102137	Sigma Aldrich Company Ltd	122	N		9351	54%
136222	Stearn Electric Company Ltd	117	Y		9468	54%
133103	SCC Exchange	105	Y		9573	55%
100552	E&E Workwear	94	Y		9667	56%

Table 91: Example details from 'top vendors list', Source working documents 2014

This review reduced the number of suppliers on the list by about 30%, and the parcel volume by 75%, to 14,464. It was agreed to regenerate the list, this time for all suppliers that delivered more than an average of 3 deliveries per month. This increased the supplier list to 1027 but added only 2000 deliveries per year. Using this list we agreed that it would likely generate circa 343 parcels per week, equating to 16,434 per annum, as detailed below in Table 92.

	Parcels	Per week (48 week year)
Top vendors	32235	672
Final list	16434	343

Table 92: Estimated deliveries per week

A procedure was written for how to use the list of targeted suppliers, week by week during the pilot, to convert each to delivering their goods to the CCCC. A dedicated member of staff would begin by identifying the main internal user of the supplied items and asking for their input and issues. If this first check proved positive, the relevant supplier would be contacted to discuss the desired change of delivery address. If no problems presented, the supplier would then be instructed to deliver all goods with a University delivery address, to the CCCC.

Redirect PO deliveries to the CCCC

It was made clear to each supplier that the address on the University's PO system would not change during the trial period, to avoid SAP conflicts over delivery addresses; the absence of any budget, in time or money, prohibited non-trivial changes to the University ICT system. In theory, buyers could have changed the delivery address on their POs to a new CCCC address, but already low compliance with the policies in place, plus the lack of centralised control, made this unviable. Instead, a supplier would agree to change their systems to show the original delivery location on the address label, but with the CCCC address replacing the actual postal address. This is exampled next, with Table 93 below showing the original address and Table 94 below showing the amended address.

Name	Name 2	Address line 1	Address line 2	Town	Postl Code
Finance Department	Newcastle University	Deliveries and Post Point	King's Gate	Newcastle Upon Tyne	NE1 7RU
Management Accounts	Newcastle University	Medical School	Framlington Place	Newcastle Upon Tyne	NE1 7RU
Management Accounts	Newcastle University	HASS Faculty Office	7th Floor, Daysh Building	Newcastle Upon Tyne	NE1 7RU
SAgE Faculty Management Accounts	Newcastle University	2nd Floor, Devonshire Building		Newcastle Upon Tyne	NE1 7RU
IT Service (NUIT)	Newcastle University	Claremont Tower	Claremont Road	Newcastle Upon Tyne	NE1 7RU
Netskills Training suite	Newcastle University	1st Floor, Herschel Building		Newcastle Upon Tyne	NE1 7RU
DARO	Newcastle University	Level 5 - King's Gate		Newcastle Upon Tyne	NE1 7RU
Human Resource	Newcastle University	Level 4, King's Gate		Newcastle Upon Tyne	NE1 7RU
HR - Safety Office	Newcastle University	Level 4, King's Gate		Newcastle Upon Tyne	NE1 7RU
HR - Radiation Protection Office	Newcastle University	M1 143 - 1st Floor, William Leech Building	Framlington Place	Newcastle Upon Tyne	NE1 7RU

Table 93: Original University delivery addresses used by suppliers, Source working documents 2014

Name	Name 2	Address line 1	Address line 2	Town	Postl Code
Finance Department	Newcastle University	Deliveries and Post Point	c/o Clipper Logistics	Wynyard	TS22 5TB
Management Accounts	Newcastle University	Medical School	c/o Clipper Logistics	Wynyard	TS22 5TB
Management Accounts	Newcastle University	HASS Faculty Office	c/o Clipper Logistics	Wynyard	TS22 5TB
SAgE Faculty Management Accounts	Newcastle University	2nd Floor, Devonshire Building	c/o Clipper Logistics	Wynyard	TS22 5TB
IT Service (NUIT)	Newcastle University	Claremont Tower	c/o Clipper Logistics	Wynyard	TS22 5TB
Netskills Training suite	Newcastle University	1st Floor, Herschel Building	c/o Clipper Logistics	Wynyard	TS22 5TB
DARO	Newcastle University	Level 5 - King's Gate	c/o Clipper Logistics	Wynyard	TS22 5TB
Human Resource	Newcastle University	Level 4, King's Gate	c/o Clipper Logistics	Wynyard	TS22 5TB
HR - Safety Office	Newcastle University	Level 4, King's Gate	c/o Clipper Logistics	Wynyard	TS22 5TB
HR - Radiation Protection Office	Newcastle University	M1 143 - 1st Floor, William Leech Building	c/o Clipper Logistics	Wynyard	TS22 5TB

Table 94: Revised CCCC University delivery addresses used by suppliers, Source working documents 2014

Inbound delivery specifications

Suppliers wishing to benefit from the pilot scheme were instructed to pack items securely into an outer carton bearing an address label that stated the number of parcels inside and the weight of the carton (15kg max as per Clipper standard working limit for hand-carried packages). Cartons containing multiple orders would then be opened on arrival at Clipper and split into individual parcels again, for onward delivery to the University.

> If a carton contains a single order, the carton should be clearly labelled as a "Single Order" and a despatch note placed within a document holder on the outside of the carton, to ensure the parcel is not opened at Clipper Logistics. If one order is split over several outer cartons, each carton label should clearly state "Single Order" but, additionally, how many cartons form the order, e.g. "Carton 1 of 3". The order despatch note should be placed within a document holder secured to one of the outer cartons for that order.

Figure 69: Single Order - Example to be shipped by Clipper to Newcastle University

> Where multiple orders are combined into one larger outer carton for carriage purposes only, the carton must be clearly labelled

up as “Order Breakdown” and parcels for each order within the outer carton must be packed securely within their own inner carton with an attached document holder containing the despatch note for that order. An additional copy of all despatch notes must be placed within the larger outer carton, for Clipper’s use only.

Figure 70: Order for Breakdown - Example to be shipped by Clipper to Newcastle University

Receipt goods onto a tracking system

The ‘combination’ address would maintain the goods delivery point on campus. The supplier would receive a clear signature, as proof of delivery, and the University and its end users a clear record of the goods receipted into the CCCC en route to final destination. Feedback from Faculty Co-ordinators had stated the need for a clear and easily interrogated tracking system, to allow users to know their goods had arrived and, in time-sensitive situations, to either collect the goods from the CCCC, or organise immediate onward despatch.

Clipper commissioned their preferred ICT suppler VIGO to provide the tracking system. Details of the receipted goods would be entered into the VIGO system on arrival - in particular the campus delivery zone; supplier details and reference number; and the University’s PO number. To facilitate this, an infrequent data export from the University’s SAP database of delivery addresses and supplier details would be supplied. The main entry procedure is detailed in Figure 71.

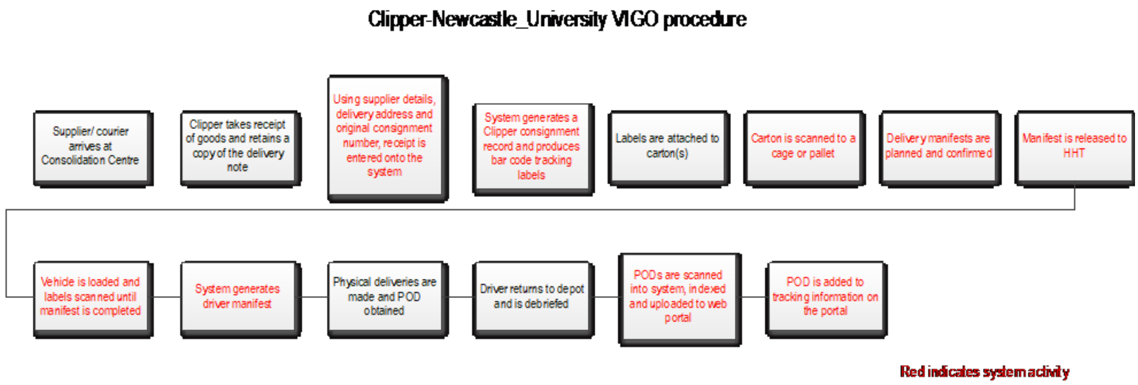


Figure 71: Physical and Virtual Goods flow through CCCC, Source VIGO Software 2014

All goods would be relabelled, using Clipper reference numbers and barcodes, to allow the use of proof of delivery systems by the driver - in this case 'signature on glass', via a handheld device.

Bundle goods onto the electric vehicle

As can be seen in Figure 71 above, the received goods would be bundled onto a manifest and shipped. A small ($3m^2$) holding area was set aside for the goods and it was agreed that all goods receipted by 10:45am would be bundled onto the vehicle, with all goods received after that time delayed until the next day. University staff were informed of the telephone number of the CCCC and advised that it had a 24/7 operation and that urgent goods could be collected at any time. It was understood that in a crisis, Clipper would make a special trip, with the cost carried by the University, unless fault lay with the warehouse.

Deliver around a distribution route

In order to deliver goods efficiently to the University, a delivery route needed to be designed. Watching and talking to delivery drivers from various companies, it was observed that many would park up once and walk the campus, rather than stopping multiple times.

In order to develop a similar 'parking place - delivery zone' structure for our service, I looked to analyse the SAP data and design a similar circuit. At first the delivery data were extracted from the SAP BW system and the volumes per year/week/day were analysed and then plotted on a map of the city.

The first step was to record all deliveries for the suppliers preselected[32] for the CCCC, by delivery address code. From that code an Excel VLOOKUP was used to link the address with a building number. In addition, the delivery addresses had encoded within them the Faculty to which they were attached, so I could then assess likely volumes of packages per building and per Faculty. An example of the spreadsheet analysis is shown in Table 95.

Storage location	**Column2**	storage code	building	Building No.	vol/year	ave/week	ave/day
UON1/C078	Castle Leazes	'UON1/C078	Castle leazes Halls of Residence	75	341	6.6	1.3
UON1/C013	HR Staff Develop	'UON1/C013	King George VI Building	19	18	0.3	0.1
UON1/C031	Robinson Library	'UON1/C031	Robinson Library	35	341	6.6	1.3
UON1/C045	ESS Direct Works	'UON1/C045	Drummond Building	47	1090	21.0	4.2
UON1/H005	GPS School Off	'UON1/H005	Claremont Tower	2	157	3.0	0.6
UON1/H013	NUBS MAIN NEW	'UON1/H013	Citygate	58	127	2.4	0.5
UON1/H021	Architecture Gen	'UON1/H021	Architecture Building	27	360	6.9	1.4
UON1/H025	SACS School Off	'UON1/H025	Armstrong Building	22	173	3.3	0.7
UON1/M032	Neuro Henry Welc	'UON1/M032	Henry Wellcome Building	61	997	19.2	3.8
UON1/S019	Chem Eng Gen Off	'UON1/S019	Merz Court	24	204	3.9	0.8
UON1/S031	AgricultureSch	'UON1/S031	Agriculture Building	16	142	2.7	0.5
UON1/X001	Please See Below	'UON1/X001	PLEASE SEE BELOW	58	790	15.2	3.0
UON1/C069	Pavillion	'UON1/C069	Newcastle General Hospital	53	2	0.0	0.0
UON1/C061	St Mary's	'UON1/C061	St Mary's College Halls of Residence	19	80	1.5	0.3
UON1/C072	Rich road Recept	'UON1/C072	Richardson Road Halls of Residence	53	116	2.2	0.4
UON1/S001	Civil Eng Cassie	'UON1/S001	Cassie Building	49	254	4.9	1.0
UON1/C032	Walton Library	'UON1/C032	Cookson building	59	2	0.0	0.0
UON1/M001	IAH labs	'UON1/M001	Newcastle General Hospital	53	181	3.5	0.7
UON1/M026	NICR O'Gorman	'UON1/M026	Paul O'Gorman Building	68	157	3.0	0.6
UON1/M031	NICR Chem Labs	'UON1/M031	Bedson Building	20	25	0.5	0.1
UON1/M035	IHS Main	'UON1/M035	Baddiley-Clark Building	69	136	2.6	0.5
UON1/M039	ICMB	'UON1/M039	Cookson Building	59	562	10.8	2.2
UON1/M040	ICMB CBCB	'UON1/M040	Baddiley-Clark Building	69	82	1.6	0.3
UON1/M046	CBC	'UON1/M046	Medical School	60	263	5.1	1.0
UON1/M049	Psychology	'UON1/M049	Ridley Building	51	40	0.8	0.2
UON1/S002	Civil Eng Drum	'UON1/S002	Drummond Building	47	146	2.8	0.6
UON1/S025	Mech Eng School	'UON1/S025	Stephenson Building	50	412	7.9	1.6
UON1/H026	Fine Art	'UON1/H026	Fine Art Building	29	517	9.9	2.0
UON1/M002	IAH MRG	'UON1/M002	Cookson Building	59	80	1.5	0.3
UON1/M008	ICM Cath Cook F4	'UON1/M008	Cookson building	59	82	1.6	0.3
UON1/M010	ICM WillLeech F4	'UON1/M010	William Leech Building	58	134	2.6	0.5
UON1/M023	MEDEV Anatomy	'UON1/M023	Medical School	60	11	0.2	0.0
UON1/M055	Genetic Medicine	'UON1/M055	International Centre For Life	20	256	4.9	1.0
UON1/S011	Biology Ridley	'UON1/S011	Ridley Building	51	81	1.6	0.3
UON1/S039	School of EECE	'UON1/S039	Merz Court	24	1116	21.5	4.3
UON1/C016	Executive Office	'UON1/C016	King's Gate	1	4	0.1	0.0
UON1/C027	MCD Resource KG	'UON1/C027	King's Gate	1	9	0.2	0.0
UON1/C030	MCD Reception KG	'UON1/C030	King's Gate	1	52	1.0	0.2

Table 95: Delivery volumes FP 2012-2013 for selected CCCC suppliers only, grouped and averaged by building number: Source: working document 2014

The buildings were then clustered to suit the physical campus parking locations available to the vehicle - seven candidates on the main campus, identified as A-G in the following Tables. As can be seen below in Table 96, by clustering all buildings with volumes of greater than one parcel per day, 56.52 of the total could be allocated. Then, by extending the scope as seen in Table 97 below, 61.59 of parcels were accounted for,

[32] *Note that whilst pre-selected, at this stage these were unconfirmed; that process would be part of the pilot*

leaving a small remainder of 7.06 which could be 'mopped up' in the final matching of delivery address to building to delivery zone.

Over 1/day delivery	choice of del point		
Building number	**1st choice**	**2nd choice**	**volume/day**
2	a		7.51
16	b		1.20
20	b		2.60
22	a	b	2.23
24	a		6.10
27	a		1.43
29	a		1.99
35	f	g	1.34
47	f		6.29
50	f		4.75
51	d		1.31
53	d		1.85
58	e		5.86
59	e		3.24
60	e		3.29
61	e		4.13
63	e		1.38
	Total routed per day		**56.52**

Table 96: Allocation of delivery buildings to potential drop zones. Source working documents 2014

Over 0.5/day delivery	choice of del point		
Building number	1st choice	2nd choice	volume
2	a		7.51
7	a	b	0.71
16	b		1.20
17	b		0.94
19	b		0.83
20	b		2.60
22	a	c	2.23
24	a	f	6.10
25	a	f	0.82
27	a		1.43
35	f	g	1.34
47	f		6.29
49	f		0.98
50	f		4.75
51	d		1.31
53	c		1.85
58	e		5.86
59	e		3.24
60	e		3.29
61	e		4.13
63	e		1.38
68	e		0.60
69	e		0.87
75	e		1.31
	Total routed per day		61.59
	Total identified per day		68.65
	Remainder		7.06

Table 97: Allocation of buildings to potential drop zones. Source working documents 2014

The University had centres outside the city: specifically farms and a marine research centre. These were to be excluded by the supplier, via use of postcode. The main campus had a single postcode, convenient for this purpose. However, there were a few city-based Sites that Purchasing *did* require to be part of the scheme: the 'Centre for Life'; Newcastle University Business School; the Centre for Aging and Vitality, on the Newcastle General Hospital campus; and the Castle Leazes Hall of Residence. These minor drop zones became 1-4 in the final delivery routing, with zones 5-9 forming the main structure of the route and delivering the bulk of the goods. The drop zones were detailed in a widely distributed map - Figure 72. Not obvious to the reader is that the vehicle had a 1 hour pause at zone 8, to top up its battery, whilst the driver delivered goods on foot. No other facilities were needed or planned for any other zones, as parking already existed. Zones 1-4, which were likely to have days with no deliveries, could be dropped from the route on a day-by-day basis. The route was preceded by, and followed by, a relatively long drive to the warehouse. The final drop zones were linked to the delivery addresses on SAP and the file passed to Clipper and VIGO to update the receipt and bundling system. A basic route 'bible' was written, as an aid for delivery drivers, who would be supported by University Security staff at start up, either in a drive-along, or at the end of a telephone when required. The estimated weekly dwell time per zone was calculated from the planned schedule as in Table 98 below.

Zone	Approx Arrival Time	Approx Departure Time	Unloading time, minutes:	
			Maximum weekly	Minimum weekly
1	11:20:00	11:25:00	00:25:00	00:00:00
2	11:30:00	11:35:00	00:25:00	00:00:00
3	11:40:00	11:45:00	00:25:00	00:00:00
4	11:50:00	11:55:00	00:25:00	00:00:00
5	12:00:00	12:10:00	00:50:00	00:50:00
6	12:15:00	12:25:00	00:50:00	00:50:00
7	12:30:00	12:40:00	00:50:00	00:50:00
8	13:45:00	14:40:00	04:35:00	04:35:00
9	14:45:00	14:55:00	00:50:00	00:50:00
Totals			09:35:00	07:55:00

Table 98: The estimated weekly dwell time per zone

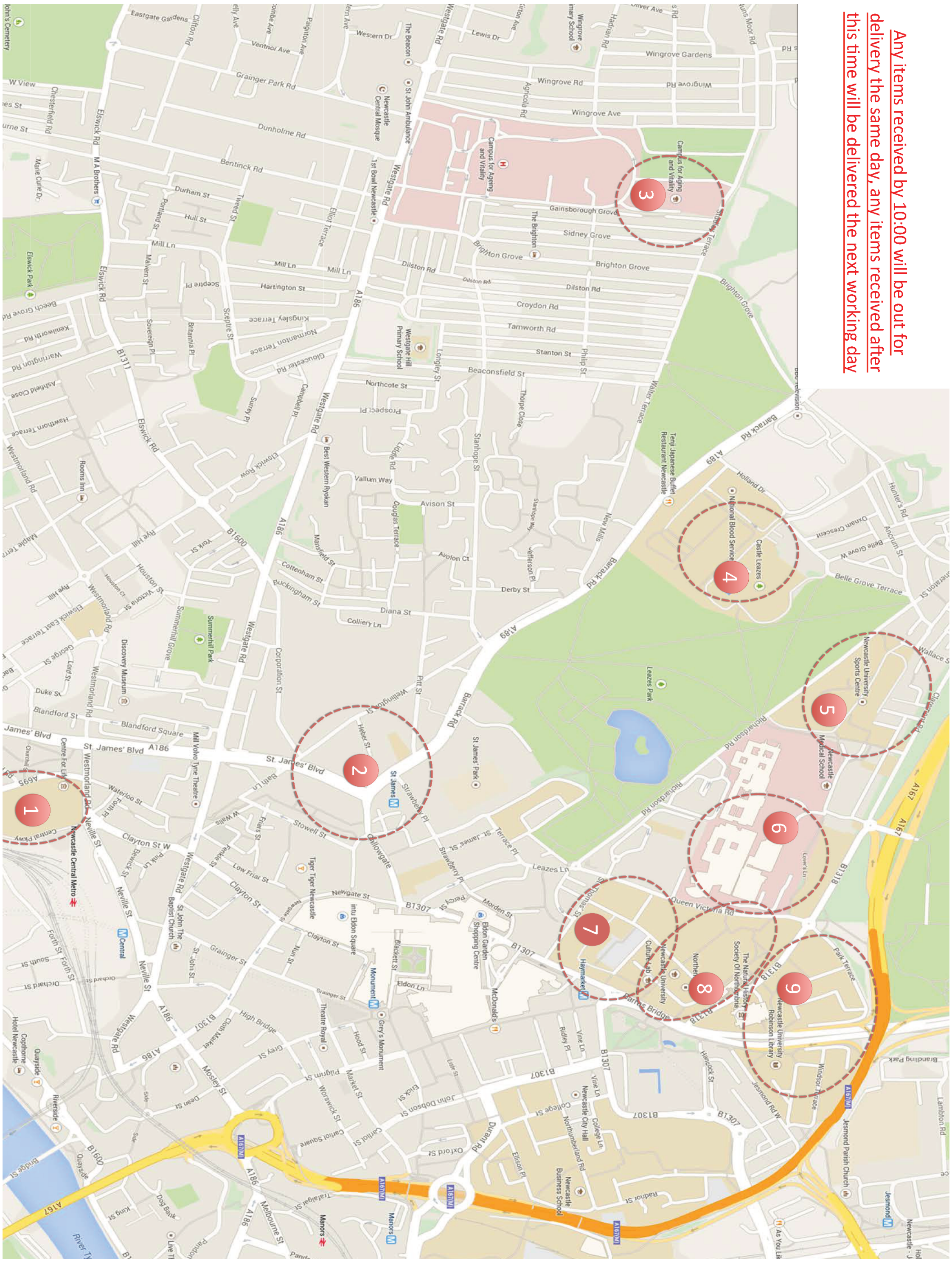


Figure 72: Newcastle University CCCC Delivery Zones. Source: working documents 2014

Maintain availability of a tracking system

Whilst the Purchasing Manager was somewhat sceptical of the clearly stated need from users, this might, for some, be the difference between supporting or opposing the scheme. Thus, VIGO were commissioned to design and build a tracking portal to allow University staff to track goods by searching for them using the University postcode, tracking code, consignment number or PO number (called Customer reference by Vigo). The login is shown as Figure 73.

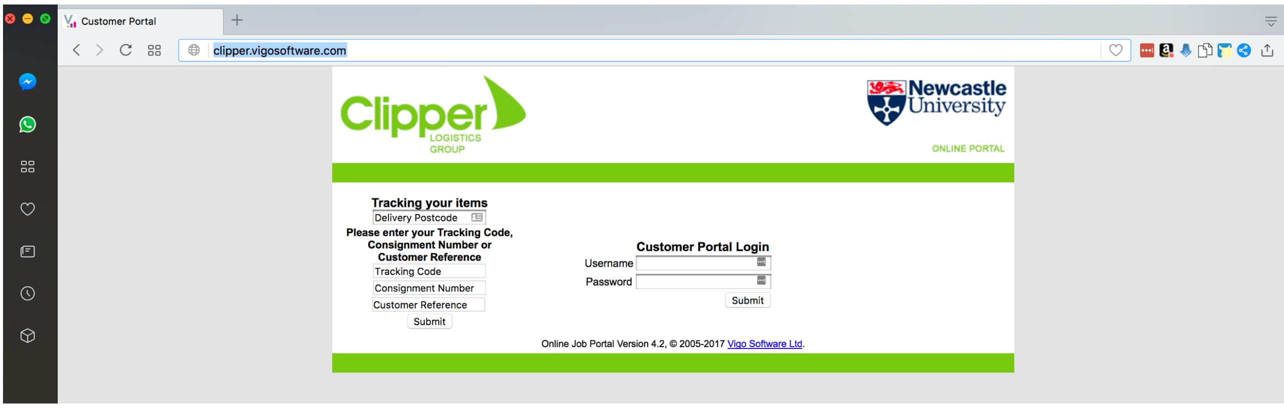
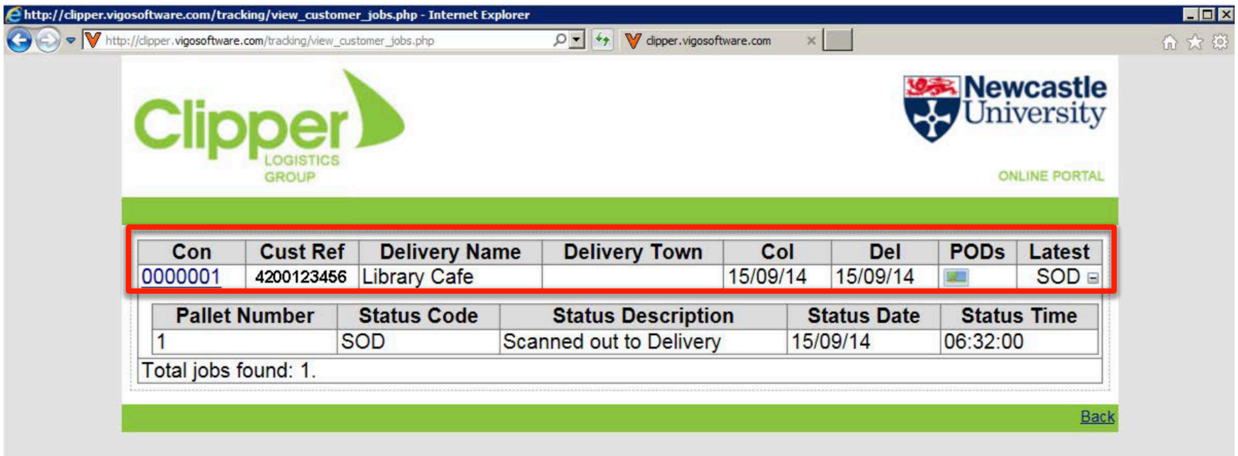


Figure 73: CCCC Online Tracking System, source: http://clipper.vigosoftware.com/

Once logged in, the user would have full visibility of their goods from receipt at the CCCC to delivery at desk, as shown below in Figure 74.



Con: - Supplier Consignment Number

Cust Ref: - University Purchase Order Number

Col: - The date the parcel/item was received by Clipper Logistics

Del: - The date the parcel/item will be delivered by Clipper Logistics

PODs: - Proof of Delivery (from Clipper) – N.B this will appear the Clipper have made the delivery and upload the paperwork.

Latest: - The status of your delivery, with more detail displayed in the section directly below.

Figure 74: CCCC Online Tracking System individual consignment, source Clipper-VIGO-CCCC documentation 2014

Performance monitoring

In order to record and report to the various stakeholders, clients, observers, and to this research, a variety of performance monitors was planned. Key were:

1. Suppliers converted to scheme from previous normal practice.
2. Parcels per day, divided by drop zone.
3. Deliveries to the CCCC, as opposed to delivery to campus, giving a metric of the degree of consolidation achieved.
4. All and any deviations from process.
5. Vehicle problems.

For 1, the conversion of suppliers was to be recorded as part of the conversion process that aimed for 5 per week at first, building to 10 per week dependent on the impact and effect of the pilot. For 2-3, data could be drawn from the VIGO system. For 4-5, the incidents would be recorded in a text diary, having been notified through the support contacts distributed and publicised through the University, or direct to the core team from an external partner or actor.

It would be possible to monitor carbon savings from use of an electric rather than diesel vehicle, by collecting data from vehicle telemetry. The degree to which this was helpful is discussed further in Chapter 10 below.

Better vehicle utilisation

For decades, a key metric utilised in analysis of freight transport had been the utilisation of vehicles, either by weight or by volume. In EU policy, it had sometimes been the only key metric, adopted on the basis that vehicles would generate a greater dis-benefit - in terms of congestion, carbon use and air quality pollutants - if they were less than fully utilised. The data collected in the pilot, combined with traffic survey data, were intended to support such an analysis; this is also reported in Chapter 10 below.

8.9.7. Key Resources

The Vehicle

I explored options for the provision of a clean electric vehicle. The pilot team developed a specification for the likely size (circa 7.5-12t gross vehicle weight, with a 20-30ft box); the operational cycle; and a 150 miles per day maximum range. This specification was published in the Official Journal of the European Union (OJEU), and on the relevant open tender websites, with links to the University tendering system. As a purchase based largely on public funding, we were obliged to follow this route, but I was also interested to see if we could find any alternative suppliers to Smith Electric. In the event, Smith Electric, of Washington, County Durham, was the only company to tender and later research by a colleague confirmed the absence of any European medium-to-large freight vehicle builder or rebuilder at that time (Tumasz, 2016).

The vehicle chosen was a Smith Newton 10t chassis truck, with a larger 120 KwH battery, to support an extended run from Teesside to Newcastle upon Tyne, as detailed in Table 99. A Backeye® 360 camera monitoring system was fitted to meet the requirements for reversing on campus[33]. Additional batteries were fitted to extend the operational range, given the location of our pilot warehouse.

Figure 75: Newcastle University's Smith Newton Truck, May 2015

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[33] The University policy for vehicles on campus stated the need for a 'banksman': an extra person to guide the vehicle into reversing, or an appropriate alternative viewing aid. The pilot met this requirement, whilst being fully aware of the fact that almost all other vehicles on campus did not.

Manufacturer	Smith Electric Vehicle UK (Washington, Tyne & Wear)
Model	Smith Newton (Originally a Daewoo Avia)
Chassis	3.9m wheelbase, right hand drive, double rear wheels
Gross Vehicle Weight	7490 Kg
Gross Unladen Weight	6303 Kg
Maximum Payload	1187 Kg
Good Compartment Volume	5.3 L x 2.3H x 2.1 W = 25.60 m3
Motor	Enova (Diff ratio 4.1:1)
Gearbox	Gearbox for Enova motor (Ratio 2.68:1)
Battery	Valence Rev2 120kWh (3 strings, 24 modules per string, 4 cells per module)
Charger	EDN (18kWh, triple phase, unidirectional)
Tyres	225/75/17.5 (2.388m rolling circumference)
Auxiliary Vehicle Controller:	No Auxiliary Vehicle Controller installed
Heater	Mes-Dea Valence (3.0kW draw)
Aircon	No aircon system installed
Operational Range	160 Km

Table 99: Smith Newton specification

The vehicle required higher ampage charging than the first-generation car charging points already on campus, so new charging points were installed both on campus and at the CCCC. These were inexpensive at £300 and were simple to install.

The Warehouse

Our logistics partner was Clipper Logistics, of Wynyard, Teesside, due to their business objective to develop viable urban logistics operations. The local warehouse was a very well provisioned facility, as detailed below in Table 100.

Key Features
340,000 sq. ft. slab
3 x mezzanine floors (2 Hanging, 1 Open Floor)
Total 840,000 sq. ft. usable space
9,906 High bay pallet locations
Multi-user location
Accredited for Bonded Operations
179 core staff
25 Operational & Site management
Dedicated Finance
Dedicated H&S
Dedicated Training Team
Dedicated HR
Dedicated Facilities
Full CCTV & security coverage
Site meets TAPA C security requirements
ISO 9001 Accreditation.

Table 100: Clipper Features and Metrics, Source: Clipper promotional materials 2017

Whilst any urban consolidation centre would logically be relatively close to the city it serves, the Wynyard distribution centre was 34 miles (54km) from the campus - a 54 minute journey along the A19, as shown in Figure 76.

Whilst this would not be appropriate for a medium to long-term service, it was highly suited to the pilot, due to its provision of 'elastic walls', signifying the ability to run the pilot as a marginal cost activity in a much larger facility, with extensive resources that could be drawn on, but which would incur no fixed costs: such as 24/7 opening; security; power; ICT resources; personnel; management; and 150 m^2 of floor space.

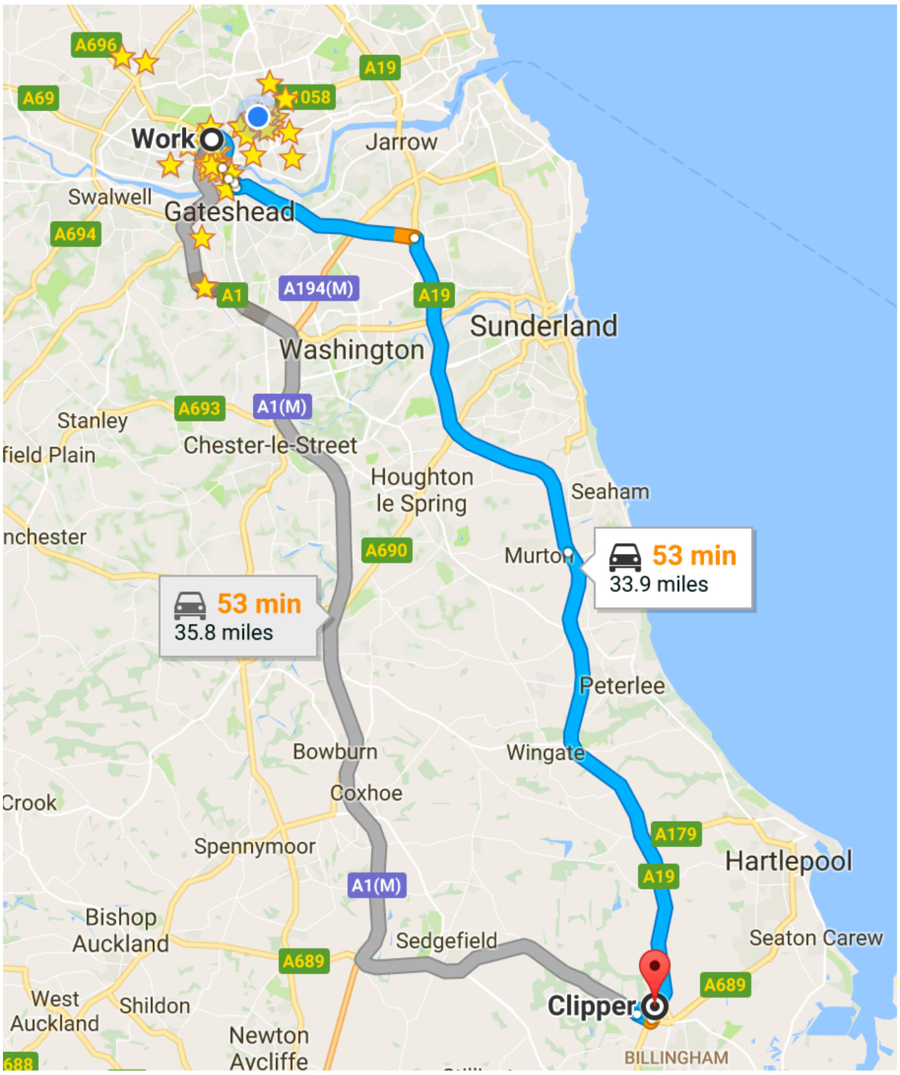

Figure 76: Clipper Wynyard Routes to Newcastle University, source: Google Maps 2017

The Personnel

To carry out the work, 3 key personnel were allocated, with back-up as required: a student in the purchasing department, employed 16 hours a week to work through the list of selected suppliers and convert them to the service; a goods inwards clerk at the CCCC, to receive and record the goods for the VIGO software system; and a driver, trained on the vehicle and in the delivery of goods to the addresses from the drop zones of the route. These could be supplemented as needed, with Clipper training additional staff to cover holidays or absence, for example. Issues needing escalation would be referred up to the General Manager at Clipper, the University Purchasing Manager, or co-ordinator Tom Zunder.

The software

The VIGO track and trace software is well detailed in Figure 71. Of note is that this was another marginal cost activity, in that it was a customised front end on an existing internal Clipper operations system, as evidenced by the occasional confusion in field names between collection/receipt and customer/supplier.

The route knowledge

The drivers' route knowledge book contained routing maps, delivery addresses clustered around zones, documentation on known delivery requirements etc., the University Security team mobile numbers, and blank pages - as route knowledge would grow on paper and in heads, as drivers learned the campus, asked questions of Security staff, and formed relationships with key goods receivers.

8.9.8. Cost structure

Although the pilot was erroneously reported as being on an "open book contract basis" (Bath_&_North_East_Somerset_Council, 2017), the cost structure of the CCCC was transparent to me as co-ordinator; however, for sound reasons of confidentiality, and the potentially misleading calculation of marginal costs at Clipper, it is excluded from this research. The broad brush estimates of other logistics operators, detailed in section 8.9.4, was used as a fall-back.

The BMC therefore reflected the costs as: 1 electric truck - about £60k second hand; 1 full-time driver; 1 despatch clerk half to full-time; and a 16 hours per week clerk during the pilot, to convert the supplier base.

8.9.9. Value proposition

Approval for the pilot was sought from the University Registrar and the Senior Professional Services team and was subsequently approved by the University's Executive Board for an Autumn 2014 start.

Having completed the demand and supply side of the BMC, the overall value proposition was encapsulated as follows:

> *As of Autumn 2014 a 'Pilot Scheme' to support the Coherent Campus policy will redirect a 'significant' proportion of deliveries placed with suppliers by*

Purchase Order, to an off-site consolidation centre where goods will then be delivered onwards to the University in a fully electric vehicle.

Clipper Logistics PLC and Newcastle University have together implemented an innovative freight consolidation solution which will improve the delivery of goods whilst reducing emissions and improving safety on the University campus. (Newcastle University, 2014)

This summary, and the FAQ section on the webpage (Figure 68) encapsulated the BMC short form: fewer vehicles on campus; centralised receipt tracking; lower carbon footprint; improved air quality; pride in sustainability; and its part in the Coherent Campus policy. The scheme was illustrated in presentations and publicity using the graphic shown as Figure 77.

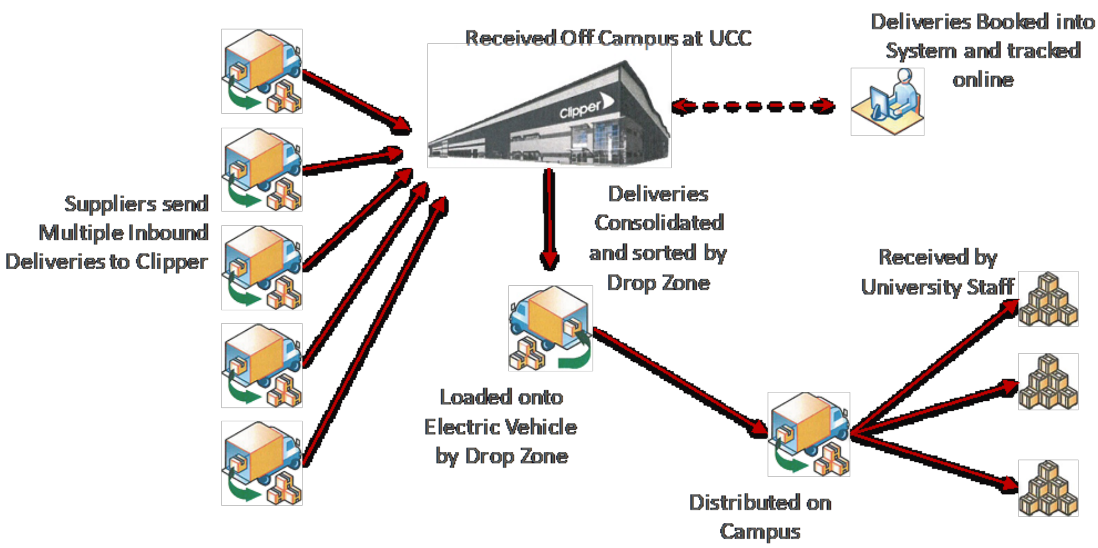

Figure 77: CCCC schematic, Source: working documents

8.10. Summary [Meta-step]

This Chapter has reported how its objectives were met, with an extensive report on the generation of a proto business model using BMC, and built upon the DMF.

8.10.1. Reflection on Content

Core

With regard to core process, the population of the 9 segments of the BMC has been detailed, as has the creation of questions in each, forming part of the evaluation in above alongside the DMF. Following completion of the BMC as a top level and broad-brush document, I have detailed how this was project-managed iteratively into an operational plan for the CCCC delivery service pilot. This followed three main stages. First, the demand side: identification of customer segments; the relationships we needed with them; and the channels that the service would use to reach them. Secondly, the supply side was detailed: the key partners and the secondary partners - noting those that were both key partners and also customers; the key activities; and the key resources needed to carry them out. On both supply and demand sides, the revenue and cost structures were less well defined, partially due to commercial confidentiality and partially to the marginal nature of the 'elastic walls' that underlay the provision of the pilot operation. Finally, the third segment was populated: the sum of the components; the value proposition; the culmination of the original contract between researcher and University; the DMF work; the BMC work; and the iterative work to organise the pilot service.

Thesis

This Chapter has detailed the process of AR Cycle 3 (see Figure **54** above). It has constructed the base knowledge and context about business models and the generation thereof; it has discussed value configuration and netchains; and detailed and evidenced the migration of the DMF to a BMC for the Newcastle CCCC, together with the key questions this raised. Various points of note were made, such as the dual nature of urban logistics as a long-linked sequential chain process and also a mediated simultaneous network activity, and also the absence of externality evaluation in the standard BMC.

8.10.2. Reflection on Process

Core and Thesis

Since core and thesis are both affected by the process of business model generation it seems appropriate, on this occasion, to reflect in them as the same for this chapter.

Given the low level of successful conversion of city logistics interventions into viable ongoing organisations, in future work I would favour a version of the Business Model Canvas for sustainable urban logistics, into which I would directly feed the developed understanding from the ZOPP process. In parallel to my research, a separate group of researchers deployed CANVAS and developed a new Urban Logistics Business Model CANVAS (ULBMC) (Macário and Marques, 2008; Quak, Balm and Posthumus, 2014) that added a tenth box in the middle: Externalities - about the internalisation of externalities, as shown in Figure 78 below. I was not minded to change the approach we had taken, and continued to use the standard BMC, since I believed externalities to be costs and as such needed to be in the left-hand side cost structure, not in the middle. I have, however, since worked with colleagues using the ULBMC and will draw out comparisons in future research outputs.

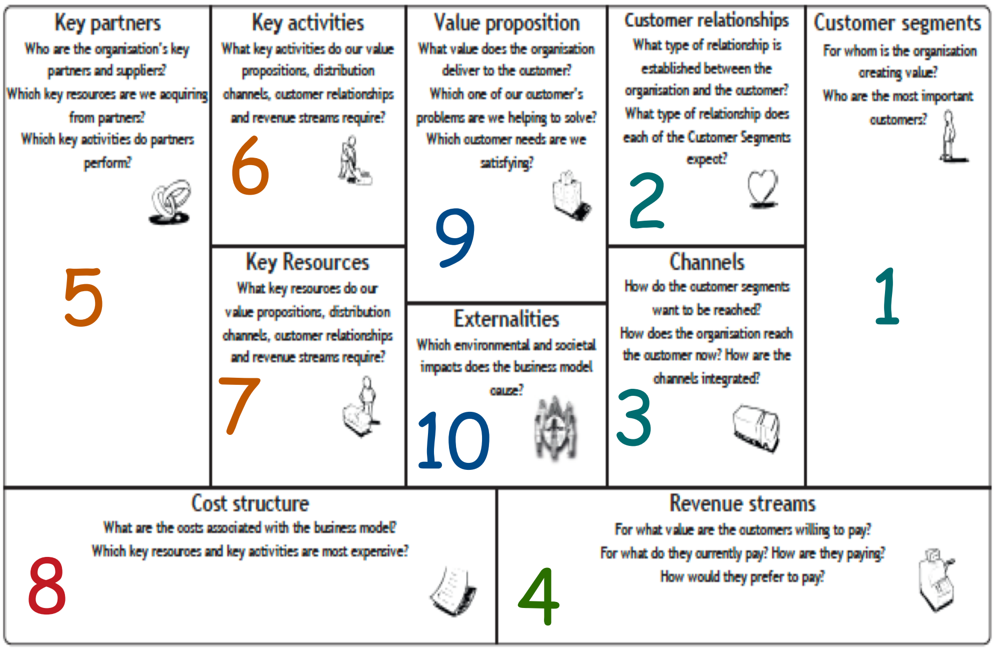

Figure 78: ULBMC (CC BY-SA 3.0) (Macário, Rodrigues and Gama, 2011; Quak, Balm and Posthumus, 2014)

8.10.3. Reflection on Premise

Core

The action work reported here showed that the premise of "best value for money" and "commercial confidentiality" obscured a detailed financial scrutiny of the underlying cost structures in place. However, there was little precedent for the business model to be developed here, and it was new to all actors. To that end it seemed understandable that the actors wanted to keep their "cards close to their chests", so as to not prejudice future negotiations.

Although my Smartfusion contract with the EU also mandated a clean urban logistics trial in Como and Berlin (Zunder, 2012; Schoemaker *et al.*, 2013; Zunder *et al.*, 2016) it did not for Newcastle where I had carefully written the proposal to allow the full choice of options. The decision to go with an electric vehicle came from the AR cycles; the choice of vehicle manufacturer came from the DMF workshops, with FIAT and VOLVO as potential alternatives. VOLVO were ultimately unable to provide a vehicle; FIAT did not have a vehicle that could be deployed outside of Italy. The alternative preferred by all was to adopt Smith Electric as a partner and trial their vehicle.

Thesis

This research activity confirmed the premise that a process model of an urban consolidation centre could be developed; it also challenged the idea that a proposed business model was not possible, as was stated in the literature review, albeit it had not yet been tested in practice. The work here also allowed reflection that the systems approach adopted, using sub-systems of actors, modelled the BMC structure well; both seemed to be functional theoretical models for work in research and in practice.

Chapter 9. Pilot of new service

The purpose of this Chapter is to record the execution of the CCCC pilot at the Newcastle University campus from 2014 to 2016 - a longer period than originally planned. With extensive primary source materials, the chapter shows how the theory and planning were validated and informed by praxis, as part of AR Cycle 4. The degree to which the pilot met the targets and goals is recorded here, and analysed later in Chapter 10 below.

9.1. Pre-step

9.1.1. Context

This chapter covers the third part of the AR Cycle 4 (see Figure 79): carrying out the pilot and reporting the operational results, which are then evaluated in 0 below. For the Newcastle University Coherent Campus pilot, an electric vehicle was used to deliver goods to campus, following consolidation at the Coherent Campus Consolidation Centre (CCCC), at Wynyard. The key operational plans for this were developed from the understanding of problems, and then the creation of objectives and interventions, in the workshops detailed in Chapter 7 above. From the five potential interventions, this was Intervention D: University Coherent Campus Consolidation Centre. This formed the basis of the written Design and Monitoring Framework (DMF), that stated the project as a logical framework, with key metrics as goals and monitors. From the DMF, and as part of Cycle 3 of the AR process, a focused partnership of actors collectively wrote a Business Model Canvas (BMC) that formed a prototype business plan for the CCCC and raised questions for testing. This was then adapted into an operational plan for the pilot as detailed in section 8.9 above.

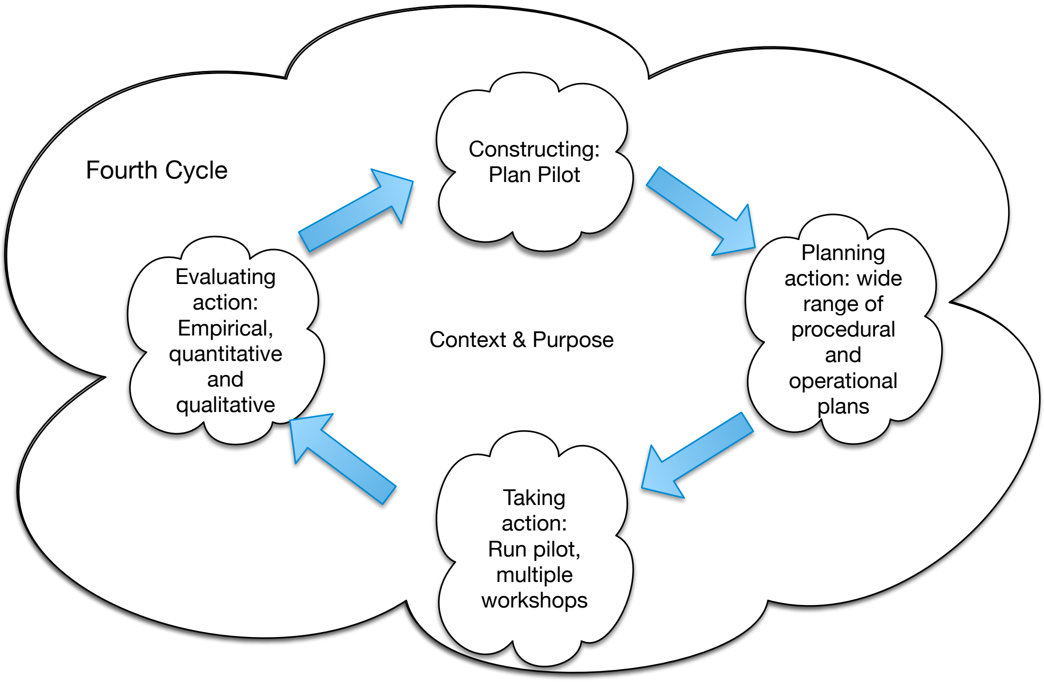

Figure 79: Newcastle Action Research Cycle 4, Source: Thomas H Zunder

9.1.2. Purpose

The primary purpose of the pilot was to test the mutually developed operational and organisational solutions and to provide data from which both practical and theoretical insight could be gained; this chapter details how that plan was put into operation. It is organised following the structure of demand, supply, finance and value proposition, as laid out on the Newcastle BMC.

9.2. Ethical considerations

The main ethical considerations for the pilot were health and safety focused: that the drivers knew where to go, how to behave on site, and that the vehicle was safe. These preparations were made in the planning of the pilot and included the writing of a delivery 'bible', and the fitting of 360° camera systems, in coordination with the Estates function (as detailed in section 8.9.7 above). Mutual contact and operational details were shared between Clipper Logistics and University Security personnel.

9.3. Demonstration Diary

The pilot ran for 21 months, from 23rd September 2014 to 30th June 2016, with a final delivery on the 1st July 2016. EU funding ended on 30th June 2015, and the University funded the scheme for a further year.

Throughout the pilot a demonstration diary was kept by all the team, parts of which are appropriate to quote as an opening narrative, as follows:

> 19/08/14 - Smith Electric delivered the Newton Vehicle to Wynyard; the collection was signed for and received.
>
> 03/09/14 - Driver Training & Induction by Stuart Gair of Smith Electric - all information passed to Darren from Clipper Logistics, at Wynyard, the on-Site training manager who documented the process from Smith to train further Clipper Logistics personnel. At the same time, Smith Electric provided telemetry access for Vehicle monitoring and performance; logins were provided for Newcastle University and Clipper staff.
>
> 11/09/14 - We held a meeting with Clipper's new Transport Manager, to brief her on the operations. This followed the departure of her predecessor, who had previously been involved from the start of operation planning.
>
> 12/09/14 - We arranged for the vehicle graphics and artwork to be fitted by Hooper Signs of Gosforth; the mock up designs had been approved by the University's Marketing & Communications department.
>
> 15/09/14 - 17/09/14 - We went to Wynyard to undertake the initial driver route training and familiarisation with 2 drivers: Peter & Les. We drove the route with individual drivers and together, over 3 days, from Wynyard to Newcastle, going around the city from locations 1-9, explaining the best locations to park and what each drop zone actually is, using the maps provided.
>
> Drivers were also shown the inside of some buildings and made familiar with internal and external university signage, plus the school offices and receptions. We explained street signage and locations best suited to parking and unloading the vehicle, as well as the on-campus charging point, a key for which was attached to the vehicle key.
>
> The drivers were introduced to the university internal mailroom manager, who was able to offer advice and support to ensure the drivers know exactly where all parcels should be delivered. At the other end of King's Road, they were shown the information point – another location where staff have been advised to offer assistance to the Clipper Logistics driver.

Mark Kerry from Clipper Logistics and Dave Morgan from VIGO software trained the expert WMS user Mark Snaith, at Wynyard, in how to use the University system. Bruce Carnaby verified all drop zones were correctly assigned to each storage location provided by the University's SAP team.

18/09/14 - Clipper Logistics arranged for the fitting of the Brigade 360 Camera system to the Smith Newton, by North East Truck & Van in Stockton - the first system Brigade have fitted to an electric vehicle. They were keen to be involved in the publicity of the operation and had thus given a 25% discount on the cost of the camera system.

Figure 80: Brigade 360^0 - Camera view fitted to the vehicle. Source: Brigade Electronics system

19/09/14 - The Smith Newton was collected by driver Les; when he turned on the vehicle the OPUS display was reporting a fault on the vehicle, as only 1 of 3 batteries was online. Les was able to recover the vehicle to Wynyard, the Smith Newton being drivable on limited protected operations only. Stuart Gair was contacted to attend to resolve the fault.

22/09/14 - Stuart Gair quickly resolved the fault, arising from not all batteries being correctly turned back on following isolation for the camera fitting. Clipper staff were reminded of the multiple isolator on the vehicle.

23/09/14 – Pilot formally started. First purchase orders to selected suppliers issued.

24/09/14 - Clipper Logistics received the first inbound drop off for the University. The Smith Newton made its first delivery to

Newcastle University Campus: 3 boxes of printer toner, from supplier XMA (Newcastle University, 2016a).

This diary was used to map the pilot, the problems and resolutions, and to inform the loop of action, reflection and learning - both in the pilot and in this thesis.

9.4. Demand Side

9.4.1. Customer Relationships

Regular drop-in sessions were to run during the pilot, where Faculty Co-ordinators and Senior Officers, the 8 potential power buyers identified in section 6.2.1, plus all and any other concerned staff from each of the 3 main University Faculties (SAgE, HaSS, FMS) would meet with the researchers, purchasing staff, and estates staff to exchange news and advice, as well as to provide an emergency warning system in the event of unknown problems emerging.

Newcastle University Consolidated Deliveries Project

The University is running a pilot for consolidating goods deliveries in a single location for onward delivery to their final destination in an electric vehicle. This reduces the number of commercial vehicles on campus and the amount of CO_2 emissions giving a cleaner, less congested campus for our students and staff. Most deliveries will be on the same day as normally happens, however, for some there will be a 24hr delay.

You are invited to attend a drop in session to ask any questions or concerns you may have on the University consolidated deliveries project. This session will be held on **Wednesday 21st January from 15:00-16:30 in room G21/G22, Devonshire Building**.

Figure 81: Invitation to first faculty focused staff drop in session

These sessions were held on the following dates:

- 21st Jan 2015
- 5th March 2015
- 22nd May 2015
- 12th August 2015
- 24th July 2016

Quite early in the process, the team identified a particular issue with the department of Electrical Engineering (EE). A wholly undocumented process allowed students to place a requirement for electrical and electronic components, with the EE staff member responsible, up to 5pm the night before required delivery; the staff member would then place an order on RS Components, before *11pm* that same night, for delivery first thing next morning. The team recognised this entirely local process, dependent on a member of staff working out of hours, as a highly just-in-time service to students that would need to be placed to one side for the pilot. This was disappointing, as circa 11 parcels per day had been estimated as coming to campus from this supplier, but customer service could not be jeopardised.

Initial wariness that the medical Faculty might not welcome the scheme proved unfounded; indeed, they expressed a growing demand throughout the pilot, as the new service proved more controlled, predictable and reliable. Representatives, which included potential power buyers, reported that the pilot had overcome the confused and ambiguous nature of goods inwards at the RVI and the Medical School whilst suited to the very small, repeated and daily just-in-time service they needed.

9.4.2. Channels: the vehicle

Initial problems were reported with the body work and roller shutter:

> `09/10/14 – Clipper's Transport Manager contacted us to say the Newton bodywork is leaking and the roller shutter door has jumped the runner because of body deforming. Smith Electric collected the vehicle and performed the repairs and resealing under warranty.`(Newcastle University, 2016a)

The vehicle performed acceptably during the pilot. Matters of note, from minutes and from the diary, were that in January 2015 concerns were raised about the vehicle running light, in high winds on the exposed A19 dual carriageway. At first a plan was made to substitute with a diesel vehicle, on days of high winds. However, the electric vehicle was then trialled in high winds with 500kg of dead weight added, where it performed well. The operating procedure was therefore amended to ensure that the vehicle always carried this ballast.

Safety on campus was a concern and, in December 2014, a pedestrian stepped out in front of the vehicle, causing the driver to swerve and collide with bollards. There was discussion about adding a system to light the road ahead of the vehicle with an LED 'symbol', but a potential supplier proved untraceable. An evaluation noted that with bright orange colouring, a very loud horn, and a 360° camera, the vehicle was safer than most other vehicles on campus and that the incident had shown adequate driver training and response. A discussion about adding artificial engine noise or a ringing bell sound (as do taxis in Florence) was placed on hold.

9.5. Supply Side

9.5.1. Select and Convert Suppliers and Internal Customers

The conversion of suppliers and their internal customers to the scheme was planned to proceed at the rate of 5 per week.

A student was appointed to a part-time job to resource the conversion of suppliers to the scheme, funded through the first year of the pilot. The target list, based on the original 251 target suppliers, was drawn up in March 2014 and is shown in Table 101.

Status March 2014	Excluded	Preliminary	Information Sent	Setup	Grand Total
Count of Vendor	86	106	11	48	251

Table 101: Original Target Suppliers, Source: working documents

However, as explained in section 8.9.6 above, this was at first reduced by 30% after removal of 'problematic' suppliers by the Purchasing department, before being increased to 1027 once the criteria for inclusion were reduced from an average of four to three deliveries per month. At a rate of 5 per week, over roughly 40 weeks, the scheme should have converted 200 suppliers. However the diary and other documents record only 35 suppliers going live during the pilot (Newcastle University, 2016a). When I analysed the data from the VIGO software (see Table 102 below) it became apparent that, out of 35 suppliers converted, only 18 actually made deliveries. Compared to the original suggestion of 251 and the revised target of 1027 this was a very low level of performance although, when compared to the DMF target of 20, it could be seen as acceptable. The main causes of the slow conversion were the lack of resource allocated to this task, inherent conservatism from the Purchasing Manager, isomorphic pressures identified as barriers to sustainable procurement (discussed in section 3.4.6 above), and the termination of the part-time student post in 2015 due to EU funding ending.

Sum of 'items'	Column Labels																										
	2014				2014 Total	2015												2015 Total	2016							2016 Total	Grand Total
Row Labels	09	10	11	12		01	02	03	04	05	06	07	08	09	10	11	12		01	02	03	04	05	06	07		
1st Choice Training Ltd								1						1				2									2
3D Laser Mapping Ltd	2				2																						2
4Muddy Feet Ltd	2				2																						2
Appleton Wood Ltd								25	12	11	14	18	20	21	14	26	11	172	12	26	20	18	13	5		94	266
Arjuna Technologies Ltd										1								1									1
Bunzl			43	7	50	19	115	67										201									251
Clipper Logistics Plc												3						3		10						10	13
CPC/Farnell (Onecall)						51	83	100	69	47	97	84	88	71	66	81	47	884	52	67	61	56	36	44	2	318	1202
DHL Express (UK) Ltd																1		1									1
Getech Ltd						2	7	7	10	48	16	79	8	7	10	8	1	203	11	5	38	7	15	33		109	312
Insight Direct (UK) Ltd												80	57	84	58	99	63	441	63	89	69	86	76	87		470	911
NEWARK						1			1									2				1				1	3
Newcastle University	1				1																						1
Pro-Ad Limited														13	6	6	1	26	8	11	4	36		4		63	89
Rocom Group Limited										22	5	7	16	11	20	5	5	91	12	19	11	7	14	5	1	69	160
SAMTEC																2		2									2
UPS Ltd													1	1				2									2
WEST COAST LIMITED	7	56	58	62	183	62	65	53	42	50	62	27	24	2	7			394					31	14		45	622
XMA Ltd													2	37	23	46	38	146	54	39	48	26	29	13		209	355
Zygology Systems Limited																	1	1	1							1	2
Grand Total	**12**	**56**	**101**	**69**	**238**	**135**	**270**	**253**	**134**	**179**	**194**	**298**	**216**	**248**	**204**	**274**	**167**	**2572**	**213**	**266**	**251**	**237**	**214**	**205**	**3**	**1389**	**4199**

Table 102: Deliveries of parcels to the CCCC; analysis of VIGO software data

Count of 'items'	Column Labels																										
	2014				2014 Total	2015												2015 Total	2016							2016 Total	Grand Total
Row Labels	09	10	11	12		01	02	03	04	05	06	07	08	09	10	11	12		01	02	03	04	05	06	07		
1st Choice Training Ltd								1						1				2									2
3D Laser Mapping Ltd	1				1																						1
4Muddy Feet Ltd	1				1																						1
Appleton Wood Ltd								11	11	11	13	15	16	19	14	24	8	142	12	23	19	16	13	5		88	230
Arjuna Technologies Ltd										1								1									1
Bunzl			12	3	15	6	25	16										47									62
Clipper Logistics Plc												1						1		1						1	2
CPC/Farnell (Onecall)						47	81	100	68	45	96	80	71	71	65	67	45	836	46	60	55	51	35	42	2	291	1127
DHL Express (UK) Ltd																1		1									1
Getech Ltd						2	7	7	10	9	14	11	8	5	8	4	1	86	2	5	7	7	8	4		33	119
Insight Direct (UK) Ltd												67	54	63	52	82	54	372	49	79	62	80	53	57		380	752
NEWARK						1			1									2				1				1	3
Newcastle University	1				1																						1
Pro-Ad Limited														4	5	2	1	12	5	6	1	5		3		20	32
Rocom Group Limited										11	5	7	11	11	13	5	5	68	11	15	9	7	9	4	1	56	124
SAMTEC																1		1									1
UPS Ltd													1	1				2									2
WEST COAST LIMITED	7	40	33	48	128	31	41	30	28	30	41	24	20	2	4			251					18	10		28	407
XMA Ltd													2	20	17	27	15	81	26	28	34	17	16	8		129	210
Zygology Systems Limited																	1	1	1							1	2
Grand Total	**10**	**40**	**45**	**51**	**146**	**87**	**154**	**165**	**118**	**107**	**169**	**205**	**183**	**197**	**178**	**213**	**130**	**1906**	**152**	**217**	**187**	**184**	**152**	**133**	**3**	**1028**	**3080**

Table 103: Inbound deliveries of packages to the CCCC; analysis of VIGO software data

9.5.2. Operational performance

The operational performance is shown below in Table 104. There were 439 working days in the pilot period: 375 with delivery runs; 64 when no deliveries were made. There were 3080 deliveries to the CCCC, composed of 4199 discrete parcels - a ratio of 1.36 parcels per inbound receipt.

Month	Total Parcel	Working Days	Average Parcels per Day (rounded up)
Sept 2014	13	6	2
Oct 2014	57	22	3
Nov 2014	101	19	5
Dec 2014	69	18	4
Jan 2015	135	20	7
Feb 2015	270	20	14
Mar 2015	253	22	12
Apr 2015	134	22	6
May 2015	179	19	10
Jun 2015	195	22	9
Jul 2015	298	23	13
Aug 2015	215	20	11
Sep 2015	248	22	11
Oct 2015	203	22	9
Nov 2015	274	20	14
Dec 2015	166	17	10
Jan 2016	214	20	11
Feb 2016	266	21	13
Mar 2016	251	21	12
Apr 2016	237	21	11
May 2016	213	20	11
Jun 2016	208	22	10

Table 104: Newcastle pilot throughput, analysis of VIGO software operational data 2014-2016

The initial conclusion was that those 3080 potential deliveries to campus were replaced by the pilot vehicle delivery, causing a c88% reduction in the number of vehicles visiting the University *for the suppliers and goods participating in the pilot.* The rough base consolidation factor was “for every 9 incoming vehicles at the CCCC, 1 vehicle went on to campus”. This is explored in more detail and nuance in Chapter 10 below0 below.

During the trial there was a continuous reporting of operational activity and the degree of consolidation that the CCCC achieved: see Table 105. Note that the 'University reduction target' was agreed between the University and Clipper and refers to the reduction of freight vehicles on campus.

By pilot end, the average number of parcels per day was around 10-11, as seen in Figure 82 below, and in Table 104. This was much lower than the 68-69 parcels a day target envisaged at the pilot design stage, noted in Chapter 8 above. Whilst the linear trend-line was often interpreted as showing a potential growth, it was clear from the data, and from the halt in supplier recruitment, that the pilot had achieved a steady state - albeit one more to do with purchasing activity than any organic limits.

	2014											
Monthly Summary	Jan '14	Feb '14	March '14	April '14	May '14	June '14	July '14	Aug '14	Sept '14	Oct '14	Nov '14	Dec '14
Total Potential Trips (e.g. non CCCC)									10	40	45	51
Total EV Trips (substitution)									5	18	11	13
Actual % Reductions	-	-	-	-	-	-	-	-	50.0%	55.0%	75.6%	74.5%
University Reduction Target %									25.0%	25.0%	25.0%	25.0%

Actual Number of Vehicle Removed/Month	0	0	0	0	0	0	0	0	5	22	34	38
Actual Number of Vehicle Removed/Day									1	1	2	2

	2015											
Monthly Summary	Jan '15	Feb '15	March '15	April '15	May '15	June '15	July '15	Aug '15	Sept '15	Oct '15	Nov '15	Dec '15
Total Potential Trips (e.g. non CCCC)	87	154	165	118	107	169	205	182	197	177	213	129
Total EV Trips(substitution)	14	20	19	17	19	19	18	15	16	21	17	16
Actual % Reductions	83.9%	87.0%	88.5%	85.6%	82.2%	88.8%	91.2%	91.8%	91.9%	88.1%	92.0%	87.6%
University Reduction Target %	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%	25.0%

Actual Number of Vehicle Removed/Month	73	134	146	101	88	150	187	167	181	156	196	113
Actual Number of Vehicle Removed/Day	4	7	7	5	5	7	8	8	8	7	10	7

	2016											
Monthly Summary	Jan '16	Feb '16	March '16	April '16	May '16	June '16	July '16	Aug '16	Sept '16	Oct '16	Nov '16	Dec '16
Total Potential Trips (e.g. non CCCC)	153	217	187	184	214	208						
Total EV Trips (substitution)	19	18	21	21	20	19						
Actual % Reductions	87.6%	91.7%	88.8%	88.6%	90.7%	90.9%	-	-	-	-	-	-
University Reduction Target %	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%
Actual Number of Vehicle Removed/Month	134	199	166	163	194	189	0	0	0	0	0	0
Actual Number of Vehicle Removed/Day	7	9	8	8	10	9	0	0	0	0	0	0

Table 105: Newcastle University Coherent Campus Consolidation Centre 2014-2016 Operation Performance, source Clipper Logistics 2016

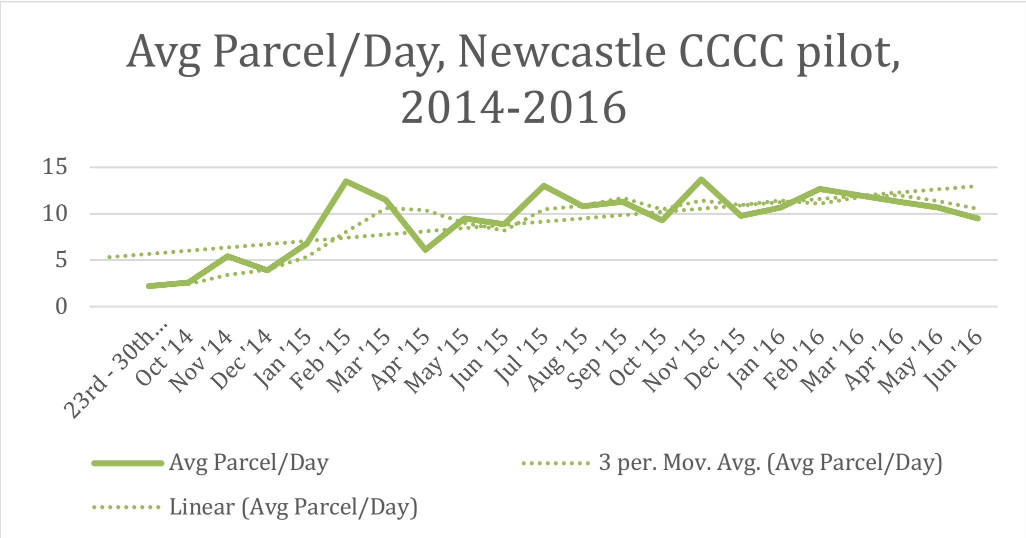

Figure 82: Newcastle pilot parcels per day 2014-2016, analysis of VIGO software operational data 2014-2016

Records were kept about deliveries by drop zone; the main drop zones used, shown below in Figure 83, were: DZ8 main campus central (42.0%), DZ6 medical & dental (26.2%), DZ9 main campus south and library (12.6%), and DZ7 city campus SW (8%). These were the main campus drop Sites and constituted 89% of all deliveries. It should be noted that this is not reflective of overall University demand, but rather of the suppliers (and therefore goods) converted to the pilot.

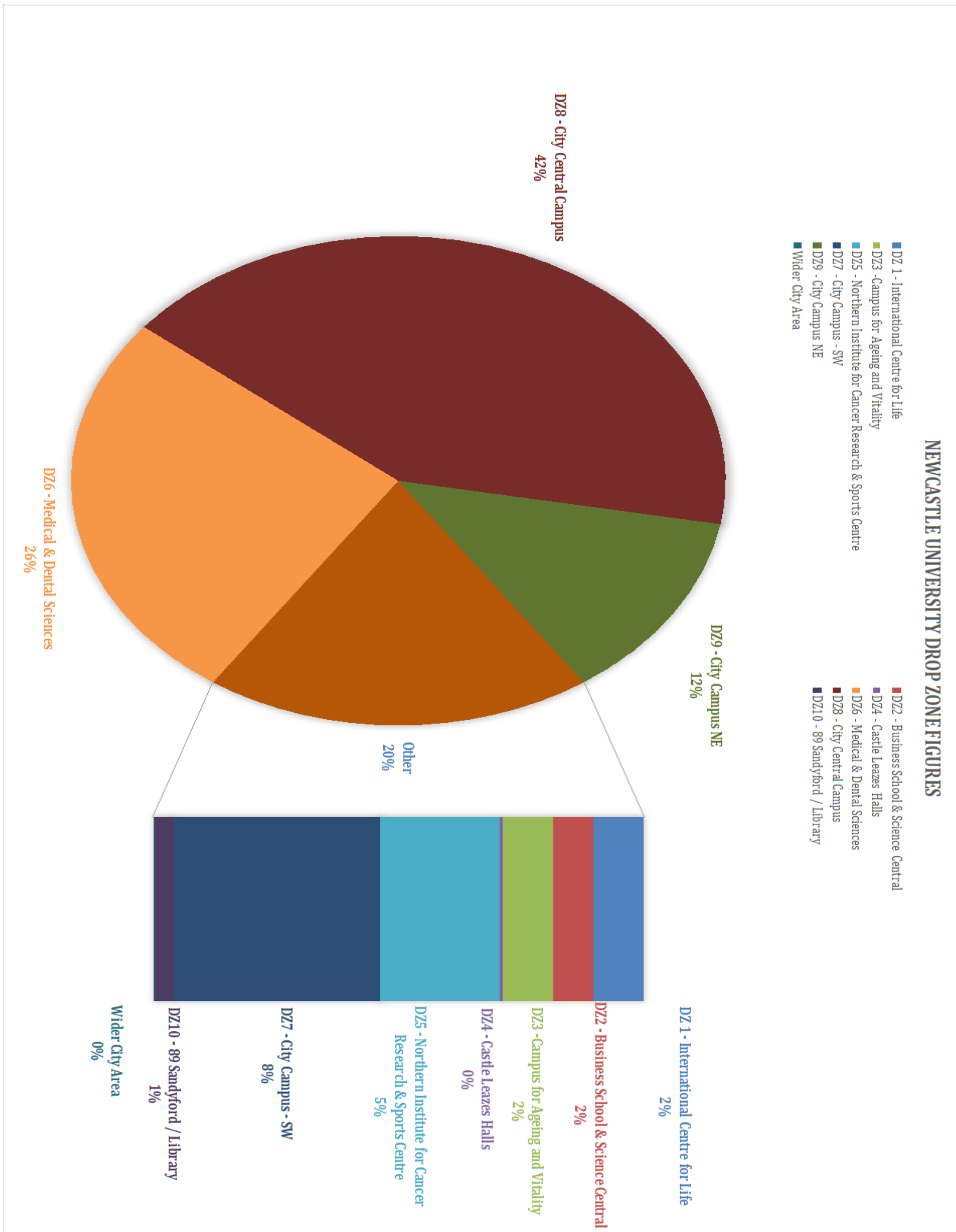

Figure 83: Newcastle pilot drop zone usage 2014-2015, Source: operational data

9.5.3. Purchasing Centralisation

As the analysis of the purchasing system and procedures in this work had revealed high fragmentation and low control of the University spend, in 2016 the Finance Director tasked the Purchasing Manager to both centralise purchasing and also move the CCCC pilot into a full service. After due consideration, it was agreed within Finance and Purchasing not to try to implement both changes at the same time. Given the fact that the CCCC service would benefit greatly from a more controlled purchasing system, and that the savings from such a Hub outweighed the costs from the CCCC scheme, the pilot was paused at end June 2016 to allow resources to concentrate on the centralised Purchasing Hub implementation. Plans to restart the CCCC scheme, following centralisation, began in April 2017.

9.6. Finance

During the middle months of 2015, the Finance Director requested the team write a Business Case (BC) for a full service. Clipper Logistics prepared various proposals for localisation of a commercial service into Tyne and Wear and the purchasing manager and I wrote and submitted a BC using the standard University forms. The main criticism of the 2015 BC was that the scheme showed no savings from the supplier base – valid, since no requests for supplier discounts had been made by the purchasing team during the pilot. Despite this, the Finance Director made it clear that the recommencement of the CCCC was a Purchasing function goal, writing it into the Purchasing Manager's personal targets for annual review. At the time of writing, a European Regional Development Fund (ERDF) bid, to fund the start-up of the CCCC, had been submitted.

9.7. Proposition

The attractiveness of the value proposition is evaluated later on in this research; however, one element: "sustainability pride" should be reported here as part of the pilot.

The pilot scheme was nominated for - and won - 2 awards in 2015. On 4th June 2015, the research won the "Best Environmental Initiative" at the Newcastle University Annual Environment Awards, that recognise projects and initiatives that demonstrate commitment to reducing the University's environmental impact and work towards achieving the University's sustainability objectives. The winner was selected by Professor Tony Stevenson, as Chair of the University's Environment and Sustainability Committee.

On 18th June 2015, the University was awarded "Outstanding Procurement Team", at the Times Higher Education Leadership and Management Awards (THELMA), for the collaborative work around the initiative to reduce delivery vehicles on campus and its carbon footprint.

The judges were impressed with the collaborative work that involved many parties in reducing direct delivery to the campus. Their comments included: "The benefits include cost savings to the university along with improvements to health and safety around the campus while protecting the environment using electric vehicles".

9.8. Summary (Meta-step)

This chapter has described the start, operation and eventual pause of the CCCC pilot service at Newcastle University, from 23rd September 2014 to 30th June 2016. The final months of the pilot were funded directly by the University, after EU project funding ended on 30th June 2015. The University saw added value in the service and was willing to continue, only pausing when they needed to embark on centralisation. The pilot has been summarised in sections relating to the demand, supply, finance and value proposition elements of the Business Model Canvas, Chapter 8 above.

9.8.1. Reflection on Content

Core

Despite some teething problems, the vehicle and underlying technology worked well. The range was adequate and whilst the location was quite distant the EV had no issues with the terrain or battery life. Safety concerns were examined after a near miss, but it was agreed that the vehicle was safer than most on site.

The attractiveness of the value proposition is evaluated later on in this research, however one element: "sustainability pride" has been noted. The scheme was recognised in two prestigious awards, one internal to the University and one external national award.

Thesis

The pilot captured as much data as possible and gave insight into nearly all concepts in the socio-technical system constructed mutually through AR cycles - primarily the "How" element: how did such a system operate when functioning? Thus, it addressed core theoretical concepts. In answer to Dablanc or Mununzuri's despondent outlook (Dablanc, 2007; Munuzuri *et al.*, 2012) that urban logistics was and would remain "Difficult to organize, difficult to modernize", the pilot showed that it was possible to organise a modern, clean and service-led solution, from a receiver-led approach built from the conceptual interest in Urban freight and procurement activity (Zunder, Aditjandra and Carnaby, 2014) centred on Higher education institutions (HEI) and freight (Zunder, Aditjandra and Carnaby, 2012; Mcleod et al., 2015). The pilot confirmed the viability of the use of electric vehicles (EVs) in freight, in parallel with two other Smartfusion projects in Como (Leonardi et al., 2014) and Berlin (Zunder et al., 2016) and the sister project of FREILOT (Gonzalez-Feliu et al., 2013). This was a continuation of the large body of work on urban consolidation centres (Schuster, 1978), with a recognition of need for viable business models - in this case developed by a mix of DMF and BMC - in parallel with, but differently to, the ULBMC developed by TURBLOG (Macário, Rodrigues and Gama, 2011) and deployed in such projects as STRAIGHTSOL, NOVELOG and U-TURN (Posthumus *et al.*, 2014; Rodrigues *et al.*, 2018).

9.8.2. Reflection on Process

Core

Customer relationships were managed during the pilot, with examples given of how the proposed scheme revealed problems in the Electrical Engineering department and generated buy-in from the Medical school.

Suppliers were converted to the scheme in far lower numbers than planned; rather than 5 per week in the first year, the diary reports conversions closer to 5-8 *per month* and in the second year *no conversions at all.* This was probably due to purchasing conservatism, as detailed in section 9.5.1 above and reflected upon further in 0 below. By pilot end, the average number of parcels per day was much lower than the target (see Table 104 and Figure 82 above)envisaged at the pilot design stage. Whilst the linear trend-line was often interpreted as showing a potential growth, it is clear from the data and the stop in supplier recruitment that the pilot had achieved a steady state, albeit one more to do with purchasing activity than any organic limits. The operational data gained, and a new traffic survey carried out in May 2015, have been used to inform the evaluation process in Chapter 8.

Thesis

In the development of the pilot, it would have been possible to develop gravity models to locate the drop zones most optimally located to the customers, but in practice the layout and infrastructure of the campus appeared more dominant.

The use of marginal space, or ‘elastic walls’, was key to the pilot and probably to the CCCC concept. The flexibility of a commercial logistics organisation to ‘flex’ and accommodate a small pilot inside a larger organisation has a lot of value for start-up and research-led pilots in this field of <u>urban consolidation centres.</u>

In the drop-in sessions (see 9.4.1 above), which were very helpful in identifying obstacles and opportunities - such as the difficulty with very fast deliveries to Electrical Engineering as well as an unexpected welcome in the Medical Faculty - we also needed to acknowledge that one group of customers – students - was being represented by proxy. Earlier research at the University of Southampton had directly addressed analysing student demand (Cherrett *et al.*, 2017) and opportunities to involve this group in future participatory work should be explored. The pilot continued to show the relevance of <u>engagement with Action Research in purchasing and supply chain management</u> (Meehan, Touboulic and Walker, 2016) as the teams, networks and relationships moved into operation; in doing so they also continued to address the issues of <u>poor ex-ante and ex-post data collection</u> (Leonardi, Browne and Allen, 2012). However, this could not account for the conservatism of the process - itself an input to thoughts about <u>barriers to sustainable procurement</u> (Chicksand *et al.*, 2012; Walker and Brammer, 2012).

9.8.3. Reflection on Premise

Core

Financially, no progress was made in gaining supplier discounts and, although the pilot was funded by the University for its second year, the scheme was paused when the opportunity to centralise purchasing into a new Hub was planned. The premise that a CCCC could be financially sustainable was not supported, or denied, by the pilot.

Out of 35 suppliers converted, only 18 made deliveries. Compared to the original suggestion of 251 suppliers and the revised target of 1027 annual deliveries this was a very low level of performance. The slow conversion and low-level of deliveries led to questioning, in 0 below, the premise of the evaluative choices and the deployment of an additional quantitative quasi-experimental model.

Thesis

Private purchasing behaviour had been surveyed, but was not included in the pilot planning, and remained a proxy demand.

Whilst I had adopted a key recognition of need for viable business models, it was not possible to reach coherent costings for the BMC, for the reasons elaborated in section 8.9.8 above. Also, whilst a business plan was developed for the University, it had not yet been put into operation at time of writing, rendering unproven the premise that it was possible to be financially viable.

Chapter 10. Outcomes

The objectives of this chapter are twofold: first to evaluate the outcomes of the work, using quantitative evaluation of the collected observational and operational data; and secondly to provide a qualitative evaluation of outcomes that are related to policy, practice, and the creation and delivery of improved logistics sustainability, as part of the Coherent Campus policy of the University. The chapter addresses the performance indicators developed in the DMF and also looks to answer the hypotheses raised in the CANVAS business model. Use is made of a model to predict future outcomes of different deployments of a future CCCC.

As Markiewicz and Patrick noted: "The evaluation literature contains many excellent guides to thinking about the nature of evaluation and provides strong complementary advice on the methods and techniques that are used in practice. An area of less attention… relates to the planning that is required to provide evaluation with an appropriate focus and guide its conduct" (Markiewicz and Patrick, 2016, p. xii).

Poor ex-ante and ex-post data collection had been a noted failure of urban freight research, innovation and intervention since the 1970s. This was most notable in the case of urban consolidation centres (Marinov, Islam and Zunder, 2010). Browne et. al. (2005) drew attention to this and proposed structured ex-ante and ex-post data collection, with a defined model for new evaluation frameworks.

I began this work with a clear intent to enable ex-post evaluation based on data collected before, during, and after any interventions. The remit set in the four research questions was broader and more holistic than the operational model proposed by Browne et. al. and as such my approach was methodological pluralism - mixing quantitative and qualitative research methods in an integrated fashion. Given my personal experience as a line and project manager, I also viewed the planning of multiple approaches to the design, monitoring and evaluation of the work as both enabling redundancy and supporting the aim of developmental complementarity, as the quantitative informed the qualitative work and the qualitative work developed plans and hypotheses to test against further quantitative data.

The approach allowed for a complementary elaboration and clarification of results from one method to another, to enable Triangulation for achieving convergence, corroboration, and correspondence of results from the different methods, in order to increase the validity of constructs and inquiry results (Greene, Caracelli and Graham, 1989, p. 259).

The work was intended to support purposeful intervention (allowing purposes to change and develop during an intervention) rather than purposive intervention (where purposes are fixed) (M Reynolds and Holwell, 2010). On this basis, the monitoring and evaluation had to not just allow but to support adaptation, as the action in the research engaged with the praxis of the intervention.

Both "... monitoring and evaluation functions have vital and complementary roles to play. Monitoring relates to the ongoing checking of progress, while evaluation involves deeper, periodic assessment of results" (Markiewicz and Patrick, 2016, p. xii). In most respects, this thesis has developed the core design and monitoring process in Chapter 3, where the adoption of the DMF and also the BMC was detailed, with baseline empirical data recorded in Chapter 6 above, the process of designing the DMF and BMC in Chapters 7 and 8, and operational data evidenced in Chapter 9. The operational data recorded in Chapter 9 were supplemented by the Action Research Cycle itself, allowing the procession of review, reflection and planning at each iterative cycle, in turn allowing for step by step monitoring.

The structure of this Chapter 10: Outcomes, evidences the exploration of evaluation against the performance target indicators of the DMF (both qualitative and quantitative, as detailed in Chapter 7 above), and the hypotheses/questions raised in the development of the BMC (see Chapter 8 above). From these evaluations the degree to which the research questions RQ1, RQ2, RQ3 and RQ4 are answered will be assessed in 0 below.

10.1. Process of evaluation

In order to process the evaluation issues raised by the DMF (indicators/targets), and the BMC (questions), this chapter documents the planned requirements from each approach, including how they were separated by type and method, and then combined where possible. The different evaluations completed to meet this combined evaluation list are then documented, before each individual approach is drawn out and answered individually. Reflection on the relative utility and practice of the differing approaches is made in 0 below.

Evaluations can take place formatively, summatively or both. An evaluation is considered formative when it adopts a focus on programme[34] processes and implementation, with the aim of improving programme design and future performance. In contrast, summative evaluations are particularly concerned with making judgements about a programme's overall performance and thus are more focused on the identification of programme results, usually at the end of a programme's life (Markiewicz and Patrick, 2016, p. 13). The review of the evaluation suggested that the DMF was primarily a summative evaluation, with the BMC more formative, being interested in a business model as a process rather than its absolute outcomes. The AR cycle included elements of both, and as such all forms of evaluation would be deployed, but with a difference in emphasis between the two key approaches: summative for DMF and formative for BMC.

10.2. DMF Derived evaluation performance indicators/targets

The DMF developed in Chapter 7 above, and presented as Table 86, was the first approach for the evaluation work reported in Chapter 10 and a shortened version is shown here in revised form as Table 106. I reduced the table to the Impact and subsidiary Outcomes, and then Outputs - often in shorter form, and then mapped the indicators/targets with the data sources and reporting mechanisms. I evaluated the type of evaluation and method likely to be appropriate and then added my qualitative evaluation of the current utility of the approach, some five years on, as a four-point scale denoted --/-/+/++.

[34] *It was appropriate to equate programme with project in our discussion of this evaluation process.*

Design summary (short version)	**Performance indicators/targets**	**Data sources/reporting mechanisms**	**Evaluation type and method**	**Utility post project**
Improved urban freight at Newcastle University (Impact)	A: Increased stakeholder satisfaction by University Executive Board by a reduction of freight vehicles on campus by 25% by end 2019.	Traffic surveys Interviews and reviews with University Exec Board.	Quantitative empirical observation. Qualitative evaluation.	++
Comprehensive University campus strategy embedding a delivery and servicing plan strategy – Delivery Strategy (Outcome)	C: One detailed policy action of new purchasing strategy implemented as pilot by 2014, one implemented as a working service by 2019.	Official publications of procurement team of the Campus	Qualitative evaluation.	++
Procurement of electric vehicles as part of the University fleet (Outcome)	D: One new EV added to University own fleet by end of 2015	Official publications of campus procurement team	Quantitative evaluation	++
The take up of external/internal consolidation centre ... via procurement contract – decongesting the Campus (Outcome)	E: Increased number of CCCC deliveries, 60% via CCCC versus direct deliveries & absolute target of 80 parcels a day, of those goods or suppliers suitable for the pilot by end 2015	Consolidation Centre productivity and vehicle use data	Quantitative empirical observation	++

Design summary (short version)	**Performance indicators/targets**	**Data sources/reporting mechanisms**	**Evaluation type and method**	**Utility post project**
	F: Decreased total freight transportation costs (-5% cost/day) expressed as the cost of the transport operation, and as the purchase cost by 2019	No clarity on source!	Quantitative but flawed	--
The uptake of clean vehicles to demonstrate the commercial viability and environmental benefits of (hybrid-) electric freight vehicles (Outputs)	G: Increased number of EVs on campus, one by end 2015.	Project outputs	Quantitative, but unclear on sources	-
	H: Decrease of emissions levels (CO_2, PM_x, NO_x) -25% of CO_2e by 2019.	H: Estimates on emissions based on fleet activity reports and factors for vehicles H: Fleet activity reports	H: Quantitative modelling from data analysis	++
Correctly parked freight vehicles via dedicated IT-solutions for planning and driver support with access maps for deliveries (Outputs)	I: Decreased number of illegally parked vehicles on campus, noticeable reduction by walking the campus.	Questionnaire among campus users. University staff measuring strategy violations.	Qualitative survey with potential quantitative analysis	--
Co-ordinated freight deliveries including … an urban consolidation centre and the effects of the procurement policy (Outputs)	J: Recruitment of 20 suppliers to a pilot trial by end 2015. Negotiation of a contract with a provider of the centre by end 2013.	CCCC performance data. Fleet activity reports.	Quantitative analysis of data records	++

Table 106: Newcastle DMF targets and indicators in short form for potential evaluation

When the stakeholders and I collaboratively designed a monitoring and evaluation framework, it was in line with the aims of SMART and CREAM, as defined in section 7.8.2. The utility of each of each target/indicator at project end does not suggest poor design at the opening of the process, but rather that the work changed as it progressed, as the iteration of the AR cycles allowed purposeful adaptation. Even the Asian Development Bank, with a results based management approach (RBM) such as logical framework, recognised this in an almost subjectivist phrase: “Indicators may change over time and, although the methodology might be the same, the indicator is really not the same” (ADB, 2007). Therefore, the evaluation of utility is the extent to which the indicator remained specific, achievable, relevant and time bound (SMART) and/or clear, relevant, economic, adequate, and monitorable (CREAM). However, as ADB noted, all such indicators must be practical.

10.2.1. Problematic DMF Indicators

Item “F: Decreased total freight transportation costs” could now be seen as flawed, in that there was a lack of clarity in the DMF as to the source of the data. In addition, as the total cost of transportation was not separated out from the price of goods in the contracts let by the University, it had ceased to be achievable.

Another item “I: Decreased number of illegally parked vehicles on campus” was to have used a robust pair of indicators: “Questionnaire among campus users” and “University staff measuring strategy violations”, but this was for an initiative that did not proceed and forms no part of this research, so must be viewed as not relevant.

The final problematic indicator “G: Increased number of EVs on campus, one by end 2015” was too broad. It was possible to measure the number of University owned EV vehicles on campus, and that was done; however, the indicator was not limited to University owned vehicles and was therefore not as clear as it should have been.

Note that source “Official publications of campus procurement team” was shared between two indicators: C and D - respectively qualitative and quantitative.

10.2.2. Quantitative DMF Indicators

The DMF called for quantitative evaluation for several key indicators - some fairly simple, such as “D: One new EV added to University own fleet by end of 2015” which was to be captured from “C: Official publications of campus procurement team”. Others would require more complex data collection and analysis.

The impact “A: Increased stakeholder satisfaction by University Executive Board by a reduction of freight vehicles on campus by 25% by end 2019” required further traffic surveys; section 10.7 is made up of further analysis of a 2015 traffic survey versus the 2012 baseline.

The indicator “E: Increased number of CCCC deliveries, 60% via CCCC versus direct deliveries, & absolute target of 80 parcels a day of those goods or suppliers suitable for the pilot by end 2015” called for analysis of the CCCC operational data. The indicator “J: Recruitment of 20 suppliers to a pilot trial by end 2015” called for analysis of “CCCC performance data”. In both cases the relevant data from Chapter 9 above have been used.

Neither noise nor safety had been raised in the DMF process as indicators for evaluation.

10.2.3. Qualitative DMF Indicators

The key qualitative evaluations included the main impact: “A: Increased stakeholder satisfaction by University Executive Board by a reduction of freight vehicles on campus by 25% by end 2019”, which was to be partially assessed using “Interviews and reviews with University Exec Board”. In practice, this became meetings with senior management and then the setting of University policy. As such, the satisfaction and direction of the Board was expressed by individual board members, not the Board as a whole.

Indicator “K: Negotiation of a contract with a provider of the centre by end 2013” was to be assessed both quantitatively and qualitatively and the source in the original DMF was “project outputs” with a simple yes/no check. Whether this is qualitative, or a simple Boolean quantitative check, is moot.

10.3. BMC Derived evaluation performance indicators/targets

The BMC developed in Chapter 8 above was the second approach which required evaluation and a shortened version is shown here below as Table 107, with the questions now in the past tense and mapped with the data sources and reporting mechanisms. I added any new sources of variant evaluation types and methods, as required, and evaluated the type of evaluation and method likely to be appropriate using the same four-point scale of utility denoted --/-/+/++.

BMC elements	Question	Data sources/reporting mechanisms	Evaluation type and method	Utility post project
1: K: Customer Segments	Did we identify the correct customer segments?	Internal Stakeholder workshops.	Qualitative	++
2: L: Customer Relationships	Did we meet customer expectations?	Internal Stakeholder workshops.	Qualitative	++
3: M: Channels	Was an Electric Vehicle suitable?	Consolidation Centre (CCCC) performance data.	Quantitative	++
4: N: Revenue Streams	Did the university put enough monetary value on benefits?	Interviews and reviews with University Exec Board.	Qualitative	++
	Did suppliers put enough monetary value on benefits?	Negotiated discounts.	Qualitative or Quantitative	++
5: O: Key Partners	Did all Stakeholders commit to the project?	Internal Stakeholder workshops. University policy Project outputs.	Qualitative	++
6: P: Key Activities	Did the Key Partners have the resources to make these happen?	CCCC performance data. Fleet activity reports.	Quantitative	++

BMC elements	Question	Data sources/reporting mechanisms	Evaluation type and method	Utility post project
7: Q: Key Resources	Did the Stakeholders committed to the project provide these [key resources]?	Internal Stakeholder workshops. University policy project outputs. CCCC performance data. Fleet activity reports.	Qualitative and Quantitative	++
8: R: Cost Structure	Were the costs reasonable?	Interviews and reviews with University Exec Board. University policy.	Qualitative	++
9: S: Value Propositions	Were the customers interested in the outcomes we wanted to achieve?	Interviews and reviews with University Exec Board. Internal Stakeholder workshops. University policy.	Qualitative	++

Table 107: Newcastle BMC questions in short form for evaluation

10.3.1. Problematic BMC questions

The key questions raised by the BMC that were problematic in evaluation were those associated with revenue streams and cost structures, as these were obscured by a mix of commercial considerations, as explained in section 8.5.3. However, some answers could be gleaned qualitatively from actions and policy by University and suppliers.

The BMC probably did not place enough emphasis on monitoring how successfully purchasing policy extracted any discount from suppliers; I supplemented this as part of my regular discussions with the Purchasing Manager, subsumed in "University policy".

Almost all data sources had high ++ utility for the evaluation process, as explained in section 10.1, but the utility of sources for the BMC was higher than the DMF.

Neither noise nor safety were raised as questions for evaluation in the BMC process.

10.3.2. *Qualitative or Quantitative BMC evaluation*

As can be seen in Table 107 above, most evaluation of the BMC was to be qualitative; that which was quantitative was shared with the DMF: i.e. "CCCC performance data and "Fleet activity reports" used effectively the same source. Almost all data sources had high ++ utility for the evaluation process, as explained in section 10.1, but the utility of sources for the BMC was higher than the DMF.

10.4. Combined Evaluation Approach

Given the shared data sources, a combined approach was valid and was adopted. The summative DMF approach, and the formative BMC evaluation, are therefore summarised at Chapter end. The following key blocks of work were completed to derive the evaluation:

- Purchasing review, time series 2010 to 2015.
- Traffic survey review, 2012 versus 2015.
- Quantitative quasi-experimental impact model.
- Combined Qualitative and Quantitative assessment.

Noise and safety were not included in the evaluation, since neither had featured in the mutually defined indicators of either the DMF or the BMC.

10.5. Purchasing review, time series 2010 to 2015.

I was interested in how the University was supplied with goods and services, at least those that generated a delivery or a visit. Of note in the DMF and BMC evaluation sources or methods was the absence of an indicator/target, question, or source that related to how purchasing had changed. Purchasing policy as a subset of University policy was implied but, as the work had progressed from using procurement data to set the initial context, it would have been neglectful not to explore how that contextual demand had changed through the period.

The procedures extant during this research were originally those dated 2010 (Addison, 2010), which then transitioned during the period of change in 2011 into the April 2012 version (Addison, 2015), and then a newer January 2015 version (Addison, 2015). The new 2015 version, applicable during the pilot, made changes from 2012 in value limits for tendering, but also made one important difference, to limit orders, that may have affected this research.

Use of Limit Orders

- *Limit Orders may not be used for purchasing goods or for items available through the P2P-Marketplace. They may only be raised in the following circumstances:*
    - *The order is for works or services and the price cannot be accurately ascertained at the time of placing the purchase order*
    - *The purchase order is for regular repeat orders with variable invoice values, but which can be budgeted for a time period. e.g. photocopier charges, gas rentals, taxis, glaziers, locksmiths.*
    - *Individual orders where the final cost is unknown. e.g. capital works, equipment maintenance/repairs with unknown final labour/parts cost.* (Addison, 2015)

This was part of the concerted policy to reduce the use of limit orders, and direct purchasing, through documented and well-structured processes with associated good data in the P2P Marketplace. As before, it is probable that procedures were followed differently by different buyers in different units during the transition. This was confirmed by various ad hoc interviews with purchasing staff, buyers, and users, as well as in the preliminary work for the processes outlined in Chapter 6 above. The potential 8 power buyers noted in section 6.2.1 were very small in number, but ordered 23% of goods by purchase order. However, the pareto split of the buyers was stable through this period. In FP 2010, 80% of all purchase orders were raised by 112 (23%) of the active buyers on the system. In FP 2015, 80% of purchase orders were raised by 100 (20%) of active buyers, as shown above in *Table 19*.

10.5.1. Analysis of Purchasing Data

In this evaluation there were procurement data available from each year (denoted as FP2011, FP2012 and so on), from financial periods FP2011 to FP2015 current. I therefore expanded the evaluation from Chapter 6 above, to evaluate any changing trends.

Overall purchasing expenditure splits changed over this period, as follows in Table 108. These expenditure splits are summarised, but absolute numbers are not included, for commercial confidentiality.

University financial year (Aug-Jul)	PO P2P (route B)	WIC (routes A & D)	Purchase-card (route C)	Expenses (route E)
2011-2012 Purchasing Analysis	70.60%	23.58%	2.35%	3.46%
2012-2013 Purchasing Analysis	72.85%	21.96%	2.47%	2.72%
2013-2014 Purchasing Analysis	78.73%	15.53%	3.00%	2.74%
2014-2015 Purchasing Analysis	80.94%	13.20%	3.11%	2.75%
2015-2016 Purchasing Analysis	82.37%	11.95%	2.97%	2.70%

Table 108: Purchasing expenditure analysis 2011-2016 , Source internal reports (Newcastle University, 2016b)

This table shows the results of the policy, embedded in the SAP R3 P2P implementation, to drive as much of purchasing as possible through formal procedures. The 'posthumous' orders (WIC) can be seen to fall from 23.58%, to 11.95% transferred to the Purchase Order system. Some of the original procurement data from FP2010 and FP2011 had been problematic. I proceeded to analyse the data as a time series, to gain insight into how this policy of formalising procedure had improved data quality and changed the demand expressed by FP2015.

10.6. Analysis of Purchasing Data

Using the University SAP Business Warehouse management reporting systems, the same data as in Chapter 6 above were collated for fiscal periods 2010-2015 and various reports prepared. As before, this did not necessarily reflect the entire population of demand placed on suppliers, as the University allowed variant routes that generated poor data, as illustrated in Figure 24 in section 6.2.1.

Normality tests of the distribution of line-items and lead-times as a whole, and also within each fiscal period using K-S tests, showed that that the data were non-parametric. As in Chapter 6 above, a decision was made to use non-parametric testing.

10.6.1. Differences in purchasing between weekends & weekdays

As with previous analysis, the questions "Do valid purchase line-items for goods that generate freight vehicle deliveries vary from weekends to weekdays?" and "If so, was it valid to remove the weekends from the dataset?" needed to be answered. With this new dataset, I again used a Mann Whitney U test for the total. The null hypothesis was rejected and there was a significant difference between weekends and weekdays. Given the clear disparity between the two, and the fact that there were traffic survey data for weekdays only, further analysis proceeded excluding weekends, save when measuring lead-times in section 10.6.5.

10.6.2. Differences in purchasing volume between weekdays

The next question to be addressed was whether weekdays were different to each other. If they were not, then analysis could proceed at an aggregated level, but analysis of median suggested a difference, see Figure 84, and this might have been helpful in model building.

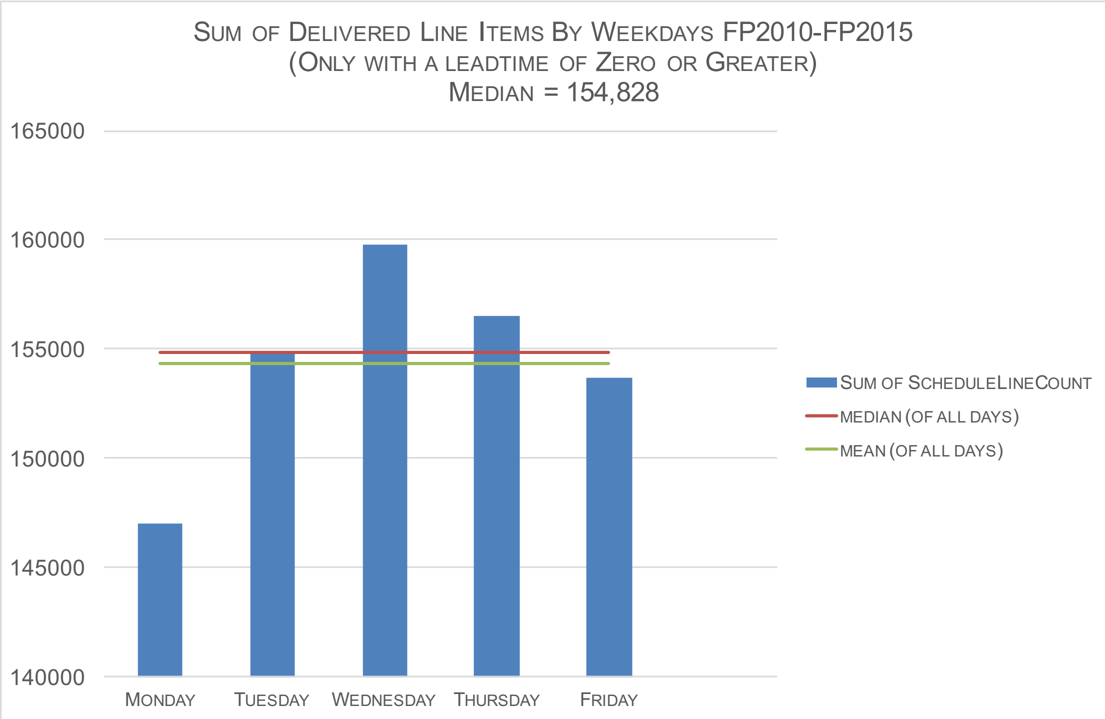

Figure 84: Delivered Line Items, fiscal periods FP2010-FP2015

My chosen Kruskal-Wallis H test showed that the variance between days was significant; I adopted the same methods used in Chapter 6 above to examine this further.

The results, shown in Table 35, showed heterogeneity between Tuesday and Friday and all other days and each other, across all days, with similarity between Monday, Tuesday and Wednesday. This was noted and was a change from the analysis in Chapter 6 above, where Monday/Friday had shown greater homogeneity.

FP2010-FP2015 Line items pairwise test for variance					
p values	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
Monday		0.001	0.074	0.200	0.001
Tuesday	0.001		0.004	0.001	0.001
Wednesday	0.074	0.004		0.616	0.001
Thursday	0.200	0.001	0.616		0.001
Friday	0.001	0.001	0.001	0.001	
Mann Whitney pairwise, alpha = 0.005, <0.001 rounded as 0.001					
Shaded green are significant and therefore vary pairwise					
Shaded amber are significant with normal alpha of 0.05					

Table 109: Weekdays pairwise Mann Whitney variance testing Delivered line items per purchase order per material group (lead-time >=zero) weekdays only

However, this heterogeneity did not help explain the pattern of medians in Figure 84 above, nor vice versa. Whilst a model may use a daily pattern based on the medians, this pairwise analysis suggested only difference - that may lie in patterns not understandable at this level.

10.6.3. Differences in purchasing volume between fiscal periods

In this longer term analysis, significant changes in the balance of demand, expressed through formal controlled processes, had been observed - see Table 108 and Table 118. The possibility that any model should be built only on later observations was tested. The results, detailed in Table 110 below, confirmed significant differences between the early, middle and last fiscal periods.

In terms of number of line-items per purchase order, by material group, for delivered goods with lead-time of zero or greater, FP2010 and FP2011 were different to all other periods and each other; there was homogeneity in FP2012, FP2013, and FP2014; and FP2015 was also significantly different to every other year. In many ways, this fitted the pattern emergent in Table 108 and suggested that a model might be best based on the final period, or definitely not the final two.

FP2010-FP2015 Line items pairwise test for variance						
p values	**FP2010**	**FP2011**	**FP2012**	**FP2013**	**FP2014**	**FP2015**
FP2010		0.001	0.001	0.001	0.001	0.001
FP2011	0.001		0.001	0.001	0.001	0.001
FP2012	0.001	0.001		0.594	0.924	0.001
FP2013	0.001	0.001	0.594		0.530	0.001
FP2014	0.001	0.001	0.924	0.530		0.001
FP2015	0.001	0.001	0.001	0.001	0.001	
Mann Whitney pairwise, alpha = 0.003, <0.001 rounded as 0.001						
Shaded green are significant and therefore vary pairwise						

Table 110: Delivered line items per purchase order per material group (lead-time >=zero) weekdays only, FP2010-FP2015

10.6.4. Difference in purchasing volume by months

In order to extrapolate in a model from a limited time period, say a single week traffic survey, or a pilot lasting some months, it was useful to understand how the University's purchasing volume varied by month through a typical year and, following the analysis in section 10.6.3, how this had varied between historical fiscal periods.

A Kolmogorov-Smirnov test for normality confirmed that the data were not distributed normally and a simple column bar chart of the filtered dataset, see Figure 32, suggested once again that purchasing demand dropped in volume at Christmas and New Year (December), Easter (April), and summer vacation (August).

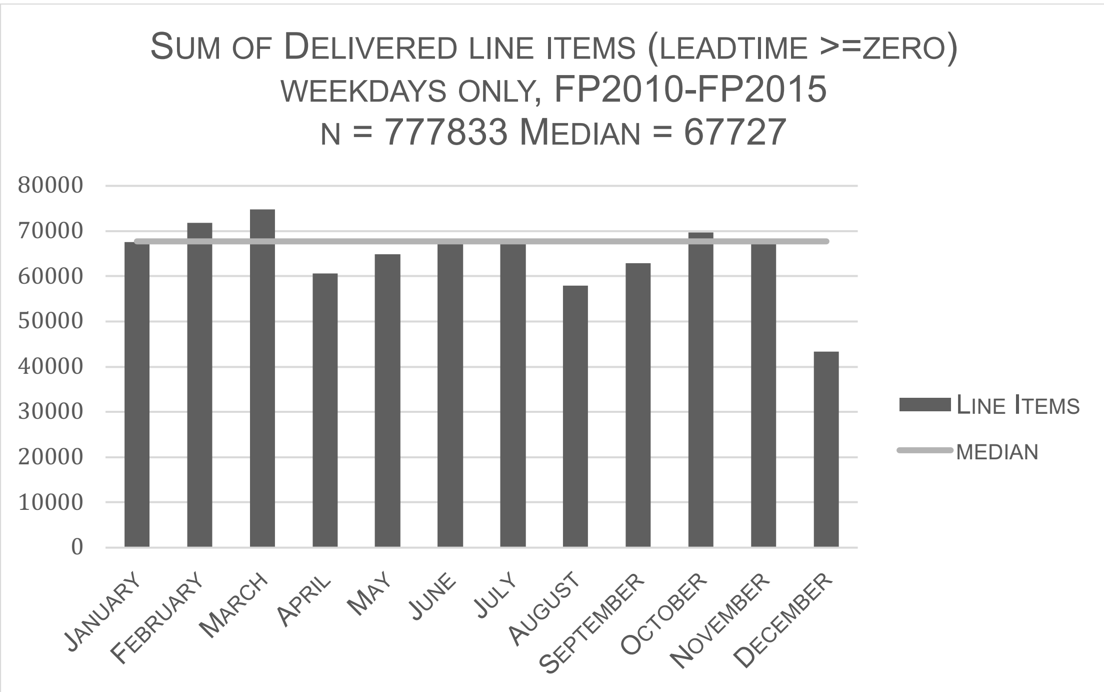

Figure 85: Sum of Delivered line-items (lead-time >=zero) weekdays only, FP2010-FP2015

Kruskal-Wallis H tests showed that with p values of 0.001-0.003 there were significant differences between the months, both as an aggregated FP2010-FP2015 dataset and also each year individually. A 12 x 12 matrix was constructed, pairwise mapping months against each other and testing variance one from the other. As with the tests in Chapter 6 above, the loss of statistical power from a Bonferroni correction was too great and I accordingly adopted a revised, less conservative alpha of 0.001 (Elwood, 2007, p. 211; Armstrong, 2014).

The most heterogeneous months for delivery were December, January, and February, as one might have intuitively expected, but which was not evidenced in Figure 32. July was the next most heterogeneous.

The key phases of a University year at Newcastle were the start of term-time activities in September and October, the Easter vacation, the Winter vacation in December, and the summer vacation - roughly covering July and August. In addition, the tax year started in April, but the University financial year started in August. One might have expected to see a rise in orders prior to the start of term, perhaps a fall in July/August, and a dip in December. Mapping the line-item median in Figure 85 did indeed show a dip in August and December; however, it also showed a substantial rise in line-items in July - a vacation month. This may have been due to the financial nature of the data, with invoices being 'cleared up' before the end of the University year, but not reflecting the actual level of delivery activity. A similar rise in March, relative to a slump in April, might have reflected the effect of the Easter vacation, but it might also have reflected an annual 'clearing' of unrecorded invoices as POs, before the end of the tax year.

p values	Jan	Feb	Mar	Apr	May	Jun
Jan		0.137	0.001	0.001	0.001	0.001
Feb	0.137		0.002	0.003	0.053	0.008
Mar	0.001	0.002		0.976	0.204	0.633
Apr	0.001	0.003	0.976		0.240	0.672
May	0.001	0.053	0.204	0.240		0.453
Jun	0.001	0.008	0.633	0.672	0.453	
Jul	0.001	0.001	0.524	0.514	0.056	0.261
Aug	0.004	0.144	0.096	0.118	0.666	0.248
Sep	0.001	0.068	0.209	0.236	0.956	0.432
Oct	0.346	0.564	0.001	0.001	0.010	0.001
Nov	0.124	0.977	0.002	0.003	0.054	0.008
Dec	0.001	0.009	0.836	0.864	0.372	0.822

p values	Jul	Aug	Sep	Oct	Nov	Dec
Jan	0.001	0.004	0.001	0.346	0.124	0.001
Feb	0.001	0.144	0.068	0.564	0.977	0.009
Mar	0.524	0.096	0.209	0.001	0.002	0.836
Apr	0.514	0.118	0.236	0.001	0.003	0.864
May	0.056	0.666	0.956	0.010	0.054	0.372
Jun	0.261	0.248	0.432	0.001	0.008	0.822
Jul		0.021	0.053	0.001	0.001	0.431
Aug	0.021		0.708	0.039	0.149	0.206
Sep	0.053	0.708		0.014	0.068	0.349
Oct	0.001	0.039	0.014		0.541	0.001
Nov	0.001	0.149	0.068	0.541		0.009
Dec	0.431	0.206	0.349	0.001	0.009	
Mann Whitney pairwise, alpha = 0.001, <0.001 rounded as 0.001						
Shaded green are significant and therefore vary pairwise						
Shaded amber are significant with normal alpha of 0.05						

Table 111: Monthly pairwise Mann Whitney variance testing Delivered line items per purchase order per material group (lead-time >=zero) weekdays only, FP2010-FP2015

However, this was the testing of the variability of line-items, per material group, per PO and may have shown that ordering patterns varied within that distribution in ways shown by the Mann Whitney pairwise analysis, but may not have reflected the total volumes in aggregate by month. To that end it was helpful in identifying that significant heterogeneity existed, but for model building a simpler aggregate volume of line-items per month, as shown in Figure 86, would have been more preferable.

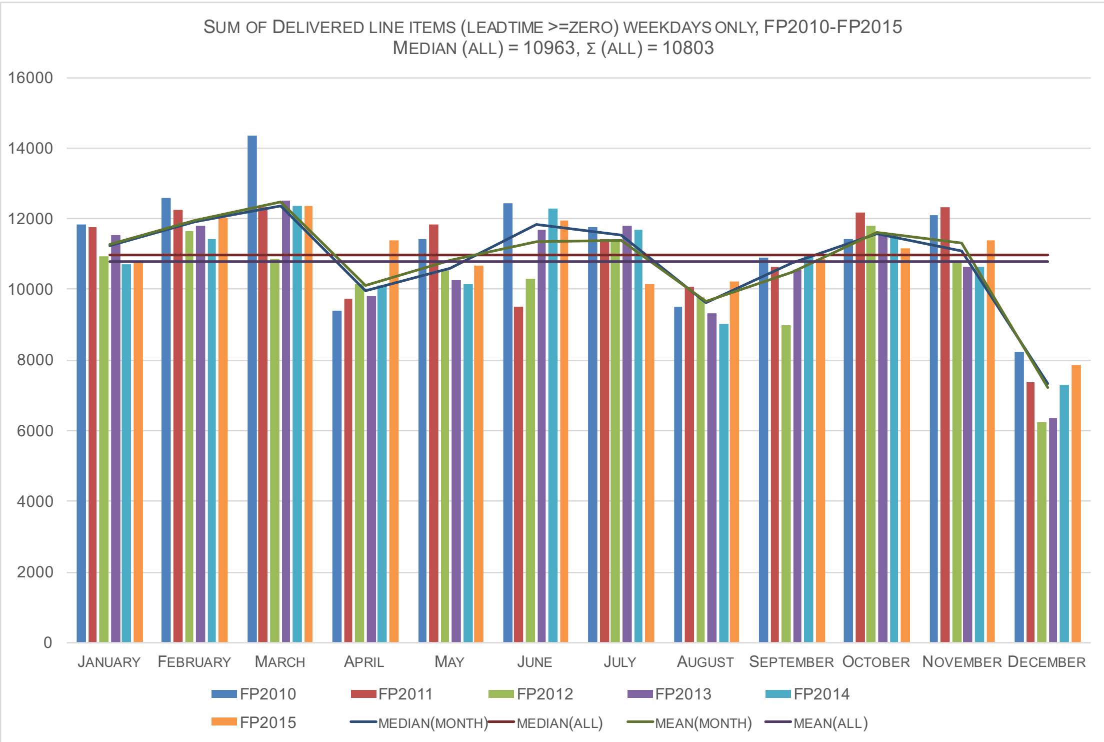

Figure 86: Sum of Delivered line items (lead-time >=zero) weekdays only, FP2010-FP2015

10.6.5. Lead-time for delivery

A key question had been the lead-time expressed to suppliers, to evaluate whether this stimulated a just-in-time response. I had noted a high degree of heterogeneity between orders required for Monday and Friday from all other days and each other, with some homogeneity between Tuesday-Wednesday and Wednesday-Thursday, and that this was probably Friday ordering for Monday delivery. I had found that the University did exhibit a very short lead-time, with a modal average of zero lead-time (38.6% of filtered samples) and a final estimate of a range of 0-4 days, with a median of 3.

With the full FP2010-FP2015 dataset, appropriately filtered, the same tests were now carried out. Further K-S and S-W tests using SPSS showed non-normality, by days of week or by fiscal period, or by days of week in fiscal period, as detailed in Table 112 and Table 113.

FP	DaysOfWeek		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
			Statistic	df	Sig.	Statistic	df	Sig.
FP2010	Lead-time	Monday	.430	3802	.000	.132	3802	.000
		Tuesday	.385	4118	.000	.304	4118	.000
		Wednesday	.395	4028	.000	.272	4028	.000
		Thursday	.391	3973	.000	.290	3973	.000
		Friday	.393	3884	.000	.277	3884	.000
FP2011	Lead-time	Monday	.396	5061	.000			
		Tuesday	.421	5132	.000			
		Wednesday	.408	5663	.000			
		Thursday	.418	5155	.000			
		Friday	.401	5648	.000			
FP2012	Lead-time	Monday	.382	4632	.000	.214	4632	.000
		Tuesday	.415	4559	.000	.150	4559	.000
		Wednesday	.433	5212	.000			
		Thursday	.432	5107	.000			
		Friday	.434	5137	.000			

Table 112: Lead-time normality by fiscal period and required day of week FP2010-FP2012

FP	DaysOfWeek		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
			Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
FP2013	Lead-time	Monday	.490	4831	.000	.007	4831	.000
		Tuesday	.416	4446	.000	.174	4446	.000
		Wednesday	.433	5089	.000			
		Thursday	.423	5130	.000			
		Friday	.492	5588	.000			
FP2014	Lead-time	Monday	.416	4738	.000	.135	4738	.000
		Tuesday	.439	4553	.000	.102	4553	.000
		Wednesday	.402	5080	.000			
		Thursday	.482	5051	.000			
		Friday	.402	5555	.000			
FP2015	Lead-time	Monday	.385	5527	.000			
		Tuesday	.413	4845	.000	.141	4845	.000
		Wednesday	.391	5351	.000			
		Thursday	.382	5544	.000			
		Friday	.383	6505	.000			

Table 113: Lead-time normality by fiscal period and required day of week FP2013-FP2015

10.6.6. *Median lead-times for binning*

As the data were non-parametric, the Inter Quartile Range was most appropriate for evaluating appropriate 'bins' for data analysis and reporting. Analysis of the data, in Table 114, showed Monday as different to the rest of the week, with a median of one consistent with the goods or services being ordered the Friday prior.

Quartiles		**DaysOfWeek**			
			25	50	75
Weighted Average (Definition 1)	Lead-time	Monday	.00	3.00	4.00
		Tuesday	.00	1.00	4.00
		Wednesday	.00	1.00	2.00
		Thursday	.00	1.00	2.00
		Friday	.00	1.00	3.00

Table 114: IQR for lead-time, required days of the week (SPSS)

The analysis by fiscal period, in Table 115 below, showed a shift in the median for FP2015 - perhaps suggesting a change in that period.

Quartiles		**FPYear_numeric**			
			25	50	75
Weighted Average (Definition 1)	Lead-time	FP2010	.00	1.00	5.00
		FP2011	.00	1.00	3.00
		FP2012	.00	1.00	3.00
		FP2013	.00	1.00	3.00
		FP2014	.00	1.00	3.00
		FP2015	1.00	2.00	5.00

Table 115: IQR for lead-time, by fiscal period (SPSS)

This possible change in FP2015 was further evidenced in analysing lead-time by required day of the week within each fiscal period, as shown in Table 116.

FP Year	DaysOfWeek			Quartiles		
				25	50	75
FP2010	Weighted Average (Definition 1)	Lead-time	Monday	.00	3.00	5.00
			Tuesday	.00	1.00	6.00
			Wednesday	.00	1.00	2.00
			Thursday	.00	1.00	2.00
			Friday	.00	1.00	3.00
FP2011	Weighted Average (Definition 1)	Lead-time	Monday	.00	3.00	4.00
			Tuesday	.00	1.00	4.00
			Wednesday	.00	1.00	2.00
			Thursday	.00	1.00	2.00
			Friday	.00	1.00	3.00
FP2012	Weighted Average (Definition 1)	Lead-time	Monday	.00	3.00	4.00
			Tuesday	.00	1.00	4.00
			Wednesday	.00	1.00	2.00
			Thursday	.00	1.00	2.00
			Friday	.00	1.00	2.00
FP2013	Weighted Average (Definition 1)	Lead-time	Monday	.00	3.00	4.00
			Tuesday	.00	1.00	1.00
			Wednesday	.00	1.00	2.00
			Thursday	.00	1.00	2.00
			Friday	.00	1.00	3.00
FP2014	Weighted Average (Definition 1)	Lead-time	Monday	.00	3.00	4.00
			Tuesday	.00	1.00	1.00
			Wednesday	.00	1.00	2.00
			Thursday	.00	1.00	2.00
			Friday	.00	1.00	3.00
FP2015	Weighted Average (Definition 1)	Lead-time	Monday	3.00	4.00	6.00
			Tuesday	1.00	1.00	5.00
			Wednesday	1.00	1.00	5.00
			Thursday	1.00	1.00	3.00
			Friday	1.00	2.00	7.00

Table 116: IQR for lead-time by required days of week by FP

Over this period, the Purchasing Manager reported good progress, with the majority of purchasing following the P2P PO route with good control and data tracking, as shown in Table 108. We therefore agreed to adopt a binning of the stats, using this IQR distribution, our shared expert knowledge, and the admonition to work "in consideration of business rules and in consideration of statistics and analytics" (Ahlemeyer-Stubbe and Coleman, 2014, p. 72). The bin structure adopted was:

- "a_less than zero";
- "b_zero";
- "c_next ";
- "d_2-7 days";
- "e_8-50 days";
- "f_50 days plus".

This binning focused analysis on the immediacy of the day or the order, the next day, and the following week, with the hinterland of long orders past 50 days separated out.

This was supported by a similar trend noted when the data were purged of non-delivered material goods and those with a lead-time of less than zero days[35]. As shown in Table 117, the percentage of line-items with a lead-time of less than zero, an approximate proxy for the ad hoc posthumous Routes A&D, fell from 6.62% in FP2010 to 1.92% in FP2015, with the most marked drop being in FP2015.

financial periods (Aug-Jul)	2010	2011	2012	2013	2014	2015
full data set (line items)	184561	165647	154632	164174	166585	167078
delivered material groups only	145604	139639	129804	134629	135356	134067
leadtimes						
a_less than zero	9644	8197	6355	6740	7123	3207
b_zero	78572	46750	53953	61074	60584	22022
c_next day	27773	46967	40697	38295	37859	59549
d_2-7 days	22394	32635	25231	23801	25390	41918
e_8-50 days	5508	4360	3163	3983	3681	6301
f_50 days plus	1713	730	405	736	719	1070

Table 117: Analysis of full purchasing data sets FP2010-FP2015

I had removed non-delivered items using material groups. I then removed the items with less than zero delivery time. This left a very large sample, close to the full population and covering the key material groups and product types that were related to road traffic deliveries. This is summarised as follows in Table 118, showing a rise of circa 5 percentile points (73.67% to 78.32%) in valid items, between the first and last period, in line with other metrics showing a more formal purchasing practice.

[35] *The rationale and process followed was as detailed in Chapter 4.*

financial periods (Aug-Jul)	2010	2011	2012	2013	2014	2015
full data set (line items)	184561	165647	154632	164174	166585	167078
delivered material groups only	145604	139639	129804	134629	135356	134067
items with leadtime >= zero	135960	131442	123449	127889	128233	130860
full data set (line items)	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%
delivered material groups only	78.89%	84.30%	83.94%	82.00%	81.25%	80.24%
items with leadtime >= zero	73.67%	79.35%	79.83%	77.90%	76.98%	78.32%

Table 118: Filtering of FP2010-FP2015 dataset

The use of a bin for all orders with lead-times less than zero allowed for the easy removal of ‘posthumous’ orders, but also made them available for reporting to senior managers. During this period, a top-level analysis of *all* line-items and purchase orders showed a substantial trend to longer and perhaps more realistic lead-times, as evidenced in Figure 87.

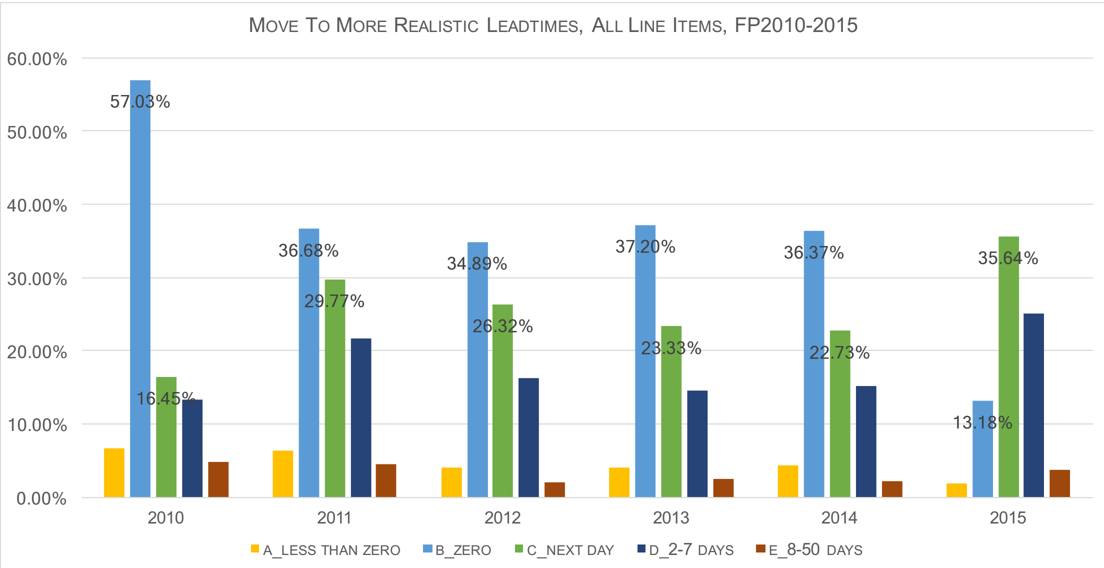

Figure 87: All line-items, binned by lead-time grouping

To summarise, the University had generated an almost just-in-time demand to its supplier base, but this had changed over time, with a step change in 2015. Given the scope of change over the period, I excluded FP2010, placed much lower emphasis on FP2011 to FP2014, and adopted the analysis from 2015. At that point the University had moved to a median lead-time for delivered goods of 1, i.e. next day, with a range of 1-7, and with orders placed for Monday showing a longer lead-time to take account of the weekend. The University was continuing to express next-day delivery demand to most of its supply base, despite the trend to more realistic lead-times as a range.

10.7. Traffic Survey review 2012 versus 2015.

In 2015, a new traffic count was carried out, with paid surveyors recording vehicles in and out at the five points that cordoned off the main campus (Sites 1 and 2); the buildings concentrated around Park Terrace (Site 3); and the access to the combined medical research and teaching facilities of the University (Sites 4 and 5). The latter were shared with the NHS Royal Victoria Infirmary (RVI) hospital, especially Site 5 which was the main RVI goods-in entrance, with Site 4 used for University receipts only. The survey points were therefore the same as in 2012 and are illustrated in Figure 88. Note that the traffic count Sites, and the main campus drop zones have a very rough parity with each other, as listed in Table 119.

Site	Drop zone(s)	Notes
1	7	South West Main Campus
2	8	East and Central Main Campus
3	9	North Main Campus
4	6	Medical School
5	None	NHS RVI hospital

Table 119: Relationships between Sites and drop zones

A tender was issued for the work, to the agreed specification, and awarded to the same experienced company that had carried out the 2012 and other traffic surveys on campus. The new survey was carried out from 7am to 7pm from Monday 27th April 2015 to Friday 1st May 2015, the same calendar week as in 2012. No major events or disruptions on the campus were expected or reported. As previously, in order to fully inform all staff and students, the University website announced the survey, both the week before and during the week; no comments were received.

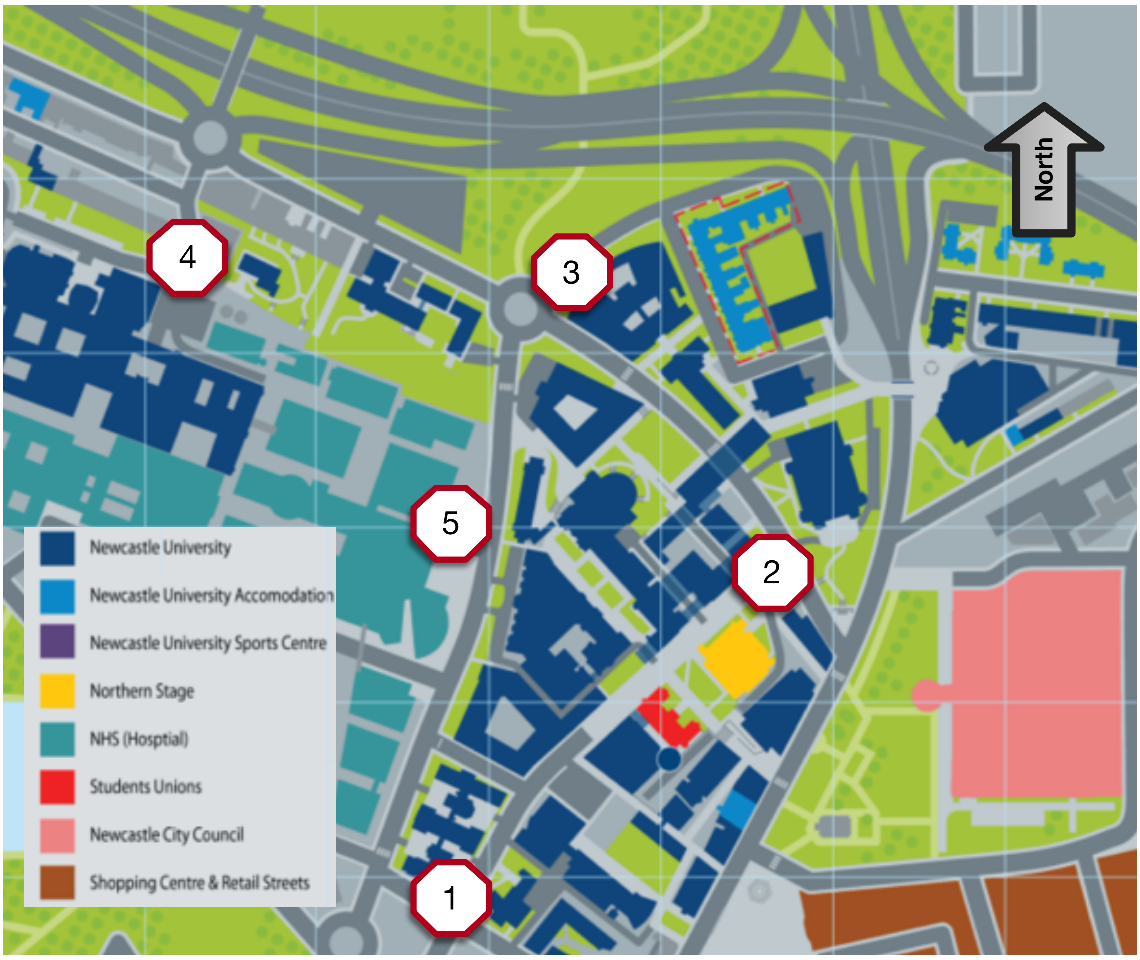

Figure 88: Main Campus of Newcastle University with numbered traffic count points 2015, adapted from University publicity materials

The 2015 survey differed from the 2012:

- The traffic movements were observed using video cameras and the data transcribed from the resulting movie files after the event, in order to allow pause, review and hopefully greater data accuracy.
- Following the query about the prevalence of 'kiss and drive' drop-offs (see 6.4.10 above), these were recorded for all Sites.
- Moving to top down video capture meant that it was not possible to note HGVs by number of axles. Freight vehicles were recorded as simply LGV or HGV.

10.7.1. Traffic survey data processing

Data recorded were: Site; time of the vehicle movement; vehicle classification; any vehicle logo or ID; and the direction of movement: IN or OUT of the campus, with additional IN directions of NVW for good inwards, and MSCP for the car park at the RVI hospital (Site 5).

The traffic classification was the same as in 2012, save for the grouping of all HGVs into a single group - resolved by an online query with the UK Driver and Vehicle Licensing Agency (DVLA) database, via a third party provider (DVLA, 2017). This identified the class and number of axles for all but 104 vehicles; these were then categorised by observation, recognition or estimation. 6 records marked as HGV were revealed by the DVLA database to be cars, motorcycles or LGVs, but the cost of the query process (10p per check) prohibited a full cross-check of all non-freight vehicles.

The data contained many fewer errors than in 2012 and the addition of a logo field provided a well populated record, covering 69% of all freight vehicles observed. In order to allow quantitative evaluation of vehicle emissions, it was important to know the type of engines in the vehicles visiting the campus. This was calculated as in 2012, and as explained in detail in Chapter 6 above.

With these adaptations, it was possible to derive a rich dataset of 34,593 observations, with a good classification of vehicle and engine type, whether entering or leaving the Sites, and at what time. This is *exampled* in Table 47.

ID	date	plate	site	direction	time	class	logo	enginetype	30minute	dropoff
20415	01/05/2015	[redacted]	Site 4	IN	08:47:00	2 Axle HGV	[redacted]	Euro IV	08:30:00	No
20416	01/05/2015	[redacted]	Site 4	OUT	08:59:00	2 Axle HGV	[redacted]	Euro IV	08:30:00	No
10044	29/04/2015	[redacted]	Site 4	IN	10:49:00	2 Axle HGV	[redacted]	Euro V & EEV	10:30:00	No
10045	01/05/2015	[redacted]	Site 4	IN	11:40:00	2 Axle HGV	[redacted]	Euro V & EEV	11:30:00	No
7562	01/05/2015	[redacted]	Site 5	IN	07:34:00	2 Axle HGV	[redacted]	Euro III	07:30:00	
24295	30/04/2015	[redacted]	Site 1	IN	07:57:00	2 Axle HGV	[redacted]	Euro V & EEV	07:30:00	No
7764	01/05/2015	[redacted]	Site 1	OUT	08:13:00	2 Axle HGV	[redacted]	Euro V & EEV	08:00:00	No
24296	30/04/2015	[redacted]	Site 1	OUT	08:14:00	2 Axle HGV	[redacted]	Euro V & EEV	08:00:00	No
7765	01/05/2015	[redacted]	Site 1	IN	09:06:00	2 Axle HGV	[redacted]	Euro V & EEV	09:00:00	No
33537	30/04/2015	[redacted]	Site 1	IN	10:09:00	2 Axle HGV	[redacted]	Euro IV/V & I	10:00:00	No
5820	29/04/2015	[redacted]	Site 1	IN	10:47:00	2 Axle HGV	[redacted]	unknown	10:30:00	No
20217	27/04/2015	[redacted]	Site 2	IN	15:30:53	3 Axle HGV	[redacted]	Euro VI	15:30:00	No
20218	27/04/2015	[redacted]	Site 2	OUT	15:55:16	3 Axle HGV	[redacted]	Euro VI	15:30:00	No
32754	30/04/2015	[redacted]	Site 3	IN	08:12:00	3 Axle HGV	[redacted]	Euro IV/V & I	08:00:00	No
15279	29/04/2015	[redacted]	Site 3	IN	08:17:00	3 Axle HGV	[redacted]	Euro V/VI & I	08:00:00	No
32755	30/04/2015	[redacted]	Site 3	OUT	08:22:00	3 Axle HGV	[redacted]	Euro IV/V & I	08:00:00	No
15280	29/04/2015	[redacted]	Site 3	OUT	08:25:00	3 Axle HGV	[redacted]	Euro V/VI & I	08:00:00	No
15281	27/04/2015	[redacted]	Site 3	IN	08:38:00	3 Axle HGV	[redacted]	Euro V/VI & I	08:30:00	No
15282	27/04/2015	[redacted]	Site 3	OUT	08:46:00	3 Axle HGV	[redacted]	Euro V/VI & I	08:30:00	No
20822	30/04/2015	[redacted]	Site 2	IN	07:08:00	Car	[redacted]	Euro 4	07:00:00	Yes
19039	30/04/2015	[redacted]	Site 2	OUT	07:09:00	Car	[redacted]	Euro 4	07:00:00	Yes
20823	30/04/2015	[redacted]	Site 2	OUT	07:09:00	Car	[redacted]	Euro 4	07:00:00	Yes
19040	01/05/2015	[redacted]	Site 2	IN	07:10:00	Car	[redacted]	Euro 4	07:00:00	Yes
20824	29/04/2015	[redacted]	Site 2	IN	07:10:00	Car	[redacted]	Euro 4	07:00:00	Yes
20825	29/04/2015	[redacted]	Site 2	OUT	07:10:00	Car	[redacted]	Euro 4	07:00:00	Yes
20826	01/05/2015	[redacted]	Site 2	IN	07:10:00	Car	[redacted]	Euro 4	07:00:00	Yes
20827	01/05/2015	[redacted]	Site 2	OUT	07:10:00	Car	[redacted]	Euro 4	07:00:00	Yes
19041	29/04/2015	[redacted]	Site 2	IN	07:11:00	Car	[redacted]	Euro 4	07:00:00	Yes

Table 120: Example anonymised processed traffic data Newcastle All Sites, all vehicles, 2015

10.7.2. Passenger versus freight vehicles

From these data, I noted that the University had a split between passenger and freight vehicles as follows in Table 121.

	2012		2015	
Row Labels	**Count of plate**	**% of plates**	**Count of plate**	**% of plates**
2 Axle HGV	800	3.37%	939	2.71%
3 Axle Artic	10	0.04%		0.00%
3 Axle HGV	88	0.37%	62	0.18%
4 Axle Artic	17	0.07%		0.00%
4 Axle HGV	158	0.67%	46	0.13%
5+ Axle Artic	32	0.13%	19	0.05%
Ambulances	200	0.84%	56	0.16%
Car	15318	64.48%	25474	73.64%
Coaches	223	0.94%		0.00%
Light Goods	4444	18.71%	5620	16.25%
Mini Buses	192	0.81%	18	0.05%
Motor Cyclist	255	1.07%	385	1.11%
Taxi	2019	8.50%	1974	5.71%
Grand Total	**23756**		**34593**	
Freight total	5549	**23.36%**	6686	**19.33%**
Passenger tota	18207	**76.64%**	27907	**80.67%**

Table 121: Split between passenger and freight vehicles Newcastle University 2012 versus 2015

The freight total of 19.33% was almost double the average for urban freight activity reported anecdotally, and in the literature, as being between 10% and 18% (Woudsma, 2001; European Commission, 2006b). It was also far higher than the 12% LGV and HGV traffic recorded in the Newcastle City central cordon traffic surveys (Newcastle City Council, 2016), illustrated in Figure 34. It was a noticeably lower proportion than in the 2012 survey, although the absolute number of both passenger and freight vehicles rose.

Note that in 2015, and based on DVLA records, not observation (and therefore sound), no 3 axle or 4 axle articulated HGVs were observed. No coaches were observed, due to a change of bus stop locations at the RVI.

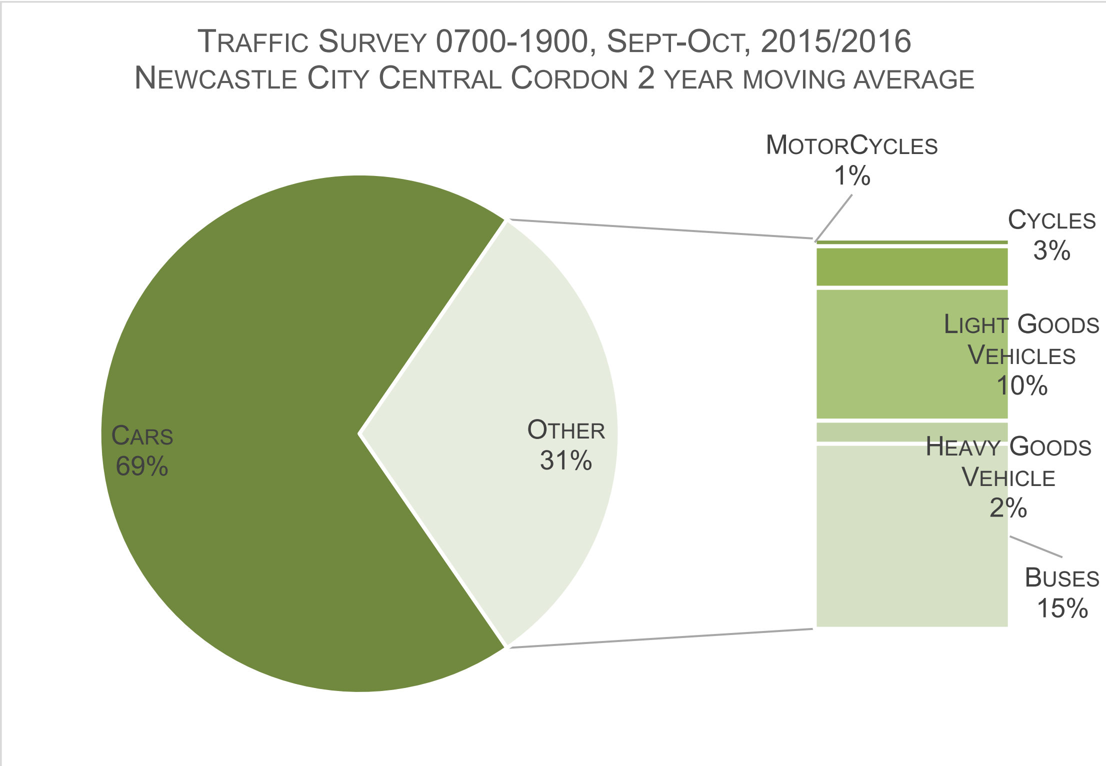

Figure 89: Traffic split by type 2011/2012, adapted from source: Newcastle City Council (Newcastle City Council, 2016)

Prior to this survey, as well as changing the location of bus stops, the RVI had altered its front curtilage, its parking policy, and had better separated goods and multi-storey access. A review of the changes in traffic volume showed very substantial increases in car traffic to Site 5, the access to the car park, and also a reduction in car traffic to Site 4, the access to the medical research facilities. Since cars were not the focus of this work, I noted these data and passed them to the University Travel Plan team.

	2012						**2015**					
Vehicle Class	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Total**	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Total**
2 Axle HGV	245	208	83	226	38	800	172	230	96	248	193	939
3 Axle Artic	10					10						
3 Axle HGV	40	24		22	2	88	10	15	8	27	2	62
4 Axle Artic	16			1		17						
4 Axle HGV	60	20	6	28	44	158	26	2		14	4	46
5+ Axle Artic	14	6		12		32		3		16		19
Ambulances			2	10	188	200	2		2	6	46	56
Car	**1235**	**1584**	**5550**	**3536**	**3413**	**15318**	**1524**	**2425**	**4896**	**2626**	**14003**	**25474**
Coaches	81	11		1	130	223						
Light Goods	887	1037	987	1049	484	4444	867	1418	986	1356	993	5620
Mini Buses	20	17	10	7	138	192		15	2		1	18
Motor Cyclist	37	102	51	63	2	255	40	108	53	76	108	385
Taxi	27	378	640	435	539	2019	50	491	345	585	503	1974
Grand Total	**2672**	**3387**	**7329**	**5390**	**4978**	**23756**	**2691**	**4707**	**6388**	**4954**	**15853**	**34593**
% change grand total							0.71%	38.97%	-12.84%	-8.09%	**218.46%**	45.62%
% change in Cars							23.40%	53.09%	-11.78%	-25.74%	**310.28%**	66.30%
% change in freight							-15.49%	28.80%	1.30%	24.14%	**109.86%**	20.49%

Table 122: Comparison of 2012 vs 2015 vehicle class by Site, Newcastle University.

The split between freight vehicle classes is detailed in Table 122 and confirms the dominance of LGVs on campus: 80% of all freight movements in 2012 and 84% in 2015.

Given that the statistics from Site 5 had changed so radically, and the method of survey had changed from human recording on the day, to human recording from later review of video recordings, I considered it unwise to draw the conclusion that traffic volumes had risen overall.

However, the data suggested that at Site 1, freight access had fallen by 15.49% and indeed Site 1 access had been reduced since 2012. Freight had risen by 28.80% at Site 2, where changes had opened it up and added parking for freight access. Site 3 had not been physically changed and showed a small 1.30% increase in freight. Site 4, a mixed area of longer, service visit LGV parking, had seen a 24.14% increase in freight vehicles, almost all attributable to a rise in LGV observations.

10.7.3. Engine emission standards

class	2012 movements	2015 movements	% change
pre Euro 3/III	84		100%
Euro 3	422	259	-38.63%
Euro 3/4	268	214	-20.15%
Euro 4	2171	1161	-46.52%
Euro 4/5	232	103	-55.60%
Euro 5	1255	3694	194.34%
Euro 6	30	24	-20.00%
Euro III	235	69	-70.64%
Euro III/IV	110	52	-52.73%
Euro IV	337	186	-44.81%
Euro IV/V & EEV	144	134	-6.94%
Euro V & EEV	213	359	68.54%
Euro V/VI & EEV		133	
Euro VI	39	97	148.72%
Unknown	9	201	

Table 123: Comparison of 2012 vs 2015 engine type, Newcastle University

The vehicle class and year data enabled us to evaluate the emission standards of the entire vehicle fleet on campus, as detailed in Table 123.

These data showed an expected transition from older to newer engine types, notably Euro 4 to Euro 5 in LGVs, and Euro IV to Euro V in HGVs - in line with the introduction of new standards and the retirement of fleets. This is evidenced in Figure 90 versus Figure 91.

The Euro standards for passenger cars and LGVs included both petrol and diesel vehicles, but it was not possible to distinguish fuel type from the vehicle licence plate.

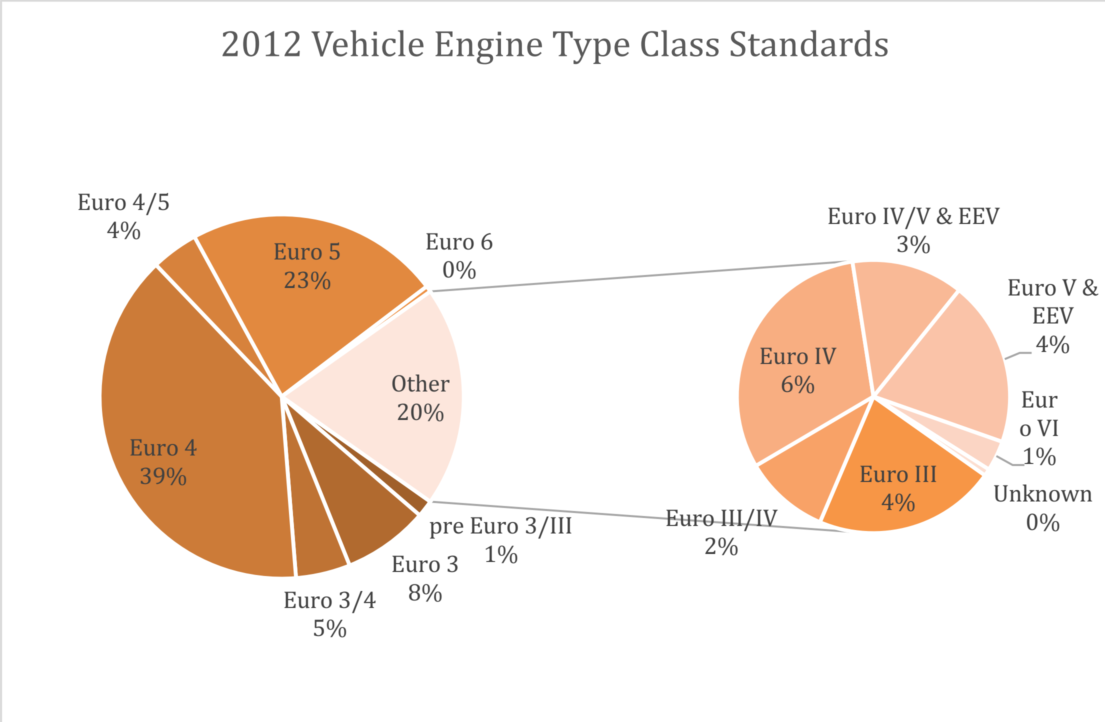

Figure 90: Split by engine class 2012, Newcastle University

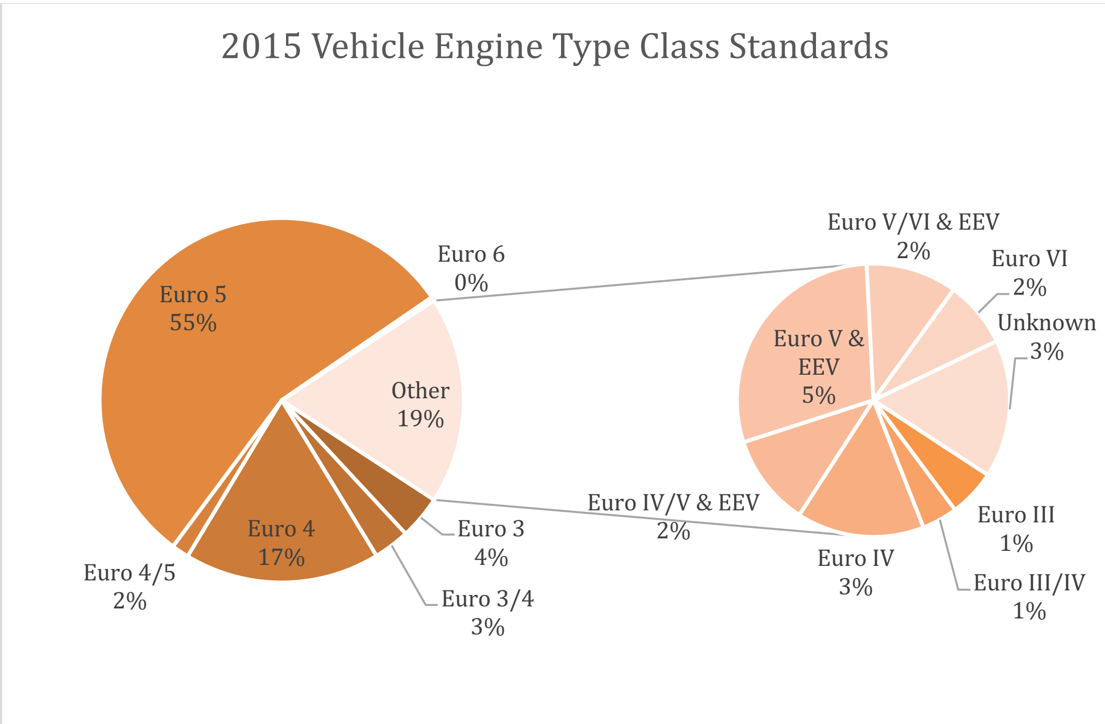

Figure 91: Split by engine class 2015, Newcastle University

10.7.4. Movements through the day

From this dataset of all vehicles, it was appropriate to 'bin' time of observed movement into a 30-minute window. The comparable table for 2012 is Table 50.

	HGVs	Car	LGVs	Others	Grand Total
07:00:00	52	449	124	34	**659**
07:30:00	64	804	175	62	**1105**
08:00:00	52	898	201	92	**1243**
08:30:00	66	896	254	109	**1325**
09:00:00	78	740	309	139	**1266**
09:30:00	68	550	319	157	**1094**
10:00:00	81	486	259	167	**993**
10:30:00	73	576	212	159	**1020**
11:00:00	75	511	264	128	**978**
11:30:00	80	478	272	133	**963**
12:00:00	54	540	221	129	**944**
12:30:00	47	489	168	102	**806**
13:00:00	71	568	193	128	**960**
13:30:00	50	587	227	131	**995**
14:00:00	42	508	234	120	**904**
14:30:00	43	544	262	129	**978**
15:00:00	27	534	201	132	**894**
15:30:00	42	629	193	125	**989**
16:00:00	14	806	147	139	**1106**
16:30:00	5	1040	79	155	**1279**
17:00:00	6	1122	46	145	**1319**
17:30:00	6	604	49	109	**768**
18:00:00	6	489	30	86	**611**
18:30:00	3	470	5	79	**557**
Totals	**1105**	**15318**	**4444**	**2889**	**23756**

Table 124: Absolute split of vehicle classification 2015 aggregated by half hour (time rounded down)

In order to observe the shape of the activity, irrespective of absolute numbers, the freight data were plotted as columns, with a moving 2-point average trend line added, as shown in Figure 92 and Figure 93.

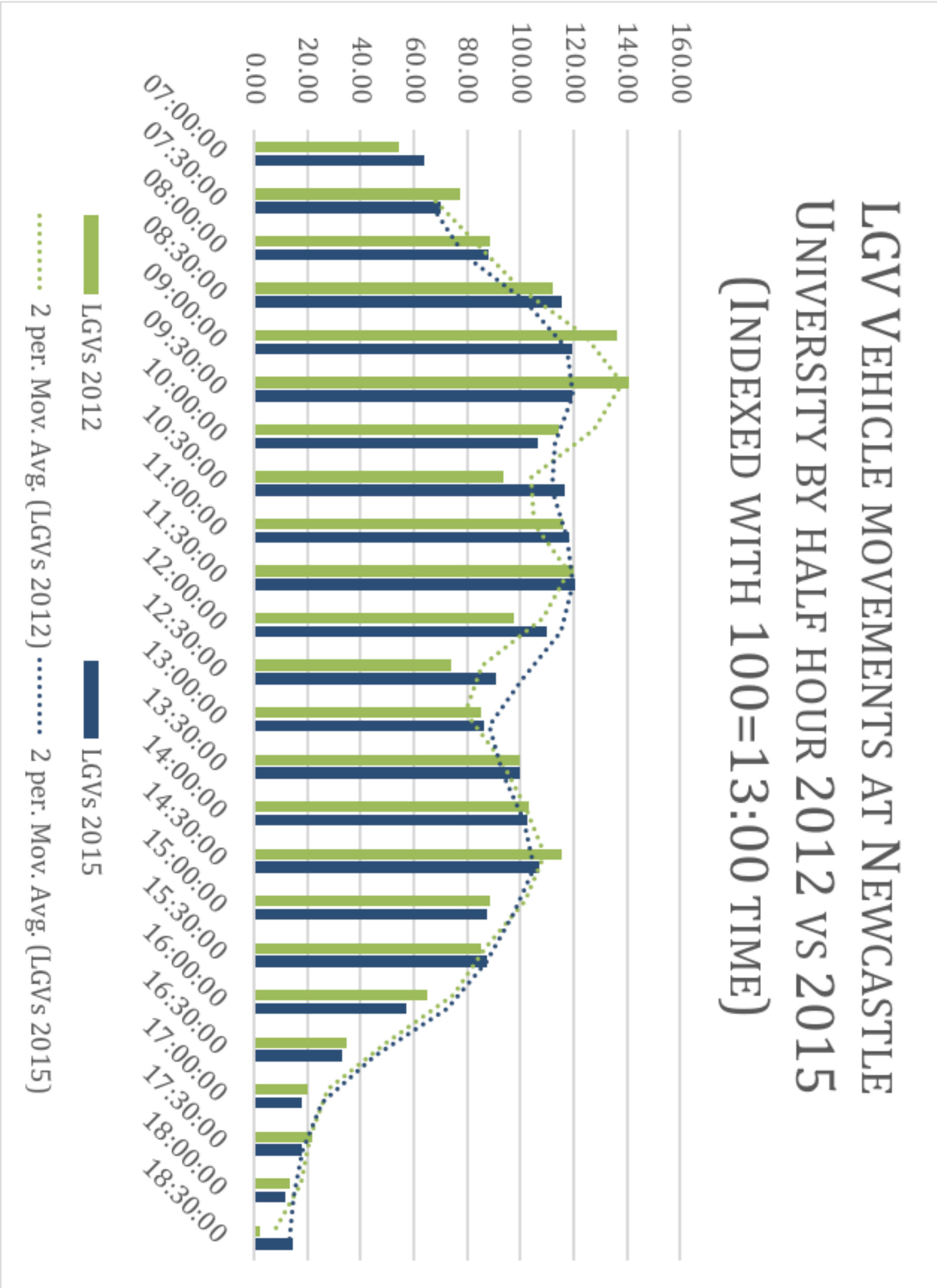

Figure 92: LGV Vehicle Movements at Newcastle University indexed by half hour, 2012 vs 2015

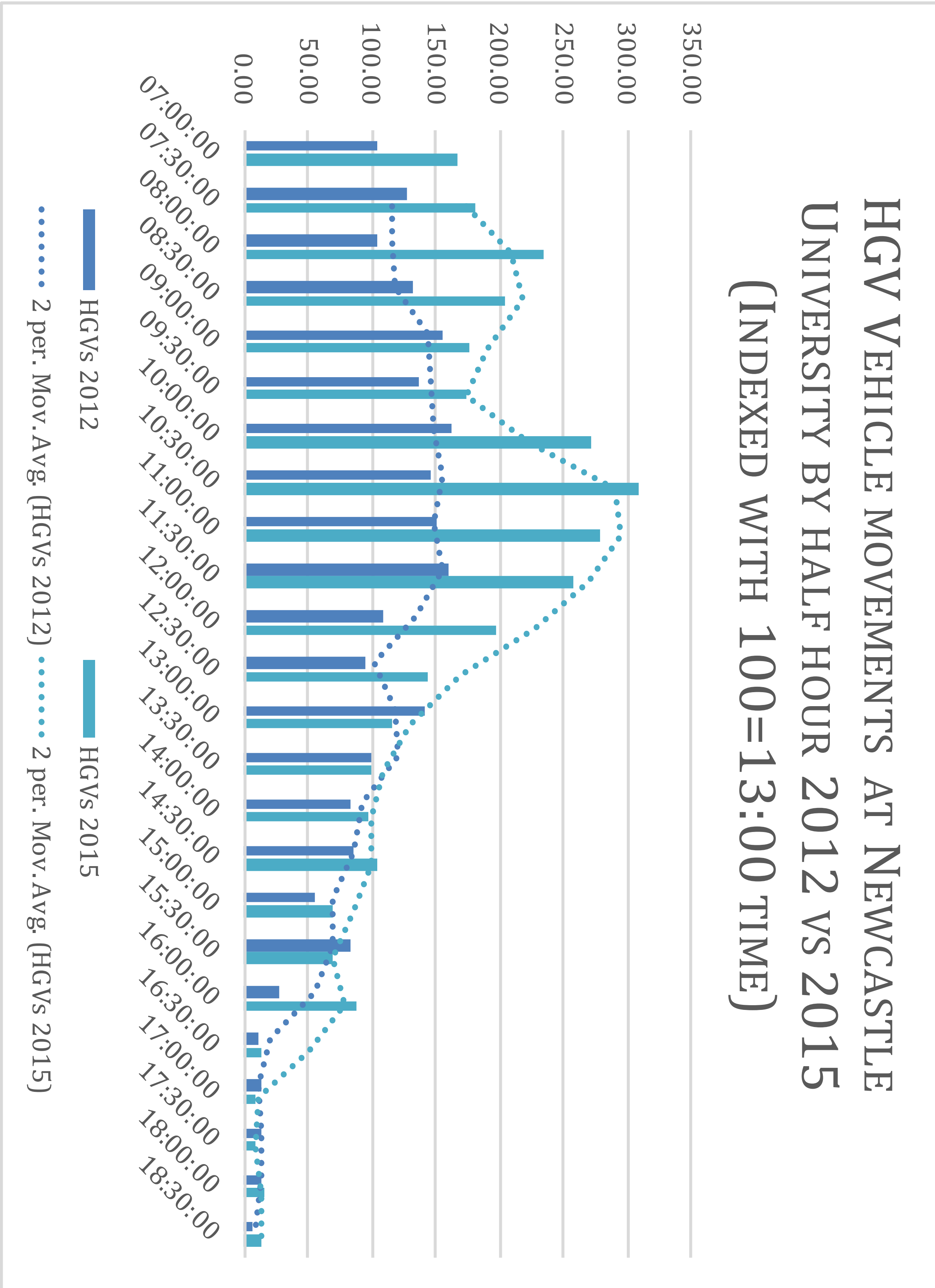

Figure 93: LGV Vehicle Movements at Newcastle University indexed by half hour, 2012 vs 2015

These data showed a similar pattern for LGVs in both surveys; HGVs exhibited a different shape, but it is worth noting that the HGV dataset was far smaller than for LGVs.

10.7.5. Drop-offs

In the 2012 survey I did not check for 'kiss and drive' - the passenger drop-offs suggested to me by an audience member at a University event. These were incorporated into the 2015 survey.

	dropoffs 2015	Site 1	Site 2	Site 3	Site 4	Site 5	All Sites
Car	No	88.93%	57.48%	84.60%	61.23%	99.95%	88.31%
	Yes	**11.07%**	**42.52%**	**15.40%**	**38.77%**	**0.05%**	**11.69%**
HGV	No	95.45%	95.45%	92.31%	93.51%	100.00%	94.01%
	Yes	**4.55%**	**4.55%**	**7.69%**	**6.49%**	**0.00%**	**5.99%**
Light Goods	No	92.27%	90.27%	88.84%	88.11%	100.00%	91.52%
	Yes	**7.73%**	**9.73%**	**11.16%**	**11.89%**	**0.00%**	**8.48%**
Taxi	No	44.00%	27.90%	47.54%	25.98%	99.80%	49.49%
	Yes	**56.00%**	**72.10%**	**52.46%**	**74.02%**	**0.20%**	**50.51%**

Table 125: Drop-offs by key vehicle classes by Site 2015, Newcastle University

Substantial drop-offs by car were noted at Site 4 (medical research) and Site 2 (main turning area at one end of Kings Road). No drop-offs were observed at Site 5, since once a vehicle had entered the RVI Site it was committed to either park in the multi-story or deliver goods at the goods inwards. Significant drop-offs by LGV were noted across campus, with a mean of 8.48%, but there was also a surprising level of drop-offs by HGV, with a mean of 5.99%. Taxi observations seemed odd, in that only Site 3 had an official taxi rank, so a 'non drop-off' anywhere else was probably a taxi awaiting a passenger pick up; these were high at Site 1 (56.00%) and Sites 2 and 4 (72.10% and 74.02% respectively). The total percentage of freight vehicle observations that were 'kiss and drive' drop-offs was a mean average of 8.07% across all Sites. Since freight was the focus, not passengers, these details were passed to the University Travel Plan team. Any observations of drop-offs in the freight data were marked as such, and included or excluded from further analysis, as appropriate.

10.7.6. Freight vehicle dwell times

Using the same script, and Excel techniques previously detailed in Chapter 6 above, the 2015 data were processed and analysed for dwell times. In the end 6,018 records (out of 6,668) were paired, after 6 iterations of processing with the script, manually editing and reprocessing - representing 90% of all freight observations on all Sites and all days. This was far greater than the 66% of pairing achieved with the 2012 dataset, suggesting that the move to video recording of number plates had been a positive move.

10.7.7. Summary of filtered data set

The 2015 dataset proved to be more accurate than 2012's, in terms of number plate recognition and pairing of IN and OUT movements. The filtering of the data in 2012 and 2015 is summarised in Table 126.

2012	cases	% of full dataset	% of freight dataset
full survey data	23756	100%	
freight data only	5549	23%	100%
non-paired data	1885	8%	34%
paired data	3616	15%	66%
2015	cases	% of full dataset	% of freight dataset
full survey data	34593	100%	
freight data only	6686	19%	100%
non-paired data	668	2%	10%
paired data	6018	17%	90%

Table 126: Filtering of 2012 versus 2015 traffic survey data

In 2012, 66% of vehicles were reported as having identifying logos, with 69% in 2015. Given this consistency, and that in 2015 the logos were recorded on video, the 2012 observation may be viewed as safer than first thought. Analysis of the logo data showed that 8% of all vehicles observed in 2015, and 10% in 2012, were identifiable as Newcastle University fleet vehicles. Whilst some of these were Catering deliveries, which had been centralised in-house since 2012 and might therefore be viewed as having substituted for an external supplier, I nevertheless decided to exclude all internal vehicles from further analysis of the 2015 data.

To summarise: the following filtering and processing options were available and applied to *2015 only* analyses:

- Freight vehicles only
- All freight vehicle passenger drop-offs removed
- All internal Newcastle University vehicles removed

However, for analyses where 2012 data were combined with 2015, only the ‘freight vehicles only’ filter was applied, since it was not possible to reliably remove passenger drop-offs by freight vehicle, nor Newcastle University internal vehicles.

10.7.8. Normality of traffic survey data

Using SPSS, I carried out Kolmogorov-Smirnov normality tests on the 2015 data for dwell time, half-hour ‘bins’ of time, and the unique times of observation. I then repeated this for 2012 and 2015 data combined. Given that sample sizes above 2000 can tend to fail to report normality, I also looked at Q-Q plots and histograms.

Dwell time, half-hour ‘bins’ and the time of observation were not distributed normally, when tested alone for 2015. I repeated the tests on these variables, grouped by the factors of: weekday; Site; direction of travel; vehicle class; engine type; and LGV versus HGV. For some of these, the sub-samples were smaller than 2000 and so Shapiro-Wilk tests were also evaluated. Apart from some few data associated with low frequency engine types (Euro 3/III) or vehicle class (4 Axle HGV), these data were not normally distributed.

I then repeated the same tests for the combined 2012 and 2015 data: the tests showed no normal distributions at all. The conclusion I drew was that, unless specific questions about minority vehicles would be useful, in all cases the traffic survey data would be treated as not normally distributed and non-parametric tests would be used. As discussed earlier in section 6.4.7, the question of dwell times for freight deliveries was of interest. The analysis in Chapter 6 above was repeated and is summarised in Table 127 following.

10.7.9. *Frequencies and ranges of 2012 and 2015 dwell times*

2012			2015		
N	Valid	1823	N	Valid	3009
	Missing	957		Missing	495
Mean		00:58:05	Mean		0:58:47.46
Median		00:16:00	Median		0:16:00.00
Range		10:30:00	Range		10:29:44.00
Minimum		00:01:00	Minimum		0:00:16.00
Maximum		10:31:00	Maximum		10:30:00.00
Percentiles	25	00:07:00	Percentiles	25	0:07:00.00
	50	00:16:00		50	0:16:00.00
	75	00:52:00		75	0:51:00.00

Table 128: Descriptive statistics for dwell time, traffic surveys 2012 and 2015[36]

As the data were not normally distributed, the median was the appropriate average to use - 16 minutes for both years' datasets. Indeed, at this top level the pattern seemed highly consistent with the findings in Chapter 6 above. However, I had recorded drop-offs in the 2015 dataset and, once incorporated, the ranges for these data suggested that the median for a drop off was 3 minutes, for a delivery was 17 minutes, and that the boundary between the two was around the 4-5 minute mark, as seen in Table 129.

dropoff		Percentiles						
		5	10	25	50	75	90	95
	Weighted Average(Definition 1)	0:02:00.00	0:04:00.00	0:06:59.99	0:17:00.00	1:12:00.00	4:02:12.00	6:28:17.99
No	Weighted Average(Definition 1)	0:04:12.70	0:06:00.00	0:09:00.00	0:17:00.00	0:49:53.50	2:22:35.99	4:19:00.00
Yes	Weighted Average(Definition 1)	0:01:00.00	0:01:00.00	0:01:00.00	0:03:00.00	0:04:00.00	0:04:00.00	0:04:00.00

Table 129: Median and ranges for dwell time by drop-off observations, 2012 and 2015

This supported the view, expressed in Chapter 6 above and based upon the literature, that a general model for the University was a bottom cut-off of 5 minutes and a top cut-off of 52 minutes. Between these times a freight vehicle movement was a delivery, below was probably drop-off, and above 52 minutes was a service visit. I could have

[36] *Only cases with direction of travel of IN were included, and any cases with no dwell time were automatically excluded from the analysis by SPSS.*

adopted the exact IQR 25 and 75 percentile limits, but I did not feel it appropriate to break totally from previous research, not least because the IQR limits did not meet, creating a potential ‘grey’ zone between them.

I explored whether it made sense to apply such a universal cut-off to the data, but analysis of IN data in 2015 at Sites 1-4 showed that, whilst c99% of all movements with a dwell time of 5 minutes or greater were not drop-offs, neither were c55% of all movements lower than 5 minutes - being some kind of delivery; thus the lower band did not contain a hard and fast rule.

Variances in dwell times

Certain key points were made in Chapter 6 above from the dwell time analysis: primarily that it was consistent between the first 4 Sites, but that Site 5 was quite different to the other Sites. I had also noted that LGVs, 2 Axle HGVs, and 3+ Axle HGVs had different dwell times. Since the 2015 data could be used to exclude drop-offs and non-observations, the 2015 data were analysed to explore dwell time variances by these factors.

As in Chapter 6 above, weekdays appeared to have similar median dwell times. Previously, Site 5 had been shown to have quite different and longer median dwell times -1 hour and 8 minutes, as opposed to 14-17 minutes for Sites 1-4. The 2015 data did not show this variance, suggesting that the new road layout at the RVI had radically changed operations. The results, shown in Table 130, suggested that once drop-offs were removed, Site 5 and Site 2 had more in common with each other than Sites 1,3, and 4. Looking at the campus, Site 2 had dedicated freight parking and, between the two surveys, had removed access control. Site 5 had a new road layout and dedicated unloading infrastructures. The other Sites were not so well provisioned with permitted freight parking.

dwelltime	25	50	75
Site 1	0:08:00.00	0:13:00.00	0:30:40.00
Site 2	0:10:00.00	0:23:12.50	1:03:00.00
Site 3	0:08:00.00	0:16:00.00	1:02:00.00
Site 4	0:09:00.00	0:15:00.00	0:39:00.00
Site 5	0:10:00.00	0:19:00.00	0:59:00.00

Table 130: Dwell time median and range grouped by Site 2015, no drop-offs

In 2012, Sites 1-4 had been found to have a common median dwell time but, in 2015, the removal of drop-offs and the new Site 5 road layout appeared to show divergent vehicle behaviour by Site. This was tested, using pairwise analysis, to see if these differences were significant.

Having noted the above it was appropriate to confirm to what extent dwell time varied by Site, first with a Kruskal-Wallis H test, and then pairwise Mann-Whitney tests with or without Bonferroni corrections, as detailed more fully in Chapter 6 above. The variance between Sites was significant. Pairwise mapping using Mann Whitney variance testing on a 5x5 matrix with a Bonferroni correction alpha-value of 0.005 was carried out. In each pairwise test the null hypothesis was that the datasets were not different.

2015 traffic survey pairwise test for variance dwelltime, no drop-offs					
p values	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**
Site 1		0.001	0.009	0.133	0.001
Site 2	0.001		0.061	0.001	0.402
Site 3	0.009	0.061			0.193
Site 4	0.133	0.001	0.150		0.001
Site 5	0.001	0.402	0.193	0.001	
Mann Whitney pairwise, alpha = 0.005, <0.001 rounded as 0.001					
Shaded green are significant and therefore vary pairwise, amber shading denotes a standard 5% significance					

Table 131: Sites pairwise Mann Whitney variance testing dwell time by Site, traffic survey 2015, no drop-offs

The 2012 survey had shown significant differences between Site 5 and all others, and between Site 4 with Sites 1 and 2. In 2015, after the access to Site 2 had been changed to be more accommodating to freight, a different picture emerged from the data. Sites 2 and 5 were not different, befitting their roles as legitimate unloading areas, and Site 1 was noticeably different from all others, save Site 4. I read from this, and the dwell time ranges in Table 130, that Site 1 was for fast, small-drop deliveries - and Site 4 similarly, but in a different way to Site 1. Sites 2 and 5 were used for longer, larger drops and Site 3 was mixed-use. A walk down Site 3 most days of the week, observing the mix of parked up LGVs, courier deliveries and lengthy unloading of 'Luton' vans[37], confirmed this reasoning.

In Chapter 6 above I concluded that the most appropriate way to analyse dwell times by vehicle class was to use a three way split: LGVs, 2 Axle HGVs, and 3+ Axle HGVs. This analysis was repeated with the 2015 data, both with and without drop-off observations. This is summarised in Table 132.

Three-way_vehicle_class		**Percentiles (Interquartile range)**		
2012	All data	25	50	75
	2 Axle HGV	00:07:00	00:13:00	00:31:30
	3+ Axle HGVs	00:15:00	00:27:00	00:48:15
	Light Goods	00:06:00	00:15:00	01:07:00
2015	Drop-offs included	25	50	75
	2 Axle HGV	00:08:00	00:14:00	00:26:00
	3+ Axle HGVs	00:08:00	00:16:30	00:41:00
	Light Goods	00:07:00	00:16:00	00:59:00
2015	Drop-offs excluded	25	50	75
	2 Axle HGV	00:08:30	00:14:00	00:26:00
	3+ Axle HGVs	00:09:45	00:19:00	00:44:00
	Light Goods	00:09:00	00:18:00	00:58:00

Table 132: Dwell time analyses 2012 and 2015, by vehicle class

The effect of removing drop-offs from the heavier vehicle classes should not be overstated; only 4 such observations were made in 2015. The range for LGVs was wider than for 2 Axle in 2015, as had been the case in 2012, with the 75th percentile extending to 58 minutes for LGVs, as opposed to 26 minutes for 1 Axle HGVs. This could still be explained by the use of LGVs as mobile workshops throughout the day - an easily observed pattern across the campus.

In Chapter 6 above, a significant difference was noted between 3+ Axle HGVs and the lighter classes and this was shown again in 2015, using a Kruskal-Wallis H test. Therefore, pairwise mapping using Mann Whitney variance testing, on a 5x5 matrix with a Bonferroni correction alpha-value of 0.017, was carried out. In each pairwise test the null hypothesis was that the datasets were not different.

[37] *A Ford Transit van with Luton body., a 2 Axle HGV.*

p values	2 Axle HGV	3+ Axle HGVs	LGV
2 Axle HGV		0.001	0.049
3+ Axle HGVs	0.001		0.001
LGV	0.049	0.001	
Mann Whitney pairwise, alpha = 0.017, <0.001 rounded as 0.001			
Shaded green are significant and therefore vary pairwise; amber denotes a standard 5% significance			

Table 133: Mann Whitney variance testing dwell time by 3 way vehicle class 2015, no drop-offs

The results, shown in Table 133, clearly showed that all three vehicle classifications should be viewed as significantly different. Whilst the 2 Axle HGV versus LGV difference failed to show significance using the Bonferroni correction, when a standard 5% significance test was adopted. When read with the interquartile ranges above in Table 132, and how the median for LGVs changed when drop-offs were removed, it seemed sound to view this 3-way vehicle classification as robust for dwell time analysis and possibly other factors.

10.7.10. Conclusions re dwell times

These results suggested that a working definition of dwell times on the Newcastle University Campus could be based on the non drop-off 2015 data.

It was a median of 23 and 19 minutes for Sites 2 and 5, both with good provision of freight unloading facilities and parking. It was 13 minutes for Site 1, a Site with little legitimate freight access. It was 15 and 16 minutes for Sites 3 and 4 respectively, both Sites with mixed access and use.

It was a median of 18min for LGVs, 14min for 2 Axle HGVs, and 19min for HGVs with 3 axles or more.

As detailed in section 6.4.10, the general model for the University was a bottom cut-off of 5 minutes and a top cut-off of 52 minutes. Between these times a freight vehicle movement was a delivery, below was probably drop-off, and above 52 minutes was a service visit. This was considered later as a potential method for differentiating goods and service visits.

10.7.11. Frequencies and ranges of time of arrival

The arrival of the freight delivery was a key issue for exploration, as listed previously in Table 50 and illustrated in Figure 36 & Figure 93. I analysed the freight dwell time data to attempt to determine key parameters: the range and median of arrival times for different freight vehicles on campus. Note that since the observation data were stored as IN and OUT cases, but that I was primarily interested in vehicle arrivals, the SPSS dataset was limited to IN only. Kruskal-Wallis H tests were used, and the following results were found.

Variances in arrival time

The data showed no difference in freight vehicle arrival time by weekday, and no difference between individual Sites (1-5). There was however a significant difference in freight vehicle arrival time by 3-way vehicle classification, where a 3 x 3 matrix pairwise mapping, utilising a Mann Whitney test and a Bonferroni correction alpha-value of 0.017, was used.

In 2012 there had been no differences between 2 Axle HGVs and 3+ Axle HGVs, but both were both significantly different to LGVs. In 2015, Axle HGVs were still significantly different, but the difference between LGVs and 3+ Axle HGVs was not significant. The analysis of 3-way classification continued to confirm that, for arrival time, LGVs had a different movement pattern to HGVs.

10.8. Potential Correlation Analyses

As found in Chapter 6 above, correlations between purchasing activity and traffic survey were not viable, given the very small spread of overlapping factors (Monday-Friday only); explorations of arrival time versus dwell time showed very weak correlations. I continued to view this as an area not relevant for this work and this evaluation. Therefore, whilst correlation and regression analysis of the data were trialled, they were found to be unrewarding.

CCCC operational data in Table 104 in Chapter 9 above had shown that the pilot redirected 4199 parcels and an average of 3080 inbound vehicles away from the campus. Examining the data for the dates of the pilot, shown below in Table 134, 27 deliveries were routed to the CCCC during this period and yet the number of freight observations increased from 2012 by 1137 vehicles - a rise of 20.49% as shown in Table 122.

This was an average of about 668 inbound freight vehicles per day during the survey week.

Count of 'items'	Column Labels								
	2015							2015 Total	Grand Total
	04				04 Total	05	05 Total		
Row Labels	27/04/2015	28/04/2015	29/04/2015	30/04/2015		01/05/2015			
Appleton Wood Ltd		1	1	1	3			3	3
Arjuna Technologies Ltd						1	1	1	1
CPC/Farnell (Onecall)	2	5	5	4	16			16	16
Getech Ltd		1			1			1	1
NEWARK			1		1			1	1
Rocom Group Limited						1	1	1	1
WEST COAST LIMITED	1	1		2	4			4	4
Grand Total	**3**	**8**	**7**	**7**	**25**	**2**	**2**	**27**	**27**

Table 134: Inbound freight vehicle deliveries to the CCCC traffic survey 2015 dates; analysis of VIGO software data

The deliveries might have been to one of the drop-zones not part of the main campus, and therefore not noted by the traffic survey, so I noted the end delivery points by post code. The main campus had a single postcode: NE1 7RU, making it simple to distinguish between those delivery addresses and those external to the main site. Indeed, only 63% deliveries were to the main postcode and could have been expected to substitute for previous inbound vehicles.

In short, it was clear that further analysis would not elaborate further on the evidence that the pilot, as run, had had no *discernible* effect on freight movements on the campus. Given the low level of operations that the pilot had achieved, this was not wholly surprising but, given the rise in freight volumes, especially at Sites 2 and 4, there were probably other unmeasured influences at work, that were also unproven.

10.8.1. Analysis of goods-generated freight deliveries to Site

The proportion of freight vehicle observations in the 2015 traffic survey attributable to ‘kiss and drive’ drop-offs was circa 8% (section 10.7.5), that of internal University vehicles was also about 8%, (section 10.7.7).

I collected all the purchasing data for fiscal periods 2015 and 2016, at line-item level, and excluded all purchases for services, or that were unlikely to generate a freight delivery, using the material group codes detailed previously in section 6.3.6 above. The result is detailed in Table 135 below, averaged into years and months. This list was then analysed, using the ratio of parcels to actual delivery drop (1.36) from the pilot - similar to ratios observed in other parcel operations. For certain key suppliers I substituted the actual parcel/drop ratio observed in the trial, as exampled below in Table 136.

Goods deliveries FP 2015-2016 by Supplier					*ratio of parcels per drop fror*		1.36						
					90	*max parcels per vehicle*							
					250	*days in typical year*							
Sap BW	***In pilot trial?***	***average monthly drop from pilot***	***unique parcel/drop ratio***	**line items over 24 months**	**average parcels per annum**	**average parcels monthly**	**number of monthly drops?**	**number of daily drops?**	**daily drop running total**	**daily drop running total**	**proportion of a vehicle needed daily**	**running vehicle total**	**running vehicle cumulative %**
Office Depot UK Ltd	No			29985	29985	1249	919	44.09559	44.09559	12%	0.666333	0.67	12%
Sigma Aldrich Company Ltd	No			21822	21822	909	669	32.09117	76.18676	21%	0.484933	1.15	21%
Fisher Scientific UK	No			17851	17851	744	547	26.25147	102.43823	28%	0.396689	1.55	28%
VWR International t/a Lab3	No			9832	9832	410	301	14.45882	116.89705	32%	0.218489	1.77	32%
RS Components Ltd	No			8259	8259	344	253	12.14559	129.04264	35%	0.183533	1.95	35%
Life Technologies Limited	No			7314	7314	305	224	10.75588	139.79851	38%	0.162533	2.11	38%
Starlab (UK) Ltd	No			7241	7241	302	222	10.64851	150.44703	41%	0.160911	2.27	41%
Lyreco UK Limited	No			6791	6791	283	208	9.98676	160.43379	44%	0.150911	2.42	44%
CPC/Farnell (Onecall)	Yes	48.16666667	4.148788927	4796	4796	200	48	7.05294	167.48673	46%	0.106578	2.53	46%
Scientific Laboratory Supplies Ltd	No			4016	4016	167	123	5.90588	173.39261	47%	0.089244	2.62	47%
BOC Gases	No			3835	3835	160	117	5.63970	179.03231	49%	0.085222	2.71	49%
New England Biolabs (UK) Ltd	No			2863	2863	119	88	4.21029	183.24261	50%	0.063622	2.77	50%
ABCAM Plc	No			2781	2781	116	85	4.08971	187.33231	51%	0.061800	2.83	51%
Arco Ltd	No			2739	2739	114	84	4.02794	191.36026	52%	0.060867	2.89	52%
Greiner Bio-One Ltd	No			2492	2492	104	76	3.66471	195.02496	53%	0.055378	2.95	53%
Insight Direct (UK) Ltd	Yes	63.33333333	1.576315789	2396	2396	100	73	3.52353	198.54849	54%	0.053244	3.00	54%
Crossling Ltd	No			2245	2245	94	69	3.30147	201.84996	55%	0.049889	3.05	55%
XMA Ltd	Yes	21.5	4.205422481	2170	2170	90	66	3.19117	205.04114	56%	0.048222	3.10	56%
Qiagen Ltd	No			2160	2160	90	66	3.17647	208.21761	57%	0.048000	3.15	57%
Becton Dickinson UK Ltd	No			2108	2108	88	65	3.10000	211.31761	58%	0.046844	3.19	58%
Bunzl Cleaning and Hygiene Supplies	No			1921	1921	80	59	2.82499	214.14260	59%	0.042689	3.24	59%
Thomas Owen And Sons	No			1766	1766	74	54	2.59706	216.73966	59%	0.039244	3.28	59%
Access Solutions Master Locksmiths	No			1744	1744	73	53	2.56471	219.30436	60%	0.038756	3.31	60%
Sarstedt Ltd	No			1731	1731	72	53	2.54558	221.84994	61%	0.038466	3.35	61%
Bio-Rad Labs Ltd	No			1628	1628	68	50	2.39412	224.24406	61%	0.036178	3.39	61%
Biolegend UK Limited	No			1587	1587	66	49	2.33382	226.57788	62%	0.035267	3.42	62%
Eurofins Genetic Services Ltd	No			1545	1545	64	47	2.27206	228.84994	63%	0.034333	3.46	63%
Alfa Aesar	No			1480	1480	62	45	2.17647	231.02641	63%	0.032889	3.49	63%
Dell Computer Corporation Ltd	No			1395	1395	58	43	2.05147	233.07788	64%	0.031000	3.52	64%
Blackwells Distribution Centre	No			1395	1395	58	43	2.05147	235.12935	64%	0.031000	3.55	64%
Eyre & Elliston Ltd	No			1355	1355	56	42	1.99265	237.12199	65%	0.030111	3.58	65%
Promega UK Ltd	No			1336	1336	56	41	1.96471	239.08670	65%	0.029689	3.61	65%

Table 135: Deliveries (examples only) attributable to goods purchase orders FP2015-FP2016

Supplier	In pilot trial?	unique parcel/drop ratio
CPC/Farnell (Onecall)	Yes	4.15
Insight Direct (UK) Ltd	Yes	1.58
XMA Ltd	Yes	4.21
Rocom Group Limited	Yes	2.26
Getech Ltd	Yes	2.66

Table 136: Unique Parcel/drop ratios from pilot trial data

Once the numbers had been entered into the spreadsheet, the estimated daily drop rate for the University was 364 external freight vehicles per day making delivery drops.

Another way to judge this, from the analysis of dwell times in section 6.4.10, was that whilst there was no reliable bottom cut-off between 'kiss and drive' and a delivery, there was possibly a top cut-off between goods delivery and service visits (52 minutes), suggesting 148 service visit vehicles per day during the trial - slightly lower than the 194 calculated in Table 137 below.

Metric	Type of vehicle	
668	observed freight vehicles	
55	kiss and drive vehicles	8.07%
55	university vehicles	8.00%
364	deliveries from purchasing analysis	
194	service vehicle as remainder	
148	service vehicles as those above 52 minutes	

Table 137: Volume of external freight vehicles making delivery drops, mean average assumption

These two analyses are shown in Table 137 above. There was a difference between the traffic survey analysis and the purchasing data analysis, regarding the observed number of freight vehicles that could be classed as service. This suggested a gap in the demand data and, given the increasing numbers of students living on campus and the prevalence of purchasing for private use by staff, these may well have been food deliveries, Amazon logistics purchases, etc. This topic is now being separately being followed up in parallel research, so for the purpose of this evaluation the figure of 364 delivery drops was used.

10.9. Summary of empirical observations

The purchasing and traffic surveys provided excellent quantitative empirical contexts and baselines when compared between 2012 and 2015; compared to the operational data from the pilot, it was difficult to perceive any correlation between the pilot and the changes noted on the campus. By the closing months of the pilot, the average parcels per day was 10-11, compared to the target of 68-69 based on 343 parcels a week - a low level of performance, due mainly to reticence of the purchasing team. Therefore, a different evaluation approach was needed.

10.10. Quantitative quasi-experimental impact model

Surveys of University traffic in 2012 and 2015, relative to the low volumes of parcels carried through the CCCC, suggested that rather than pursuing statistical analysis to tighter and micro levels, a model using a quasi-experimental approach would be more helpful. Such a model would take the data from the operationally successful, but lower volume pilot and combine it with knowledge gleaned from the purchasing analysis and the traffic survey. This would then be scaled to model likely changes in freight vehicle volumes directly attributable to University purchasing demand. This baseline, and this scaled up model of activity, would then be combined with industry and research standard data to suggest the likely impact of such traffic on CO_2 emissions, NO_X and particulate matter. With multiple scenarios, this could then be used to approximate, with collected and standard data, the likely sustainability impact of a full scale pilot.

Most evaluation in this field had focused primarily on the operations of a single logistics provider, or scheme, servicing multiple clients - an approach championed in the literature by Leonardi and others (Léonardi and Baumgartner, 2004; Browne, Allen and Leonardi, 2011; Balm *et al.*, 2014; Leonardi and Yamada, 2017) to illuminate the benefit to a logistics operation of adopting various interventions from alternative propulsion vehicles, better routing systems, or recognition of the role of walking in final delivery.

What this approach did not yield was an understanding from the perception of a receiver, with goods delivered to, and serviced by, multiple logistics providers, in multiple transport chains and networks. Even microsimulation research carried out alongside this work, and on the campus, had a ‘network’ rather than ‘chain’ approach, and did not meet the evaluative perception of the receiver (Aditjandra *et al.*, 2016).

The early evaluation of the (then) emergent Binnenstad (BS) service in Nijmegen, in 2008, had been an example of the ambiguous nature of consolidation scheme evaluation. It was noticeable in the analysis that at first, four scenarios were evaluated: business as usual; partial use of the service for some part of the deliveries in the city; and two scenarios where *every single delivery in the city* was routed through the BS system (Quak and Tavasszy, 2011). The partial use analysis showed low sustainability benefits for the scheme, but the work then proceeded to support and promote the service on the basis of the total conversion of a city to a single service provider. That such a scheme could work in a non-EU, restricted entry city like Monaco, or a closed space such as Heathrow Airport, was well known (Allen *et al.*, 2012), but was not only *improbable* in an EU city, but also *illegal* under restriction of trade directives and legislation.

A different lens was needed, that would draw together the observed purchasing analysis, the traffic data, some external data about typical logistics distances between drops, standardised energy and emissions data, and the pilot operational data. I chose a quasi-experimental model, focused on using observed causal relationships between the baseline observed in 2012 and updated to 2015, the core data from the pilot, assumptions from the literature, and a scaled-up full implementation of the CCCC services as originally envisaged, with a parcel flow of 343, as noted in Chapter 7. This quantitative approach followed the classic research principles for conducting an experiment; however, whereas a true experimental design randomised between cases and different contexts, a quasi-experimental design made matched comparisons between the intervention and a baseline without it (Markiewicz and Patrick, 2016, p. 64). It was an approach that underlay many cost benefit analyses and ‘what-if’ business modelling.

Since the University, as well as Newcastle City Council and the North East Combined Authority (NECA), had expressed interest in planning the recommencement of the CCCC in 2017, possibly as a shared service, such a model would serve both for evaluation of this work and for future planning. Therefore, in order to judge the potential impact of scaling-up the consolidation centre pilot to as broad a range of goods types as possible, I adopted the approach of building a model.

10.11. Design of model

Given the nature of multi-drop delivery rounds, and also the likely shared utilisation of common carriers, a prudent approach one was adopted. This was based on reporting only measured reductions in emissions directly attributable to each delivery, based on the data collected during the pilot. Such a conservative approach was taken in this final evaluation. Further research gaps and opportunities were identified and are elaborated upon in 0 below.

At this point, consideration was given to whether the results or data from the LBCC pilot, which had run in parallel to this work in 2014-2015, had yielded data, methodology or results. There had been very limited data available from the pilot. In a procedia from the TRA conference 2016, it had been reported that:

- CO_2 emissions had been reduced by 7% to 1.33 kg per delivery/pick-up;
- the amount of PM had been reduced by 5% to 0.35 g per delivery/pick-up; and
- NOx emissions had been reduced by 6% to 35.7 g per delivery/pick-up.

The calculations above had led to suggestion that the economic and environmental impact of the LBCC was "marginal and therefore not obvious" (Clausen, Geiger and Pöting, 2016). However, no data on operational performance were available, nor the core impact reports cited by Clausen, making no further comparison possible at the time of this evaluation.

10.12. Stem distances and Logistics sprawl

Previously, goods had been delivered directly to University Sites, from multiple delivery rounds, performed by multiple carriers. This was often portrayed from the sole perspective of the receiver, as shown in Figure 94.

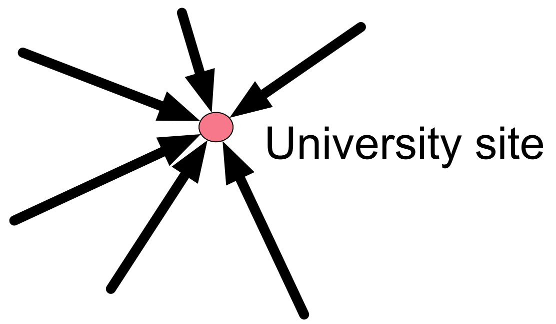

Figure 94: Simple view of deliveries into a single Site

This was better illustrated as a full delivery drop cycle of ‘stem’ distance to the first delivery drop, with each ‘leaf’ distance thereafter the movement between each drop, until the round was over.

In most cases the aggregate round could be known, with a simple averaging of leaf distances being adequate; this is illustrated below in Figure 95. More complex modelling could benefit from exact attribution of the leaf distances, but this was not needed here.

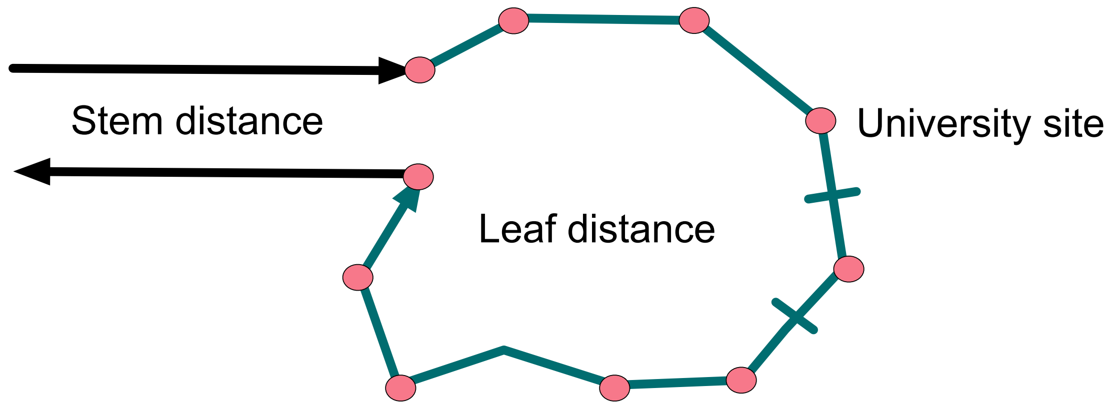

Figure 95: Generic delivery round showing stem and leaf structure.

This original model, essentially expressed from the perspective of the transport operator, was too simple, since the network of multiple carriers was better seen as a multiple overlaying of multiple stem and leaf delivery rounds, in which one drop-off zone occurred in multiple delivery rounds, as illustrated in Figure 96.

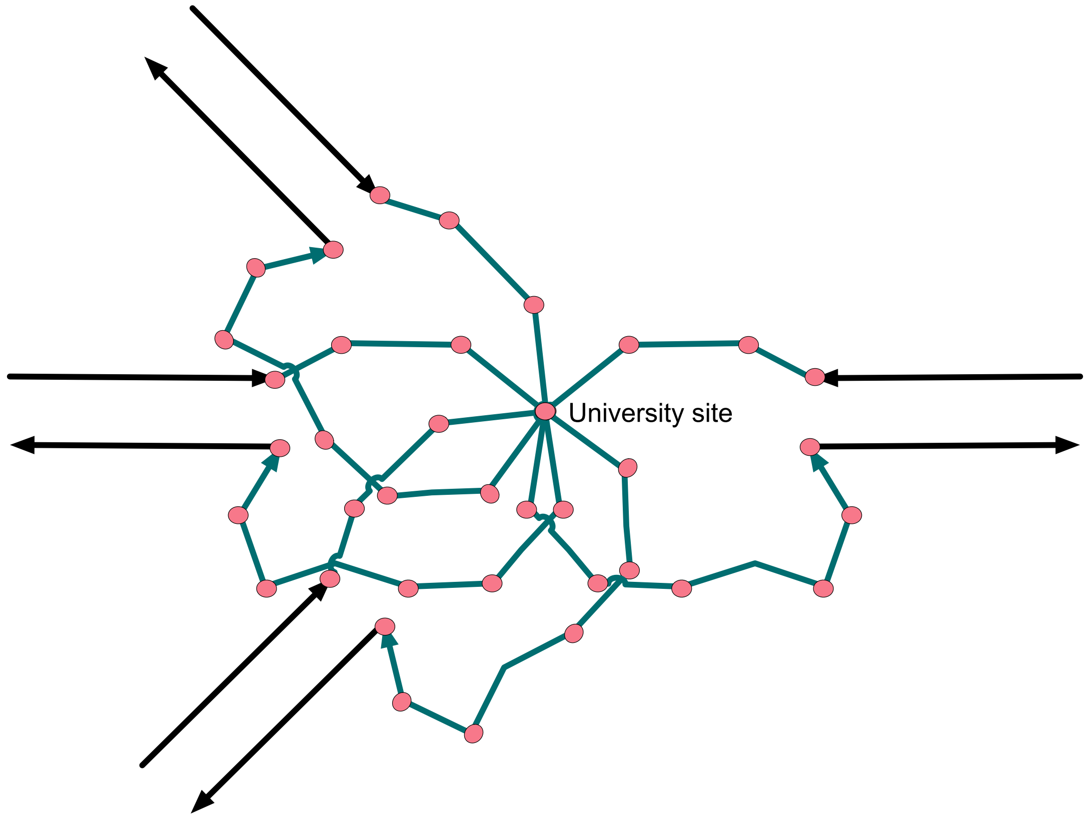

Figure 96: Generic multi delivery rounds showing stems and leaves

It was important to note that each delivery drop can legitimately have not just the leaf distance attributed to it, but also a proportion of the stem distance. Not all of the stem distance can be attributed to a delivery drop, but a proportionate attribution of that total stem.

Thus, the CCCC pilot scheme was best conceptualised as shown schematically below in Figure 97.

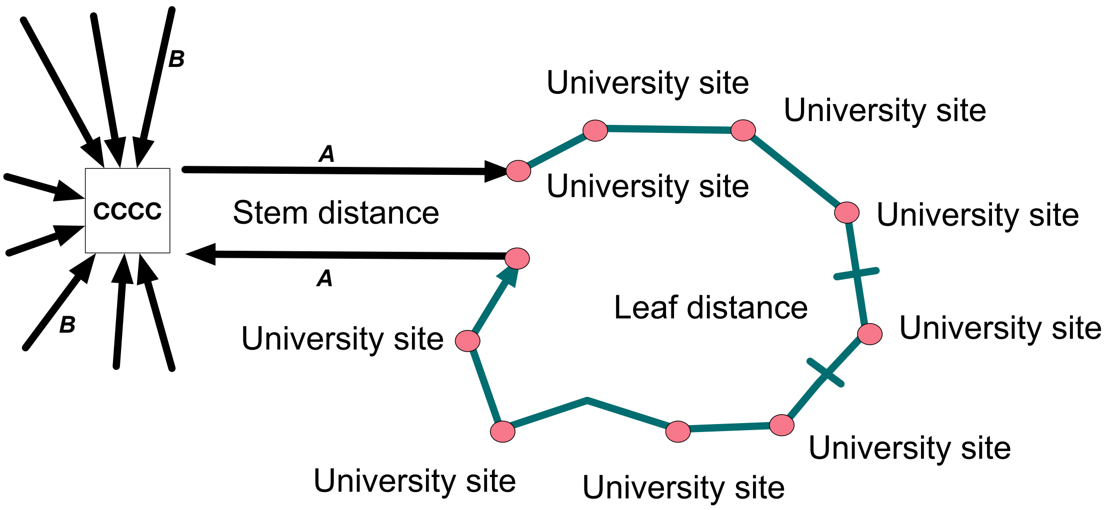

Figure 97: CCCC delivery round showing stem and leaf structures

Note that the stem distance in the CCCC example above may be very different from the many stem distances for the multiple delivery rounds illustrated in Figure 96 above. For example, pilot records showed that the goods delivered to the CCCC in the pilot came from multiple sources - some close, but some as far away as the Midlands. Whilst this may have been relevant in terms of the total transport chain, it was only relevant to assess how the utilisation of energy, CO_2, NO_2 and particulates had changed *within the new delivery round relative to the old multiple drop pattern*. Therefore, irrespective of the distance to the CCCC, denoted by *B* in Figure 97 above, the only relevant stem distance to be attributed in the baseline had to be *A*.

This was due to, and took account of, another key factor: the removal of a delivery drop in the pre-existing delivery rounds of the previous carriers was unlikely to be so important that it changed the round greatly or predictably.

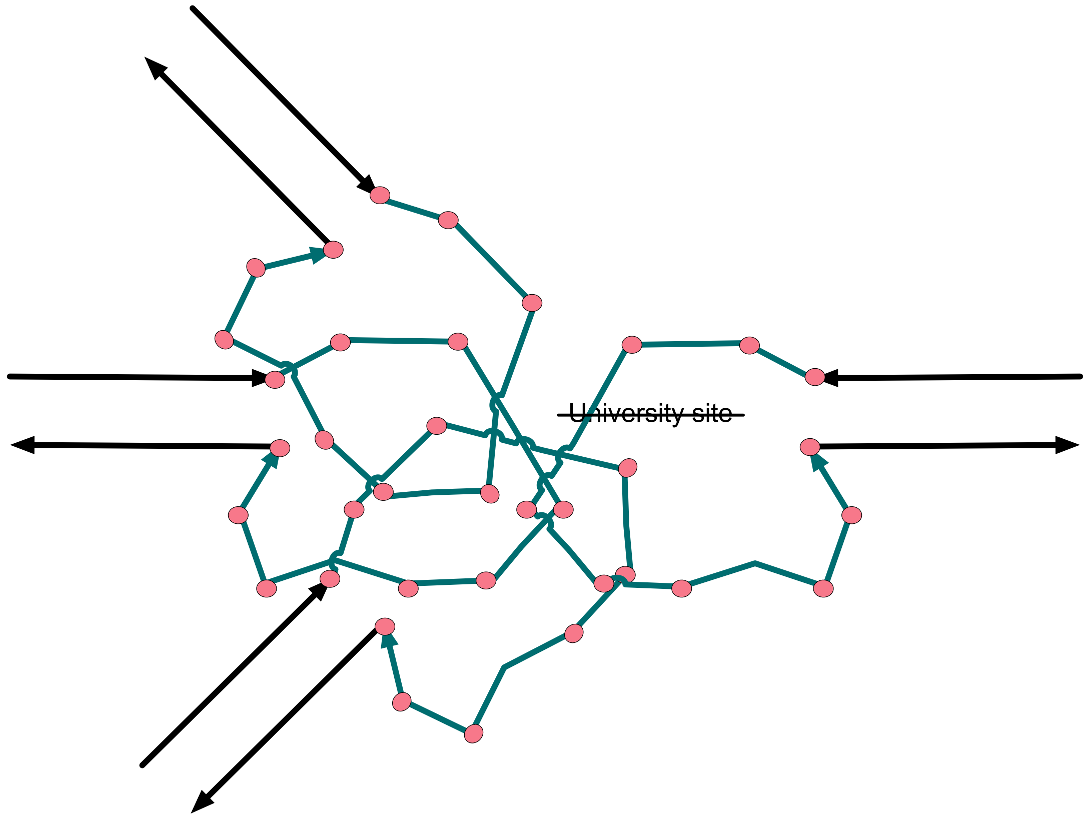

Figure 98: Generic delivery rounds following removal of a delivery drop

As can be seen in the generic pattern in Figure 98 above, the removal of a delivery drop may shorten or increase leaf distances; it may reduce the number of drops and increase the stem distance attributable to each; or the change may be subsumed in the regular dynamic ebb and flow of delivery patterns and daily schedules. The only example in this research where the move to the CCCC would have a significant effect on the delivery round was for Office Depot, where the round would be less sustainable *in the short term*, reducing the drops and therefore making the attribution of stem distance per leaf higher. This is why this particular supplier was not included in the pilot but, for future planning - with a *longer term horizon* - it would be reconsidered.

10.12.1. Typical logistics distances between drops

Figures from carbon auditing research into home delivery networks proved very useful. It was noticeable from the pilot development, detailed in Chapter 8 above, and from the pilot operational data, that the goods planned to use the CCCC were carried in parcels and delivered largely by parcel carriers. It had been reported by others that an average city centre parcel delivery round in the UK was 80 kilometres and 120 drops, while a city centre round was 40 kilometres and 110 drops (Edwards, Mckinnon and Cullinane, 2009). As long as the evaluation was of a subset of the items purchased by the University, and that subset was of goods suitable for a parcel delivery operation, then this delivery round profile was appropriate. As could be seen from a breakdown of the purchasing patterns of the University, a very large proportion of the goods delivered was well suited to a parcel delivery operation, as shown in Table 138.

Material Group Purchasing Analysis	Sum of Line Items FP2015-16	% of total	cumulative %
Goods-General Stationery	30214	13.62%	13.62%
Goods-General Chemicals	26816	12.08%	25.70%
Goods-Molecular Biology Reagents etc.	24676	11.12%	36.82%
Goods-Laboratory Equipment	21317	9.61%	46.43%
Goods-Electrical Sundries	11187	5.04%	51.47%
Goods-Antibodies	8073	3.64%	55.11%
Goods-Laboratory Plasticware	6717	3.03%	58.13%
Goods-Workshop/Maintenance Other	5903	2.66%	60.79%
Goods-Oligos/Primers	5745	2.59%	63.38%
Goods-Cleaning Consumables	5081	2.29%	65.67%
Goods-Computer Equipment	4834	2.18%	67.85%
Goods-Laboratory Glassware	4259	1.92%	69.77%
Goods-Safety/PPE Consumables	3910	1.76%	71.53%
Goods-Laboratory Gases	3906	1.76%	73.29%
Goods-Hand Tools & Workshop/Maintenance Equip	3841	1.73%	75.02%
Goods-Dental/Med Consumables	3487	1.57%	76.59%
Goods-Plumbing Sundries	3360	1.51%	78.11%
Goods-Office Equipment	3177	1.43%	79.54%
Goods-Tissue Culture Plastics	3013	1.36%	80.90%

Table 138: Top 80% of ordered material groups by line-item, FP2015 - FP2016

An assumed baseline generic delivery round was adopted from Edwards et al, then split into a 'stem and leaf' pattern. The 'stem' was the routing from the depot to the commencement of the round and then back again, at the end. The 'leaves' were the trip distance attributable to each drop. On Tyneside, the majority of parcel carriers operated from Team Valley or Follingsby Park, both in Gateshead and 6.4 km and 10.7 km respectively from the first drop zone at the Centre for Life in Newcastle. Since the location of a generic start point was not known for Newcastle upon Tyne, I assumed the same point of origin. This also reflected the discussion illustrated in Figure 97. For this estimate I constructed the delivery structure detailed in Table 139.

'Stem' distance averaging the two main distribution parks on Tyneside for CCCC	6.4km+10.7km/2 = 8.56km per leg or 17km per day (rounded)
Number of drops per generic non CCCC day	110 drops
Total generic non CCCC distance in a day	40km
Total generic non CCCC 'stem' distance	17km
Generic non CCCC distance attributable to each 'leaf'	(40km-17km)/110 = 0.209km
Generic non CCCC 'stem' distance attributable to each drop	(17km/110) = 0.155km
'Leaf' distance for complete CCCC round trip	6km [from Google Maps]
Number of drops per CCCC delivery route	50
Generic CCCC distance attributable to each 'leaf'	6km/50 = 0.120km

Table 139: Stem and Leaf Delivery Structure for Evaluation

As a cross comparison I summarised the findings of an urban consolidation scheme adopted by Office Depot in the City of London 2009-2010 (Leonardi, Browne and Allen, 2012). I was interested in the baseline 'before' summary, which is summarised in Table 140.

vans per day	7
stem km	29
parcels per van journey	168
km leaf distance in total	10
stops	20
parcels per stop	8.40
km per stop	0.50
spent unloading and delivering on foot	48%
total time per journey	03:41:00

Table 140: City of London Stem and Leaf Delivery Structure for Comparison, from (Leonardi, Browne and Allen, 2012)

Given the much higher density of the City of London (daytime working population excluding tourists of 5,691 people per square kilometre (Piggott, 2014)) versus that of

Newcastle upon Tyne (2,613 people per square kilometre (ONS, 2017)), this could not replace the working assumptions for generic delivery rounds. Therefore, pending evidence to the contrary, I adopted the UK average numbers from Edwards et al (2009), as listed in Table 139. These seemed more appropriate for a medium-sized English city.

10.12.2. Standardised UK energy and emissions data

The UK Government provided GHG Conversion Factors for Company Reporting (BEIS, 2017). These listed CO_2e and NO_2 emission figures per km travelled, for a range of delivery vehicles using UK derived sources for fuel use, fuel sourcing, and the energy mix of electricity generation. Other evaluation approaches often utilised fuel consumption in litres of diesel and converted that to CO_2e and NO_2 but, given the availability of UK focused standardised data for company reporting, this work has used those official data.

Electricity generation in particular could vary widely across Europe, from nuclear-powered generation in France, or hydro-electric generation in Norway, to brown coal generation in Poland. The UK Government conversion factors were based on the energy mix of generation in the UK and the transmission losses on its National Grid and local regional distribution networks. Of note was that a company purchasing certified carbon neutral energy, from renewable sources, could report that it used zero carbon in its reporting of electricity use: the government had allowed for this in the carbon conversion factors.

Since the range of electric battery powered vehicles in the official conversion factors only covered light vans up to 3.5t, for the Smith Newton vehicle it was necessary to use the energy conversion and efficiency supplied from telemetry data, to create a unique conversion per km for the pilot vehicle.

10.12.3. Conversion Factors

For NO_2 and CO_2e I used the latest UK Government GHG Conversion Factors for Company Reporting 2017 1.0. These provided both emissions as a conversion factor for LGV and HGV freight vehicles, in various gross vehicle weight classes and, in the case of HGVs, at different levels of loading. For CO_2e these were expressed as kilogrammes per kilometre travelled, and for NO_2 as grammes per kilometre. Factors were also provided in the same format for battery powered EV vans and, in addition, for electricity generation, in kWh. This last factor could be combined with the energy consumption of an EV for which the government had no available data. The conversion factors were based upon the fuel types and mix usually used to fuel diesel vehicles in the UK, as well the mix of hydrocarbon, nuclear and renewable energy generation in the relevant electricity generation supply. Of note is that this was not provided by class of vehicle engine type, such as Euro 5 or 6.

I used the Smith Electric Newton's inbuilt telemetry software that recorded energy consumption to define a unique emission conversion factor for the vehicle.

With the kind use of PHEM (Hirschmann *et al.*, 2010) software, licensed by colleagues at the Transport Systems Catapult[38], various particulate emissions levels associated with different drive cycles were generated. PHEM was developed to simulate a full fleet of heavy-duty vehicles, passenger cars, and light commercial vehicles. The supporting data-set included gasoline and diesel vehicles, from EURO 0 to EURO 6, and calculated vehicle fuel consumption and emissions using speed trajectories as model input.

PHEM had the ability to use modelled 'drive cycles', to further model the different performance of a vehicle in different situations. The major alternative drive cycles available were the Federal Test Procedure (FTP) (United States Environmental Protection Agency (EPA), 1978); the London Drive Cycle (LDC) (Transport For London, 2016); Worldwide harmonized Light vehicles Test Procedure (WLTP) (May *et al.*, 2012); and the Common Artemis Driving Cycles (CADC) (André and Andre, 2004; Boulter and McCrae, 2007). These were all 'transient' drive cycles that reflected changes in driving patterns between stop-start city driving, suburban driving, and motorway driving. TfL had found these transient drive cycles to be more appropriate than the 'modal' cycle approach used in the New European Driving Cycle (NEDC), which was based on protracted periods at constant speeds and had been criticised for generating figures unachievable in actual driving conditions (Transport For London, 2016). WLTP was worldwide; FTP was US based; CADC was homogenised for average European conditions; and LDC was UK based. Whilst London was not Newcastle-upon-Tyne, I nevertheless considered a UK transient model to be the best option available for emissions model data and duly adopted it.

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[38] *https://ts.catapult.org.uk*

This and the relevant conversion factors are listed in Table 141.

Parameter	Metric	*notes*
LGV Average (up to 3.5 tonnes) diesel kg CO_2e per km	0.25749	UK Government 2017 1.0
HGV All rigids 50% laden diesel kg CO_2e per km	0.78189	UK Government 2017 1.0
LGV Average (up to 3.5 tonnes) diesel kg NO_2 per km	0.00187	UK Government 2017 1.0
HGV All rigids 50% laden diesel kg NO_2 per km	0.00763	UK Government 2017 1.0
Battery Electric Vehicle 3.5t electricity generation CO_2e per km (UK mix)	0.07848	UK Government 2017 1.0
Battery Electric Vehicle 3.5t electricity generation NO_2 per km (UK mix)	0.00047	UK Government 2017 1.0
Electricity generation UK Mix CO_2e per kWh	0.35156	UK Government 2017 1.0
Electricity generation UK Mix NO_2 per kWh	0.00209	UK Government 2017 1.0
Smith Electric's Newton pilot CCCC vehicle kWh per km	0.82625	Smith Electric data 02-Feb-2015
Smith Electric's Newton pilot CCCC vehicle CO_2e per km	0.29048	Derived from above
Smith Electric's Newton pilot CCCC vehicle NO_2 per km	0.00173	Derived from above

Table 141: Conversion Factors for Evaluation

10.13. Particulate Material

No standardised UK emission data existed for particulates; I therefore used a dataset extracted from PITHEM, by Dr. Paul Goodman of Newcastle University. This dataset was an interpretation of the data in the Emissions Factor Toolkit Version 5.1.3 (a mix of Earlier TRL emissions, and COPERT4 v8 data) (Goodman *et al.*, 2014; Goodman, 2017). It was structured as a series of PM_{10} g/km travelled emission factors, by the distance travelled in the trip, as well as the vehicle class. For this thesis I evaluated PM_{10}, rather than $PM_{2.5}$, it having the greater regulatory importance for planners at the time.

Proportion of vehicles observed by vehicle class	
Proportion of HGV Euro III or less	6.70%
Proportion of HGV Euro IV	23.11%
Proportion of HGV Euro V	47.86%
Proportion of HGV Euro VI	22.33%
Proportion of LGV Euro 3 or less	4.75%
Proportion of LGV Euro 4	25.21%
Proportion of LGV Euro 5	69.61%
Proportion of LGV Euro 6	0.44%

PM_{10} emissions 2017 (based on PITHEM extract from Dr Paul Goodman)	leaf 5km rate	stem 40km rate
Particulate g/km (Euro III-)	0.740081	0.299258
Particulate g/km (Euro IV)	0.291599	0.146168
Particulate g/km (Euro V [EGR and SCR are equivalent])	0.295565	0.146872
Particulate g/km (Euro VI)	0.129197	0.114328
Particulate g/km (Euro 3-)	0.101639	0.0561816
Particulate g/km (Euro 4)	0.0793686	0.0502087
Particulate g/km (Euro 5)	0.0400218	0.0400218
Particulate g/km (Euro 6)	0.0400218	0.0400218
Particulate g/km (EV) EFT5.1/PITHEM	0.02792	

Table 142: PM10 emissions data

Proportional allocation of PM_{10} by vehicle classes observed as g/km	leaf 5km rate	stem 40km rate
Particulate g/km (Euro III-)	0.049578242	0.020047381
Particulate g/km (Euro IV)	0.067379186	0.033774742
Particulate g/km (Euro V [EGR and SCR are equivalent])	0.141469461	0.070298928
Particulate g/km (Euro VI)	0.028849816	0.025529553
Particulate g/km (Euro 3-)	0.004825756	0.002667467
Particulate g/km (Euro 4)	0.020005834	0.012655722
Particulate g/km (Euro 5)	0.027857521	0.027857521
Particulate g/km (Euro 6)	0.000176081	0.000176081
Particulate g/km observed HGV fleet	0.287276705	0.149650604
Particulate g/km observed LGV fleet	0.052865192	0.043356791

Table 143 PM10 emissions interim calculations

From the dataset, I assigned the 5km distance to the leaf distances and the 40km distance to the stem distances. By allocating a proportion of each vehicle class emissions, in line with the observed proportion of vehicle classes in the 2015 survey, it was possible to create a typical emission rate of PM_{10}, for the observable fleet, as g/km on the campus. The key metrics and derived data are illustrated in Table 142 & Table 143, above.

One caveat was that the dataset had no variance for the PM emitted from battery electric vehicles by mileage. It did have a figure for 'urban cycle' and 'motorway', so the first was used for this modelling.

10.14. Scenarios

In this quasi-experiment, 6 scenarios were tested to analyse the impact of a fully scaled-up pilot replacing 69 parcels a day within a new CCCC service. The scenarios were developed iteratively, as parameters were adjusted in a One at A Time (OAT) sensitivity analysis, with experts' opinion taken and given at each stage.

A. Business as usual
B. Consolidation using a diesel rigid HGV [Luton Van]
C. Consolidation using the SMITH Electric 10.5t rigid EV HGV
D. Consolidation using two 3.5-5.5t GVW electric vans
E. Consolidation using two 3.5t-5.5t GVW electric vans at higher utilisation
F. A baseline business as usual with 80% generic deliveries and 20% one-offs

Scenario A was the baseline, utilising the adopted assumptions of a generic delivery round for a UK city centre parcel delivery operator (Edwards, Mckinnon and Cullinane, 2009) with no form of consolidation scheme at the University.

Scenario B was the CCCC pilot scheme, scaled at the original target levels of 69 parcels per day, displacing 50 delivery drops at the campus. However, this scenario evaluated a diesel HGV rigid of similar size to the Smith Electric actually used.

Scenario C was the CCCC pilot scheme, scaled at the original target levels of 69 parcels per day, displacing 50 delivery drops at the campus. This scenario evaluated the SMITH Electric 10.5t rigid EV HGV actually used, collecting operational data from the vehicle telemetry.

Scenario D was the CCCC pilot, scaled at the original target levels of 69 parcels per day, displacing 50 delivery drops at the campus, but using twin 3.5t-5.5t GVW battery electric powered vans.

During the evaluation process, it became clear that another evaluation scenario merited analysis, which was added as Scenario E.

Scenario E was an alternative scenario that postulated that the CCCC could operate with the same operational parameters as the generic parcel delivery operation in Scenario A, with 110 drops a day rather than the 50 in the originally targeted CCCC level, and using the twin EVs of Scenario D.

Scenario F was an alternative scenario that postulated that the baseline was split as in a pareto analysis: 80% of generic deliveries (110drop/40km), with 20% of deliveries made by a vehicle that made a single one-off delivery in Newcastle upon Tyne before continuing on a much wider delivery route in the North of England. For this scenario, I adopted the same model as Scenario E: 110 drops and twin EV vans.

10.14.1. Core parameters

These scenarios were built on the assumed continuance of all deliveries by various suppliers and carriers; the model therefore adopted the following key parameters, detailed in Table 144:

Parameter	Metric	*notes*
Average daily parcels into CCCC (consolidated)	69	*original forecast (see Chapter 8)*
Ratio of parcels per incoming vehicle	1.36	*average ratio from pilot operational data (Chapter 9)*
Average daily incoming vehicles to University Sites (non-consolidated)	50	*original forecast (see Chapter 8) rounded*
Observed freight vehicles on campus daily	364	*2015 traffic survey*
Average daily vehicles from CCCC to University Sites (consolidated)	1	*if using 10.5-12t GVW rigid HGV [scenario B and C]*
Average daily vehicles from CCCC to University Sites (consolidated)	2	*if using 3.5t-5.5t EV LGVs [scenario D]*
Proportion of vehicles that are HGV	16%	*from traffic survey 2015 (Chapter 10), all assumed to be diesel*
Proportion of vehicles that are LGV	84%	*from traffic survey 2015 (Chapter 10), all assumed to be diesel*
Working days	250	*5 day week*
Stem distance from new CCCC kilometres (total for whole round)	17	*Team Valley or Follingsby Park (average)*
Leaf distance for whole CCCC round trip kilometres	6	*from Google Maps*
Stem distance for non CCCC delivery km per drop as a proportion of whole round of 110	0.364	*see section 10.12.1 above*
Leaf distance for non CCCC freight delivery km (40km-17km/110drops)	0.209	*see section 10.12.1 above*
Stem and leaf distance for 1 non CCCC freight delivery to University Sites km	0.364	*see section 10.12.1 above*
Share of stem distance for CCCC delivery km per drop as a proportion of whole round of 50 per day	0.340	*see section 10.12.1 above*
Leaf distance for CCCC freight delivery km (6/50)	0.120	*see section 10.12.1 above*
Stem and leaf distance for 1 CCCC freight delivery to University Sites km	0.460	*see section 10.12.1 above*

Table 144: Operational Parameters for Evaluation

10.14.2. Scenarios A-D emission evaluation results

The first run is reported in Table 145 and Table 146.

It showed that the CCCC, using the original target levels of parcels and trips, decreased the CO_2e emissions in scenarios C and D, compared to the baseline. In scenario B, a CCCC using a diesel rigid, the service would use an extra 2052 kg of CO_2e per annum, due to: the use of a heavier vehicle than the LGVs that made up 84% of the existing vehicle visits; the higher level of CO_2e emissions from such a vehicle; and the far greater allocation of stem and leaf distances to the vehicle than the equivalent generic vehicle in a more productive route.

In scenario C - effectively the originally targeted CCCC pilot levels - a small absolute saving of 774kg of CO_2e per annum (32%) was predicted. If the Smith Electric vehicle were replaced by two 3.5-5.5t battery electric vehicles, the saving rose to 1542kg per annum. The relative inefficiency of using a large electric HGV rigid on this CCCC scheme, with a CO_2e kg per km of 0.29048 versus the smaller LGVs with a CO_2e kg per km of 0.07848, was clearly shown. This did not mean the Smith Electric vehicle was poor for its type and class, but simply that the extra volume and weight of such a large vehicle was unsuited to this example. In this scenario PM_{10} fell by 350.04g, or 69%.

NO_2 savings followed a similar pattern per annum: a rise in scenario B of 23.91kg; a fall of 10.03kg (50%) in scenario B; and a fall of 14.55kg (73%) in scenario D. For PM_{10} the figures were 481.96g (94%) for scenario B, and 189.50g (37%) for D. Note that when using a single diesel HGV for the CCCC in scenario B, whilst CO_2e rose, PM_{10} fell: particulate matter appeared to be more reducible by using fewer vehicles, than any other emission.

The approach of assessing the CCCC versus the small proportion of a wider generic delivery round, captured the minimal network effect that such a scheme would have on the emissions in the city as a whole. The proportional drops in emissions were significant, but the absolute reductions were very small. The University itself had a targeted level of justifiable expenditure of £100-£120 per tonne of CO_2e saved per investment. The UK Government's (then) current central forecast carbon trading value for policy appraisal was around £4.18 per tonne of CO_2e, rising to £55.33 by 2017 (Department of Energy and Climate Change, 2017, p. 4). The return on almost any investment beyond a nominal amount could not be justified by these CO_2e savings.

Scenario	A	B	C	D
Daily vehicle traffic	Non-consolidated (no CCCC)	Consolidated through CCCC using diesel HGV rigid (Luton Van)	Consolidated through CCCC with NEWTON 10.5t	Consolidated through CCCC with twin 3.5-5t EV
Vehicles onto University Sites	50.00	1	1	2
HGV vehicles onto University Sites	8.00	1		
LGV vehicles onto University Sites	42.00			
EV vehicle onto University Sites			1	2
HGV kilometres attributable to campus	4.58	23.00		
LGV kilometres attributable to campus	24.05			
ICE kilometres attributable to campus	28.64	23.00		
EV kilometres attributable to CCCC			23	46

HGV heavy goods vehicle, primarily rigids on University main campus
LGV light goods vehicles, usually 3.5t, assumed to be diesel
ICE internal combustion engine
EV electric powered motor vehicle
CO_2e CO_2 equivalent
NO_2 nitrous dioxide
PM particulate matter

Table 145: First run evaluation operations

Scenario	**A**	**B**	**C**	**D**
Daily vehicle traffic	Non-consolidated (no CCCC)	Consolidated through CCCC using diesel HGV rigid (Luton Van)	Consolidated through CCCC with NEWTON 10.5t	Consolidated through CCCC with twin 3.5-5t EV
CO_2e emissions				
CO_2e emissions generated per day by HGV kg	3.5825	17.9835		
CO_2e emissions generated per day by LGV kg	6.1938			
CO_2e emissions generated per day by EV kg			6.6810	3.6101
CO_2e emission generated per day by all deliveries kg	9.7763	17.9835	6.6810	3.6101
CO_2e emissions over a 250 day year kg	2444	4496	1670	903
Saving in CO_2e emissions 250 work day year kg		-2052	774	1542
		-84%	32%	63%
NO_2 emissions				
NO_2 emissions generated per day by HGV kg	0.0350	0.1755		
NO_2 emissions generated per day by LGV kg	0.0449			
NO_2 emissions generated per day by EV kg			0.0397	0.0216
NO_2 emission generated per day by all deliveries kg	0.0798	0.1755	0.0397	0.0216
NO_2 emissions over a 250 day year kg	19.96	43.87	9.93	5.41
Saving in NO_2 emissions 250 work day year kg		-23.91	10.03	14.55
		-120%	50%	73%

Table 146: First run evaluation CO_2e and NO_2 comparisons

Scenario	A	B	C	D
Daily vehicle traffic	Non consolidated (no CCCC)	Consolidated through CCCC using diesel HGV rigid (Luton Van)	Consolidated through CCCC with NEWTON 10.5t	Consolidated through CCCC with twin 3.5-5t EV
PM10 emissions (based on PITHEM extract from Dr Paul Goodman)				
PM emissions generated per day by HGV g	5.7243	0.0854		
PM emissions generated per day by LGV g	1.1264			
PM emissions generated per day by EV g			0.6422	1.2843
PM emission generated per day by all deliveries g	6.8507	0.0854	0.6422	1.2843
PM emissions over a 250 day year grammes	1712.67	21.34	160.54	321.08
Saving in PM emissions 250 work day year grammes		1691.34	1552.13	1391.59
		94%	69%	37%

Table 147: First run evaluation PM_{10} comparisons

10.14.3. Scenario E emission evaluation results

The greater carbon savings available within Scenario D, and the minimal increase in vans on campus, deserved further attention. The assumed generic delivery round from Edwards *et. al.* and also the Gnewt cargo data from Leonardi *et. al.* had suggested that 110 parcels per round was quite achievable. I also talked to IVECO, with whom I had worked on EV developments in Como, Italy, and noted that they were bringing to market, in 2017, an EV battery powered van nominally LGV but with longer wheelbase and box configurations (IVECO, 2017).

Given this, and a confirmation that higher numbers of parcels were deliverable in a delivery round, I evaluated a 110 drop, or 149 parcel delivery round, assuming the same 1.36 parcel to drop ratio from the trial. This evaluation, detailed below in Table 148, showed greater projected emissions savings of about 4474kg of CO_2e, 38.50kg of NO_2 and (perhaps) 1.691kg of PM_{10} per annum; however, these were still not of a volume that justified intervention on the basis of emissions alone.

10.14.4. Scenario F emission evaluation results

I knew that the origin and destination of vehicles coming to the campus could make a significant difference to the emissions savings attributable to the scheme, in absolute terms. I checked the supplier details stored on the SAP system but, unfortunately, they had been updated with the registered office of the supplier, in the move to outsourced purchase ledger and invoice paying, some years previously. The address stored for a supplier now often had no relation to the origin of any vehicle. Even with the despatch address, many vehicles would have been the final 'spoke' delivery of a 'hub and spoke' network. Such a last mile delivery would quite probably have come from Team Valley or Follingsby Park.

However, when discussing the results with transport planners in the city, and in the region, as well as with fellow academics and logistics operators, it was clear that some proportion of the vehicles visiting the University may have had only one drop in the city, within a delivery route that covered a much wider part of the North of England. In the absence of resources to carry out a full origin-destination survey, from which to build an 'O-D' matrix, I adopted the pareto 80/20 rule and analysed a scenario where 80% of all vehicles followed the efficient local model of 110 drops over 40km, but 20% made a visit to campus, made a one-off drop, and left the city to deliver elsewhere. In this scenario the whole stem distance of 17km, and a nominal individual leaf of 0.12km, were taken into consideration. The higher efficiency 110 drops, twin EV approach of Scenario E would be used to calculate savings. This scenario (again see Table 148 below) exhibited substantial absolute emission savings of 106543 kg (circa 107t) of CO_2e per annum - an 88.89% reduction. Savings of 871.98kg of NO_2 would be made - a reduction of 89.09% - and PM_{10} per annum would be reduced by 23.78%, or 1186.27g. Since the University bought all electricity from carbon neutral sources, it would be legitimate to view those savings as 119862kg (circa 120t) of CO_2e per annum, and 979kg of NO_2.

Such savings would make the CCCC attractive on the basis of emissions savings alone.

Scenario	F	E
Daily vehicle traffic	Total non-consolidated 80% generic/20% one drop only	Total vehicular traffic with scenario E
CO_2e emissions		
CO_2e emissions generated per day by HGV kg	175.69	18.20
CO_2e emissions generated per day by LGV kg	303.76	31.46
CO_2e emissions generated per day by EV kg		3.61
CO_2e emission generated per day by all deliveries kg	479.45	53.27
CO_2e emissions over a 250 day year kg	119861.92	13318.44
Saving in CO_2e emissions 250 work day year kg		106543.49
Saving in CO_2e emissions 250 work day year %		88.89%
NO_2 emissions		
NO_2 emissions generated per day by HGV kg	1.71	0.18
NO_2 emissions generated per day by LGV kg	2.20	0.23
NO_2 emissions generated per day by EV kg		0.02
NO_2 emissions generated per day by all deliveries kg	3.92	0.43
NO_2 emissions over a 250 day year kg	978.77	106.79
Saving in NO_2 emissions 250 work day year kg		871.98
Saving in NO_2 emissions 250 work day year %		89.09%
PM_{10} emissions 2017 (based on PITHEM extract from Dr Paul Goodman)		
PM_{10} emissions generated per day by HGV g	9.2533	6.4570
PM_{10} emissions generated per day by LGV g	10.6985	7.4654
PM_{10} emissions generated per day by EV g	0.0000	1.2843
PM_{10} emission generated per day by all deliveries g	19.9518	15.2067
PM_{10} emissions over a 250 day year grammes	4987.95	3801.68
Saving in PM_{10} emissions 250 work day year grammes		1186.27
Saving in PM_{10} emissions 250 work day year %		23.78%

Table 148: Evaluation of emissions reductions Scenario E versus Baseline F

10.15. Evaluation of vehicle visits reductions

The carbon and emissions savings of the scaled-up CCCC could be minimal on a conservative model, or impactful on a pareto model, but the desired goal for the

University, as part of the Coherent Campus policy, was a reduction in freight vehicles on campus - a lower level of intrusion. 668 freight vehicles were observed as a mean daily average in the 2015 traffic survey, as detailed in Table 137. How many of these could be removed from campus if the CCCC were to scale-up to the targeted level of operation? As shown in section 10.8.1 above, out of the 668 total freight vehicles observed, 364 visits to campus were goods related. Of these, either 50 vehicles could be removed in scenario D, or 110 vehicles in scenarios E or F.

As shown in Table 149 below, scenarios D and E/F could reduce the total number of freight vehicles, of any type, by 7.19% and 16.17% respectively and, when compared to external freight vehicles making a delivery drop, by 13.19% and 29.67% respectively. These were reductions of such scale that they needed to be evaluated for value by the University, for a renewal of the CCCC service.

Scenario	A	D	D	E	E	D	E
Daily vehicle traffic	Total non-consolidated	Remainder if scenario D CCCC	Consolidated through CCCC with twin 3.5-5t EV	110 drop CCCC with twin EV	Remainder if scenario E CCCC	Total vehicular traffic with scenario D	Total vehicular traffic with scenario E
Vehicles onto University Sites	364	314	2	2	254	316	256
HGV vehicles onto University Sites	58	50			41	50	41
LGV vehicles onto University Sites	306	264			213	264	213
EV vehicle onto University Sites			2	2		2	2
HGV kilometres attributable to campus	33.36	28.77			23.28	28.77	23.28
LGV kilometres attributable to campus	175.12	151.06			122.20	151.06	122.20
ICE kilometres attributable to campus	208.47	179.84			145.47	179.84	145.47
EV kilometres attributable to CCCC			46.00	46.00		46.00	46.00
HGV vehicle reduction on campus						8	18
LGV vehicle reduction on campus						42	92
EV vehicle reduction						-2	-2
Total freight vehicle reduction on campus as a % of 668						7.19%	16.17%
Total freight vehicle reduction on campus as a % of 364						13.19%	29.67%

Table 149: Evaluation of vehicle visits reductions, Scenarios D and E versus Baseline A

10.15.1. *Operational caveats*

The operational issues associated with the CCCC, in any scenario, would lie in the receiving side of the operation. In scenarios B, C and D, the CCCC would have to receive, unload and process 50 vehicles a day, and in scenario E, 110 a day. These would most likely arrive in the morning. Whilst the pilot was carried out at a very large distribution centre, with many loading docks, the sheer volume of vehicles for a future CCCC would be a major issue to address.

10.15.2. *Summary and Conclusion of Impact Model*

A quasi-experimental evaluation model was adopted, since the empirical observations of purchasing data, traffic survey data, and the pilot operational data did not yield statistical results able to suggest the emission and vehicle reduction targets of the CCCC scheme. This approach suggested that the impact of any CCCC scheme would depend very much on the origin and onward destination of vehicles to campus.

A very conservative evaluation for the originally targeted pilot CCCC operation, of 69 parcels a day, using a 10.5t Smith Electric Newton vehicle, suggested a very small effect on reducing emissions of CO_2e, NO_2 and particulate matter - as low as 774kg of CO_2e and 10.03kg of NO_2 per annum. Given the current state of uncertainty on PM_{10} emissions from EVs, then all results on such savings were placed to one side.

Other scenarios were explored and, the most promising, 149 parcels a day delivered in two 3.5t-5.5t battery electric vans, yielded 4474kg of CO_2e and 38.50kg of NO_2 saving per annum. The small reductions were due to the small proportion of the overall stem and leaf distances that could be attributed to the CCCC from the wider network of carriers delivering to a multiplicity of delivery locations across the city.

However, discussion with colleagues and experts suggested a scenario based on a pareto split of vehicles: 80% part of a 110/40km delivery route, and 20% that entered the city for a single drop at the University before travelling elsewhere. This scenario suggested savings of about 107t of CO_2e and 872kg of NO_2 per annum.

The key aim of the University's Coherent Campus policy was to reduce freight vehicles on campus. To that end, the reduction of freight vehicle numbers was more interesting. The most promising operational approach could save 16.17% of all freight vehicles engaged in any activity on campus and 29.67% of all external freight vehicles engaged in delivery.

The effect on traffic volumes at the city level was proportionally lower. The Newcastle Central cordon was observed in 2016 to have 6076 LGV and 1056 LGV movements (Newcastle City Council, 2016). On that basis, the best CCCC scheme would reduce numbers by 185 LGV and 35 HGV movements, 3.04% and 3.33% respectively.

10.16. Combined Quantitative and Qualitative assessment

Having completed quantitative, statistical, and quasi-experimental approaches to evaluation, it was now appropriate to combine the quantitative and qualitative into a combined assessment. This would mix quantitative and qualitative research methods in an integrated fashion, within the structure of summative evaluation through the DMF, and formative evaluation through the BMC.

The intent was to achieve complementary elaboration and clarification of results, from one method to another, to enable Triangulation to achieve convergence, corroboration, and correspondence of results from the different methods. This was done in the way that the summative and formative evaluations were evaluated, using the mix of quantitative and qualitative results as previously listed in Table 106 and Table 107. Using updated versions of these two tables, and the data already reported in Chapters 6 through 10, it was possible to address the targets and indicators of the DMF and answer the questions of the BMC below, in Table 150 & Table 151.

10.16.1. Summative DMF evaluation

The DMF was primarily a summative evaluation, concerned with making judgements about overall performance, more focused on the identification results, and usually at the end of a clear passage of time, or at the end. The pilot could be seen as the end - albeit a pause before a future scheme – and, as such, the results are laid out in Table 150.

Design summary (short version)	Performance indicators/targets	Data sources/reporting mechanisms	Evaluation
Improved urban freight at Newcastle University (Impact)	A: Increased stakeholder satisfaction by University Executive Board, by a reduction of freight vehicles on campus of 25% by end 2019.	Traffic surveys. Interviews and reviews with University Exec Board.	The traffic survey showed no reduction in traffic due to the pilot trial. The quasi-experimental model suggested 16.97% or 29.67%, dependent on definition. The University decided to continue with the pilot and, as of late 2017, had scheduled its scaling-up and recommencement.
Comprehensive University campus strategy embedding a delivery and servicing plan strategy – Delivery Strategy (Outcome)	C: One detailed policy action of new purchasing strategy implemented as pilot by 2014, one implemented as a working service by 2019.	Official publications of procurement team of the Campus	The University adopted the CCCC scheme and implemented the procurement and operational policy to implement it.
Procurement of electric vehicles as part of the University fleet (Outcome)	D: One new EV added to the University's own fleet by end of 2015	Official publications of campus procurement team	Separate to this piece of work, 8 EVs were purchased and replaced ICE vehicles in the University fleet (as at September 2017).

Design summary (short version)	Performance indicators/targets	Data sources/reporting mechanisms	Evaluation
The take up of external/internal consolidation centre via procurement contract – decongesting the Campus (Outcome)	E: Increased number of CCCC deliveries, 60% via CCCC versus direct deliveries & absolute target of 80 parcels a day, of those goods or suppliers suitable for the pilot by end 2015	CCCC productivity and vehicle use data	The pilot did not meet the original target of 69 parcels a day, nor the end goal of 80 in the DMF.
	F: Decreased total freight transportation costs (-5% cost/day) expressed as the cost of the transport operation, and as the purchase cost by 2019	No clarity on source!	This proved to be unmeasurable given that the cost of transportation could not be extracted separately from the costs of goods.
The uptake of clean vehicles to demonstrate the commercial viability and environmental benefits of (hybrid-) electric freight vehicles (Outputs)	G: Increased number of EVs on campus, one by end 2015.	Project outputs	By September 2017 the University alone ran 8 vehicles on campus.
	H: Decrease of emissions levels (CO_2, PM_x, NO_x) -25% of CO_2e by 2019.	Estimates on emissions based on fleet activity reports and factors for vehicles Fleet activity reports	The low pilot activity was substituted by the quasi-experimental model results which showed likely savings of 107-120t of CO_2 per annum, and 872kg-979kg of NO_2. In percentage terms this equated to 88.89%-100% of $CO2_e$ and 89.09%-100% of NO_2.

Design summary (short version)	Performance indicators/targets	Data sources/reporting mechanisms	Evaluation
Correctly parked freight vehicles via dedicated IT-solutions for planning and driver support with access maps for deliveries (Outputs)	I: Decreased number of illegally parked vehicles on campus, noticeable reduction by walking the Site.	Questionnaire among campus users. University staff measuring strategy violations.	Although not part of this piece of work, a survey was done of University staff on these matters, and was published 2017 (Aditjandra and Zunder, 2017)
Co-ordinated freight deliveries including … an urban consolidation centre and the effects of the procurement policy (Outputs)	J: Recruitment of 20 suppliers to a pilot trial by end 2015. Negotiation of a contract with a provider of the centre by end 2013.	CCCC performance data. Fleet activity reports. Smartfusion project outputs.	35 suppliers were converted to the scheme and yet only 18 made deliveries. A contract was negotiated and let to Clipper Logistics, in line with the deadline.

Table 150: Newcastle DMF targets and indicators addressed

10.17. Formative BMC evaluation

An evaluation was considered formative when it adopted a focus on processes and implementation, with the aim of improving design and future performance. A BMC was a tool to generate business models and then to assess and improve that design, to achieve a future performance that would create, deliver and capture value in a manner that was sustainable in terms of the triple bottom line.

Osterwalder's CANVAS contained nine building blocks – the different elements that could be used to define a proposed operations and value configuration. As shown in Table 151 below, the demand side [1-3: customer segments, relationships, and channels] was identified, engaged with, and received support. The finance [4: revenue streams & 8 cost structure] was unclear, due to the reluctance of the purchasing team to pursue financial support from suppliers, the effect of EU funding on costs, and the marginal nature of those costs. However, the University was happy to fund the scheme after the end of EU co-funding, and the costs known to me were comparable to those reported in the literature from other such schemes. The supply side [5-7: key partners, activities and resources] was well developed, well-resourced and functioned well, with the exception of the slow speed of conversion of suppliers to the scheme, leading to low levels of operation.

The value proposition [9: the accrued goods, services and benefits] was valued and well received by the key customer and, in 2017, was incorporated into University policy and the planning of a revised, larger scheme. In terms of formative evaluation, the BMC was, and continue to be, key in improving the design and practice of the scheme.

BMC elements	Question	Data sources/reporting mechanisms	Evaluation
1: K: Customer Segments	Did we identify the correct customer segments?	Internal Stakeholder workshops	The workshops enabled us to identify both suppliers that were suitable for, and not suitable for, the trial, based on customer feedback. They also identified new customers segments we had at first assumed to be negative to the trials but in fact embraced it.
2: L: Customer Relationships	Did we meet customer expectations?	Internal Stakeholder workshops	We maintained customer feedback both through the workshops and the supplier conversion process; feedback was positive and the new workshops in 2017 were also positive and keen to start the scheme again.
3: M: Channels	Was an Electric Vehicle suitable?	CCCC performance data. Fleet activity reports.	The EV worked very well, apart from a single period of maintenance, concern about running empty in wind on the A19, and a near miss accident.

BMC elements	Question	Data sources/reporting mechanisms	Evaluation
4: N: Revenue Streams	Did the university put enough monetary value on benefits?	Interviews and reviews with University Exec Board. University policy.	The University did place value on the benefits and continued to fund it into 2016.
	Did suppliers put enough monetary value on benefits?	Negotiated discounts	The University did not enact a policy of asking suppliers to contribute to the scheme, in terms of funding or discounts, so this is unknown. However, some suppliers appreciated being able to bundle multiple parcels into single cartons.
5: O: Key Partners	Did all Stakeholders commit to the project?	Internal Stakeholder workshops. University policy. Smartfusion project outputs.	All stakeholders committed to the project and worked as a team to deliver the pilot scheme. Even the negative feedback with regard to some supply arrangements was engaged with as positive feedback.
6: P: Key Activities	Did the Key Partners have the resources to make these happen?	Consolidation Centre (CCCC) performance data. Fleet activity reports.	The partners had the resources, either funded from EU funding or directly by partners as co-funding.

BMC elements	Question	Data sources/reporting mechanisms	Evaluation
7: Q: Key Resources	Did the Stakeholders committed to the project provide these [key resources]?	Internal Stakeholder workshops. University policy. Smartfusion project outputs. CCCC performance data. Fleet activity reports.	The warehouse & delivery operation was well funded. I had doubts as to whether supplier conversion was adequately resourced. The research and innovation aspects were well resourced, as was the provision of ICT resources. Stakeholders engaged and participated in workshops and the University provided senior and executive management time.
8: R: Cost Structure	Were the costs reasonable?	Interviews and reviews with University Exec Board. University policy.	Given the mix of confidentiality, EU funding, and marginal costing it was not possible to give a definitive answer. However, the cost structure was not dissimilar to other schemes reported in the literature.

BMC elements	Question	Data sources/reporting mechanisms	Evaluation
9: S: Value Propositions	Were the customers interested in the outcomes we wanted to achieve?	Interviews and reviews with University Exec Board. Internal Stakeholder workshops. University policy	The stakeholders at workshops were positive and supportive. Senior management incorporated the CCCC scheme into University policy and expressed a wish to develop it further. The scheme received 2 awards, one internal and one a prestigious national award.

Table 151: Newcastle BMC questions answered

10.18. Summary and Conclusions

This chapter has described the outcomes of the work. First, it evaluated the outcomes of the work using quantitative evaluation of the collected observational and operational data. Secondly, it provided a qualitative evaluation of outcomes that were related to policy, practice, and the creation and delivery of viable change. This process followed the principles of SMART and CREAM and used summative evaluation of the DMF, and a formative evaluation of BMC, to meet the twofold objectives, mixing quantitative and qualitative data in the process. This achieved Triangulation to achieve convergence, corroboration, and correspondence of results from the different methods. This was done in the way that the summative and formative evaluations were evaluated, using the mix of quantitative and qualitative results previously listed in Table 106 and Table 107.

The evaluation found from the purchasing review time series 2010 to 2015, that the University had progressively succeeded to formalise the way that demand was expressed, with a higher proportion of orders placed through the P2P system - 82.37% in 2015-2016, compared to 70.60% in 2011-2012. This coincided with the median lead-time expressed to suppliers moving from zero, to 1 day, by 2015 - albeit the University still expressed a median ‘next day delivery’ demand pattern to suppliers.

The traffic Survey review 2012 versus 2015 found that overall freight traffic had risen, especially at Site 5, the RVI hospital. This was probably closely linked to major infrastructural changes at that Site, as was the rise at Site 2 on the main campus. The main increase in freight was due to LGV growth and, of these, 8.48% were ‘kiss and drive’ drop-offs: effectively passenger transport in a freight vehicle. 5.99% of all HGV observations were also such drop-offs. 8% of all freight vehicle observations were Newcastle University internal vehicles; however, no correlation or regression analysis could reveal useable links between purchasing analysis, traffic survey, or the pilot operational data.

A quasi-experimental model was therefore constructed to model the likely impacts of different scenarios and baselines. This approach suggested that the impact of any CCCC scheme would depend very much on the origin and onward destination of vehicles to campus.

A very conservative evaluation for the original targeted pilot CCCC operation of 69 parcels a day, using a 10.5t Smith Electric Newton, suggested a very small annual absolute effect on reducing emissions of CO_2e, NO_2 and particulate matter, as low as 774kg of CO_2e, 10.03kg of NO_2 per annum and 350.04 g of PM_{10} per annum. Noted was that the proportional reductions, 32%, 50% and 69% were significant, but against a low absolute volume.

Other more developed scenarios were explored and the most promising - 149 parcels a day delivered in two 3.5t-5.5t battery electric vans, based on a pareto split of vehicles, 80% part of a 110/40km delivery route and 20% that entered the city for a single drop at the University before travelling elsewhere - suggested notable savings in the order of 107t (88.89%) of CO_2e, 872kg (89.09%) of $NO_{2,}$ and 1186.27g (23.78%) of PM_{10} per annum.

The key aim of the University in the Coherent Campus policy was to reduce freight vehicles on campus and here the reduction in freight vehicle numbers was more interesting, with the most promising operational approach saving 16.17% of all freight vehicles engaged in any activity on campus, and 29.67% of all external freight vehicles engaged in delivery.

All parts of the research will now be reflected upon in Chapter 11 following, before extrapolation to a broader policy and practice context, in Chapter 12.

How to improve the sustainability of logistics on the Coherent Campus at Newcastle University?

Chapter 11. Reflections and Meta learning

This chapter reflects on the research completed, with a view to the meta learning for the author as researcher. It shows how this has redefined the systems approach socio-technical framing. It shows the extent to which the practical knowing generated can address the concepts within that framing and add to scholarly knowledge and theory around urban freight. It addresses the contribution to scholarly knowledge by the work, the strategies, data generation, and difficulties, critiques the underlying assumptions of the research, and considers how well actionable knowledge was generated.

11.1. Meta Learning

A key part of the Action Research process was meta learning, as detailed in section 5.7.8. Its key purposes were reflection for the Core (the action as praxis) and for the Thesis (action as research).

Meta learning in the core AR project was part of the iterative cycle: each cycle feeding evaluation into the diagnosis step of the next cycle. This chapter focuses on the reflection and meta learning for the thesis, roughly addressing:

- Content:
  - Thesis: challenging the contribution to knowledge by the work.
- Process:
  - Thesis: thinking about the strategies, data generation processes, and how one coped with difficulties.
- Premise:
  - Thesis: critiquing underlying assumptions re the role of action in research to generate actionable knowledge.

11.1.1. Theoretical Framing

In order to set the Action Research, the core action, within the context of a thesis where theoretical knowledge would be added to the academy of researchers around urban freight, a semi-systematic literature review was completed and then reiterated (see

Chapter 2). The field was found to be new, emergent, with 77% of all articles published after 2011 - the start of this piece of research. Using a mix of peer-reviewed and grey literature, a combination of online scholarly databases, the NOVELOG toolkit database, a CASP checklist, and textual-graphical analysis using word clouds, the literature - a body of 219 works - was reviewed and key concepts identified; these were grouped as irrelevant, recurring, or with noticeable gaps (see section 2.9.1 on page 50).

The key gaps identified were: urban freight and procurement activity; private purchasing behaviour; Higher Education Institutions (HEI) and freight; barriers to sustainable procurement; engaging with Action Research in purchasing and supply chain management; little or no theory development; and the use of electric vehicles (EVs) in freight.

The concept of ‘why, who, with what, where and when’ (Zunder and Dellinger, 2005) existed in the literature and this gelled well with a systems approach socio-technical framing that I had previously deployed. This approach was then later deployed by Aditjandra and Zunder in the development of a multi-dimensional, poly-parametric typology for city logistics, with the addition of a ‘how’ element (Aditjandra and Zunder, 2018). The ‘why’ was not appropriate for the framing, as that lay in the needs of the local, national and EU level actors, defined in Chapter 1.

It is this framing that has been reflected upon at the end of each AR cycle (chapters 6, 7, 8, and 9), as meta-steps. The key elements of the framing are now reflected upon and the final theoretical contribution to concepts detailed.

How to improve the sustainability of logistics on the Coherent Campus at Newcastle University?

11.2. Reflections on the Systems Approach Socio Technical Framing

Figure 99: Revised systems approach socio-technical system for framing (adapted from Figure 15 *earlier on page 53)*

The concepts from the review were ascribed to 3 sub-systems: society, techniques, and actors. On reflection, the 6 top-level groupings - 5W+H - worked well and were adequate to the task, with the addition of a 'meta' grouping: each concept was suitably placed within each one. This new framing is shown in Figure 99 above. Note that the 5W+H were now placed with equal importance inside the potential system, removing the 'flow arrows' from the first version, representing the holistic nature of the revised approach following AR. A version of this socio-technical framing was used in research to develop the NOVELOG toolkit, from 2016 onwards (Aditjandra, Zunder, Islam, *et al.*, 2016; Aditjandra and Zunder, 2018; Rodrigues *et al.*, 2018).

In the following sections, only those concepts touched upon by the research are discussed.

11.3. Who

Figure 100: Final concepts related to "Who"

From the earliest BESTUFS (BESTUFS Consortium, 2008) project reports, through to peer-reviewed conferences and journals (Dablanc, 1997; Allen, Thorne and Browne, 2007; Anand, Quak, *et al.*, 2012), the key importance of actors or stakeholders was notable in the literature.

Given that such systems are by their very nature temporal and contingent on place and people (Dewey, 1917; Trist, 1978, 1981), it is pertinent to note that the actors in this piece of AR were from: the relevant University functions; the staff of the Tyne and Wear LTP3; project staff; and invited members of the local Freight Partnership (see section 7.2.). Analysis of SAP data revealed clear evidence of 8 potential power buyers, largely in FMS, and this potential group should be noted as important for future researchers. The use of DMF ZOPP workshops as process (see section 7.3) worked effectively: in drawing together semi-strangers and enabling the mutual definition of problems and objectives, as well quality relationships that drove the rest of the project. Of importance for premise was the cancelled workshop (see section 7.5) and the non-attendance of transport operators: whether they had interest, resources or mandate is a learning point for future research.

As to content of note regarding HEIs and freight, I detailed a freight total on campus of 23.36%/19.33% of all traffic (2012/2015) - above the average for European urban freight activity, as reported anecdotally and in the literature as lying between 10% and 18% (Woudsma, 2001; European Commission, 2006b). It was also noticeably above the 13% LGV and HGV traffic recorded in Newcastle City traffic surveys (Newcastle City Council, 2016). The University campus was evidenced as a major attractor of freight and, of the freight vehicles, 80%/84% (2012/2015) were LGVs. Of these vehicles, 39.11% were Euro 4 engines, 21.78% Euro 5, and 15.10% Euro 3. Challenging the premise that all freight vehicles were freight movement I noted that, in 2015, 8.48% of freight vehicle visits were ‘kiss and drive’ drop-offs: effectively passenger transport in a freight vehicle. 6% of all HGV observations were also such drop-offs. 8% of all freight vehicle observations were Newcastle University internal vehicles. Dwell times, noted in section 6.4.10, showed a bottom cut-off of 5 minutes and a top cut-off of 52 minutes. Between these times a freight vehicle movement was a delivery, below was probably a drop-off, and above 52 minutes was a service visit. These data have all contributed to the growing theoretical interest in HEIs and freight (Balm *et al.*, 2016; Zunder *et al.*, 2016; Aditjandra and Zunder, 2017; Cherrett *et al.*, 2017).

11.4. With What

With regard to core, this was a continuation of the large body of work on urban consolidation centres (Schuster, 1978), in parallel with two other Smartfusion projects I co-ordinated in Como (Leonardi et al., 2014) and Berlin (Zunder et al., 2016). The use of marginal space, or ‘elastic walls’, was key to the pilot and probably to the CCCC concept. Walking as a delivery mode proved key on the main campus, where a limited number of sites allowed coverage of well over 200 delivery locations. The flexibility of a commercial logistics organisation to ‘flex’ and accommodate a small pilot inside a larger organisation has offered a lot of value for research-led and start-up pilots in this field of urban consolidation centres. The research has made a strong case that a

Figure 101: Final concepts related to "With What"

receiver-led consolidation scheme can have impact: a scenario of 149 parcels a day, delivered in two 3.5t-5.5t battery electric vans, based on a pareto split of vehicles - 80% part of a 110/40km delivery route; 20% entering the city for a single drop at the University before travelling elsewhere - suggested notable per annum savings in the order of 107t (88.89%) of CO_2e; 872kg (89.09%) of NO_2; and 1186.27g (23.78%) of PM_{10}, combined with a reduction in freight vehicles engaged in any activity on campus of 16.17%, and a reduction of 29.67% in all external freight vehicles engaged in delivery.

With regard to process, the pilot was mutually on the basis of the DMF-BMC; it operated well, and was usefully recorded. The EV worked to plan, battery issues were negligible, and no service problems emerged.

However, take-up of the pilot scheme was very low; the conservatism of the Purchasing Manager in converting suppliers to the scheme - both when dedicated resource to do so was available, and later on - suggested deep issues associated with barriers to sustainable procurement, adding to the knowledge on isomorphic pressures developed by others (Meehan, Ludbrook and Mason, 2016).

This work did not adopt the DSP process developed by TRAILBLAZER, and deployed by TfL, but it did use alternative methods to develop establishment surveys, using techniques to provide methodological triangulation. The use of traffic surveys and archival SAP purchasing data provided rich data and insights, and yet, as others found in Brussels (de Radiguès, Verlinde and Macharis, 2019), finding correlation between datasets cannot always yield that which comes from face-to-face discussions. The Dingwall (1997) approach to social research worked well in the pilot drop-in sessions, where problems unique to Electrical Engineering, and unexpected enthusiasm from the Faculty of Medicine, were both discovered: again challenging some pre-understood premises (see section 9.4.1).

In the content of the action, the barriers to sustainable procurement in the University were not at first obvious; only during the pilot, and in the extended period, thereafter, did these become more apparent. I decided not to risk the trust I had with the Purchasing Manager, by pursuing this too vigorously - an example of how the politics of insider research can impede process. The premise that the conversion of suppliers would be slowed by internal client or supplier objections was not evidenced - rather, the delay was in the procurement function, due to isomorphic pressures; these could be explored by others in the future, with likely added value.

My colleague Paulus Aditjandra and I investigated private purchasing behaviour, in detail, in March 2014 (Aditjandra and Zunder, 2017). Ideas for intervention in this area were widespread and not restricted to experts (Adtjandra *et al.*, 2016). We saw this as confirmation that bottom-up stakeholder-led interventions could generate a strong body of innovative ideas (for further discussion, please see Österle et al., 2015; Zunder et al., 2013, 2016). 8.26% of the who staff responded reported purchasing goods for personal use delivered to the workplace. Qualitative data, reported by the respondents, pointed to the fact that private purchasing was deemed ‘unusual’ or ‘unacceptable’ practice, although comments were made to illustrate its usefulness. Belief that the behaviour would be deemed unacceptable had no basis in University policy and appeared entirely cultural. This can be seen as a key addition to knowledge emergent in this field: not just for HEIs, but also for any organisation where there may be important inbound personal flows (Transport for London, 2008; McLeod *et al.*, 2016). This was not captured as part of the SAP data analysis. The associated vehicles would have been contained in the traffic survey, making the process of correlating purchasing and traffic less informative. Therefore the premises for future work should take into consideration that a DSP delivery survey would capture private and public deliveries (Allen, Browne and Cherrett, 2012).

11.5. Where

The quantitative quasi-experimental impact model (see section 10.10 above) made substantial contribution to the content, process and premise of evaluation and modelling of urban consolidation centres, based on their geography and the assumptions about freight trip generation and/or attraction. This was largely due to a rigorous rethinking of the proportion of any ‘stem’ and ‘leaf’ delivery legs attributable to a receiving site. This was a consequence of moving from an operator-focused view of urban freight transport operations, to one that was receiver-led. This replaces the extant approach in the literature, of analysing single transport operator chains, or assuming that an entire city’s logistics chains could be subsumed into controlled consolidation schemes (Léonardi and Baumgartner, 2004; Browne, Allen and Leonardi, 2011; Balm *et al.*, 2014; Leonardi and Yamada, 2017).

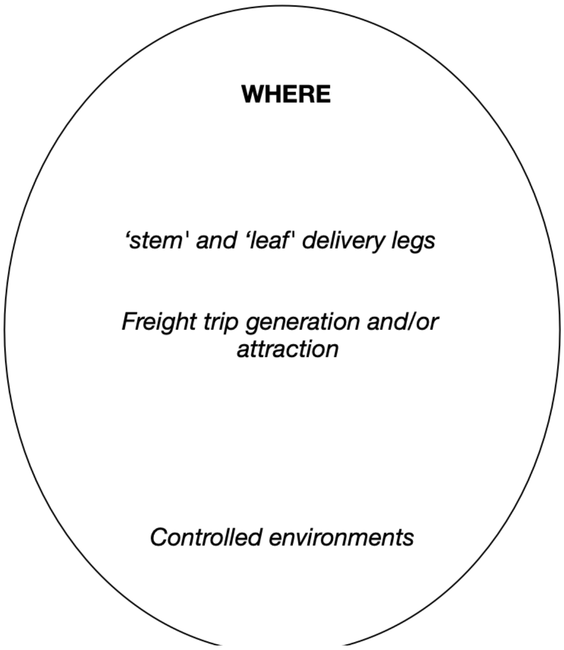

Figure 102: Final concepts related to "Where"

The model process I have developed requires robust archival purchasing data, or a comprehensive DSP-style establishment survey, combined with traffic survey data. It also requires - and this work had to adopt a pareto 80/20 split - an origin-destination matrix, to identify the number of vehicles making a single visit to a city to drop off goods.

The work reported new data on freight attraction demand from an HEI and Chapter 10 widely details when, how much, and on what lead times. The University generated Just-In-Time demand, on a next day basis, and suppliers responded in kind. Traditional trip generation models may be less suited to certain types of urban logistics and the literature showed emergent work on addressing the attraction of freight to a locale, institution, or campus. This had roots in the foundational work of Trailblazer (Wagdahl, 2010), in Europe, and related to land-use and zoning work. This was not touched upon by this work, since the UK does not have the type of zoning data available in North America (Holguín-Veras *et al.*, 2011). However, it did evidence that analysis of demand from a receiver can be built up by the use of purchasing data and, with further analysis, it may be possible to develop metrics that could be deployed in a more generalised fashion. Initial work to attempt this at the Vrije Universiteit Brussel, and the Brussels Central Administration, had been unconvincing so far (de Radiguès, Verlinde and Macharis, 2019) but, combined with more robust consolidation data (see Table 144), this merits further work. This supports our premise that it could be more productive to view urban freight as a receiver-led demand based activity, rather than a supply- or transport chain activity.

The degree to which a regulator, government, or landlord controlled the environment in which an urban consolidation centre operated, had been noted as key to the success or failure of such schemes (Marinov, Zunder and Islam, 2010). The premise that the University campus would be a controlled environment, where control could support the ready implementation of a receiver-led consolidation scheme, has been challenged by the recognition that, whilst the coercive nature of a purchase order should enable total control over inbound logistics, many pluralist factors present in a University mitigate the ability to wholly or speedily exercise control and change: multiple purchasing routes both formal and informal; multiple decentralised buyers in multiple groups; unknown localised systems (e.g. Electrical Engineering); purchasing conservatism and obscured isomorphic pressures; private purchases inbound to site for staff and students; and the existence of autonomous bodies on share sites (e.g. RVI, Northern Stage, and the Students' Union).

The processes adopted to progress the action were well suited to this 'complex pluralist' situation, as identified by SOSM (section 5.4). They were well addressed by AR, and within that DMF and BMC, and all well-suited to the complexity present in the socio-technical system used as an overall framing. The fact that SOSM did not offer a systems approach for complex pluralism suggested that this technique could now be augmented by AR/DMF/BMC. For a study focused on 'power buyers', exploring the actual power exercised, then the CSH systems approach may be suitable, with its research lens on power structures and boundary judgements.

The theoretical content on controlled environments can now be nuanced, from the complex coercive models of an airport, or a building, site to include 'collegial' institutions like HEIs.

11.6. When

This part of the groupings sat outside of the core sub-systems of society, techniques and actors, and allowed groups concerning chronology, history and timing to be examined, utilised and benchmarked. In some systems approaches this might include some concept of chronology, or history, and as such it was important to note that this research started in 2011, the core funded project ended in 2015, consolidation activities were paused in 2016, and the thesis was written up in 2019. The University in 2020 will have a different set of purchasing procedures - largely due to the inputs of this work - and as such this analysis was contingent on time, as much as on place.

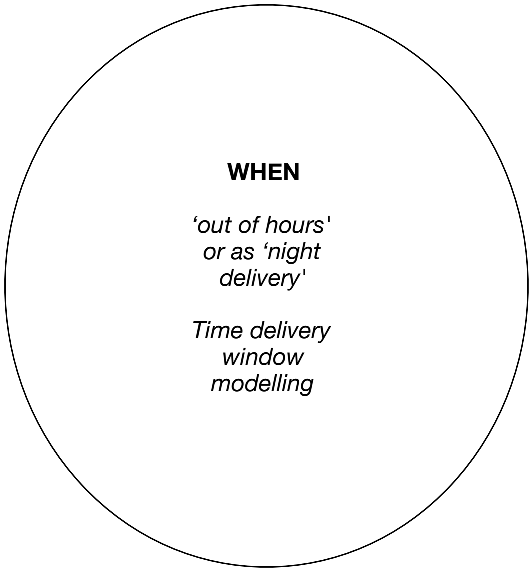

Figure 103: Final concepts related to "When"

Whilst the SPSS analysis of SAP archival data showed that the University was a weekday only operation, and the traffic surveys showed that the peak of deliveries was earlier in the day (confirming a tendency for deliveries to peter out by 2pm), this added little to the concepts of out of hours or night delivery. The richness of the datasets has added new knowledge for those with the competencies to engage in detailed time delivery window modelling, mixed with the modelling in Chapter 10.

11.7. How

The lack of long-term financial viability, and the recognition of the need for viable business models, were well evidenced in the theoretical framing. The most commonly identified and largest barrier to the uptake of UCCs had been financial viability. The TSC's hypothesis was that enhanced visibility of the cost and benefits would stimulate greater interest among potential client organisations. Due to commercial confidentiality this thesis adds little to the evidence on costs, whilst adding considerable evidence on the benefits (see section 10.18).

From 2011 there had been developments in the modification and deployment of the ULBMC - as adapted to urban logistics by the addition of an 'externalities' box (see Figure 78) (Macário, Rodrigues and Gama, 2011; Posthumus et al., 2014; Quak, Balm and Posthumus, 2014). This work adopted the unmodified BMC and, having worked later with the ULBMC, in the NOVELOG project (Rodrigues et al., 2018), I find that both work well and that a choice should be made based on how much the extra box fits with the 'lens' of the participants. There are other versions of the BMC that are more radical in their adaptation from the core BMC, such as the Service Model Canvas shown in Figure 104 below.

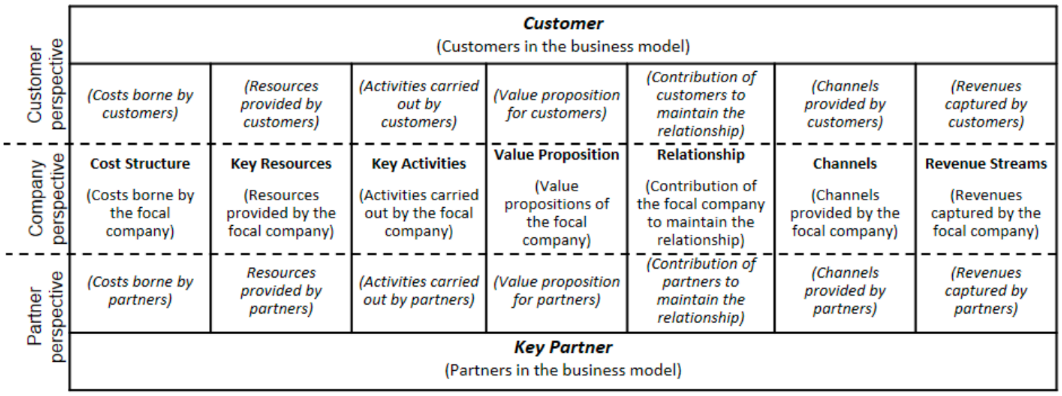

Figure 104: Service Business Model, adapted from (Zolnowski, Weiß and Böhmann, 2014)

The paucity of good ex-ante and ex-post data collection, coherent evaluation frameworks (Leonardi, Browne and Allen, 2012; Jacques Leonardi *et al.*, 2015) and the lack of data standards across Europe (Ambrosini and Routhier, 2004) were highlighted most clearly and convincingly in the literature. The need for quantitative data, ex-ante and ex-post, and for coherent evaluation, was a key concept for this research undertaking, as well as looking to see how the thesis had added knowledge to the theoretical or methodological state of the art.

This informed the clear planning for data collection before, during and after the pilot (see Framework: Methods and techniques). This premise proved to be a sound and rigorous process, ensuring data that enabled the later development of the quantitative quasi-experimental impact model. This was confirmation that such a process should be key in all such work to generate practical knowing in this field.

The utility of <u>engagement with Action Research in purchasing and supply chain management,</u> as called for by Meehan, Touboulic and Walker (2016), proved highly important to the development of the content, contributing multiple theoretical insights - not least the importance of having the right people in the process and of talking beyond the core group; for example, the insight into 'kiss and drive' came from wider engagement with staff. The limitations of a democratic process in an organisation also have to be recognised: whilst academic staff may be collegial, professional services staff reported upwards along traditional lines and this was possibly the origin of the isomorphic pressures that delayed uptake. However, for the 'mess', and others in the VUCA world of purchasing and supply chain management, AR allowed dynamic and purposive interventions. These delivered insights; were recognised locally and nationally with awards; feed back into the theory; and have led to changes in purchasing structures.

The field of supply chain management, logistics and urban freight exhibited <u>little or no theory development, w</u>ith the possible exception of 'logistics sprawl' (Dablanc, Ogilvie and Goodchild, 2014). The field was largely empirical observation, with a potential tendency to 'naïve empiricism'; (Solem, 2003; Adamides, Papachristos and Pomonis, 2012; Borgström, 2012; Meehan, Touboulic and Walker, 2016). The inability to address 'meta' issues may explain the difficulty in both developing theory and also "that much of the debate and criticism over methodology involves researchers who are failing to communicate with one another because they hold varying basic assumptions about their subject" (Mangan, Lalwani and Gardner, 2004).

The work addressed the 'meta' issues well, by the process of DMF ZOPP workshops, which were a process of mutually defining interests, resources, and mandates, before building a common definition of problems and objectives, and addressing the varying assumptions and languages that the semi-strangers normally used. Like all case study work, this agreement was contingent on time and place and, as such, I contend that the socio-technical framing of 5W+H, presented in this chapter, has made a direct contribution to theory development - not just its form, but the process by which it can be recreated, in each situation, and in doing so rebuild the premises, assumptions and pre-understandings of the co-researchers.

11.8. Quality and Rigour

AR had standards of quality and rigour, as detailed in section 5.7.9 above. Coghlan and Shani (2014) noted that, integral to this, were: publishability; the generation of practical knowing; purposeful action; implications beyond the remit of the immediate project; generating valid knowledge (both actionable and theoretical); and sustainable impact of one kind or another. Rigour was evidenced by the use of data-drive multiple methodologies, the methods of data generation, co-evaluation, cycles of planning, action, review and reflection. The work needed to evidence reflection: impact, collection, repeated application. Relevance could be evidenced as practical impacts beyond the remit of the study: teachability, interest, and passing the 'so-what' question (Pasmore, Woodman and Simmons, 2008; Bryman, 2012).

Moreover, it is worth adding that AR within a thesis must meet the requirements of "achieving doctorateness": high levels of competence in research skills; appropriate choices of methodology; explicit research design; "correct" data collection; deep discipline knowledge; a clear contribution to knowledge; a stated gap in knowledge; an explicit research question; a cogent conceptual framework; and competence in presentation of oral and written argument: clear/precise presentation; full engagement with theory; cogent argument, throughout; research question answered; and conceptual conclusions offered (Trafford and Leshem, 2009; Coughlan *et al.*, 2018).

Shani and Coghlan (2019) reviewed 11 AR studies in business and management and noted weaknesses that could be viewed as benchmarks for increasing the quality and rigour of future AR projects and the reporting of same. These studies demonstrated how critical context is, in setting the scene and the tasks for the AR, with limited levels of detailed description of the context revealed. The studies fell short on depicting the richness and impact of the quality of the relationships on the work. Much variation was found, regarding the emphasis and level of detail that captured the AR process itself.

I assert that this work, both as action and as thesis, has achieved the requisite AR standards of quality and rigour and, in parallel with my viva, has met the requirements of achieving doctorateness. I evidence this as follows, using the structure first laid out in Table 13 above, on page 111.

11.8.1. Purpose and rationale for the action and inquiry

The essence

The rationale for the operational research was based upon international, national and local needs of The European Union, the United Kingdom (UK), and Newcastle University, as detailed in Chapter 1. Within the University, the presence of freight delivery vehicles generated a steady flow of complaints from senior management, generating pressure on the Estates Service and the Purchasing function. Subjective impressions suggested a high proportion of freight on campus, with frequent complaints from senior management to Purchasing and Estates staff with regard to vehicle intrusion.

Rigour

The rationale, contract and access given was clearly stated in Chapter 1. The semi-systematic literature review, reported in Chapter 2, stated clear research gaps which were well framed in the systems approach socio-technical framing of 5W+H developed in Chapter 3 and finally presented in Chapter 11 including: higher education institutions (HEI) and freight; barriers to sustainable procurement; engagement with AR in purchasing and supply chain management; private purchasing behaviour; urban freight and procurement activity; little or no theory development; and the use of electric vehicles (EVs) in freight.

Reflective

The action and inquiry were directly linked to concepts in the literature that had significant gaps. These were also the contemporary issues and concerns of the University, with regard to intrusion by inbound vehicles on the Coherent Campus, and as such looked to support the policy of the same name. They also supported the regional needs of the city, and the North East Freight Partnership, and formed part of a much wider international research and innovation programme of the EU.

Relevance

The research questions, based on local, national and international needs, clearly identified two key clients: the EU and the University. For both, the wish to reduce urban freight traffic was viewed as necessary and desirable at the local micro level and at a European macro level.

11.8.2. Context

The essence

The business and organizational context was researched and reported in Chapter 4. The University had a very high level of freight traffic compared to typical cities and had a highly fragmented demand pattern generating a 'just-in-time' demand, similar to a car plant, or consumer retail.

Rigour

The contextual data were collected using archival analysis of SAP purchasing data and cordon-based traffic surveys. A clear example of a gap in the literature was the poor ‘ex-ante and ex-post’ data collection; therefore, the contextual data collection was carefully planned and executed to allow before and after comparison. Between the traffic surveys, changes in the method of data collection were addressed and mitigated and, where appropriate, extra data were collected where these had value. The iterative AR cycles, especially the DMF and the BMC processes, generated deeper and richer contextual data that led to both actionable knowledge in the pilot (Chapter 9) and thesis (Chapter 11).

Reflective

The contextual data gathered built upon previous work by others covering the concepts of delivery and servicing plans (DSP); higher education institutions (HEI) and freight; barriers to sustainable procurement; freight trip generation and/or attraction; private purchasing behaviour; and specific knowledge about dwell times of freight vehicles.

Relevance

The analytical frameworks applied to contextual analysis were appropriately placed in terms of the categorisation by Allen et al. (Allen, Browne and Cherrett, 2012); the work covered quantitative ‘commodity flow survey’, and ‘vehicle traffic surveys’. Combined with the collaborative DMF workshops - primarily qualitative - this formed a sound basis for methodological pluralism looking for Triangulation.

11.8.3. Methodology and method of inquiry

The essence

Two contracts were in place: one with the EU as a subset of the Smartfusion project, for which I was the Co-ordinator and PI; the second with Newcastle University, that provided commitment and access to investigate inbound logistics for the institution.
Top-level concepts such as epistemology, procedures of reasoning, ontology, and axiology were used to develop the overall philosophy of this research in Chapter 4.
Chapter 5 described the methods and techniques that were considered for the research, the approaches evaluated, and the design process used. The complementary methods and techniques within the final framework were detailed and the final research project design summarised.
The philosophy was based in the social sciences, was pragmatist, used abductive reasoning, was constructionist, and could deploy subjective and objective axiological approaches.
Ethical issues were addressed in the initial project reviews, then reviewed iteratively as

reported in various parts of the thesis, commencing at section 5.7.10 .
I chose mixed methods research – explicitly: methodological pluralism - mixing quantitative and qualitative research methods in an integrated fashion, looking for Triangulation between qualitative and quantitative data.
A systems approach was adopted and AR selected, as reported in Chapter 5.

Rigour

The AR process of contracting was collaborative, in that the discussions with the Estates, Purchasing and Executive staff within Newcastle University identified local problems that aligned with, and were incorporated into, a proposal to the EU that funded a multi-city multi-stakeholder research and intervention project. The adoption of AR, DMF and BMC was less collaborative, being driven more by researcher evaluation of the methodologies and techniques available. Here selection tools, such as SOSM, were used to adopt AR; a desktop review and discussions with the wider research group led to the choice of DMF; and BMC was chosen because it had become an increasingly standard tool for business model generation. However, all tools chosen were *purposeful*, in that purposes were allowed to change and develop during an intervention, rather than *purposive* intervention, where purposes are fixed; this dynamic reorientation in both action and thesis was founded in mutual co-research. The selection and justification of each mode and approach is stated in detail in Chapter 5 and reflected on in Chapter 11.

Reflective

The AR cycles are extensively detailed in Chapters 6-9, both textually and graphically. The larger scale domain of urban freight transport is reflected on, in parallel, in the meta-steps reported at the end of each of these chapters.

Relevance

The SOSM analysis (see section 5.4 and 5.5) suggested the case to be 'complex pluralist', with strong elements of potential or actual coercion. I chose AR as the preferred systems approach. Part of the reasoning was that AR incorporates the researcher as change agent in a process that is abductive, outcome oriented, pragmatist, and flexible. This fitted well with the idea of the insider action researcher, identified by

Coghlan (2014; 2016; 2019). The DMF ZOPP problem-objective tree process (see Chapter 7) allowed a group of semi-strangers to reach a shared mutual definition of shared problems that they as a group had interest in, responsibility for, and the mandate for intervention. The final DMF logframe was of less use, but the BMC allowed the problem concept of long-term financial viability to be addressed and used as the proto-business model for the pilot.

11.8.4. Design

The essence

A clear AR process, consisting of pre-step, followed by four iterative cycles, was designed. Meta-learning was incorporated into each step and forms the opening and closing of the key chapters reporting action in this thesis. Vehicle traffic surveys and the analysis of SAP purchasing data were adopted. A logframe approach, the DMF, was selected for stakeholder interaction and BMC for the generation of a proto-business model and the pilot. Relationships were built upon existing networks and developed further in the DMF process, the development of the BMC, pilot planning, drop-in sessions during the pilot, and ongoing informal conversation and dissemination inside the University, region and the EU. As an insider researcher, this was an insider action research project, with issues such as 'pre-understanding' recognised and accepted.

Rigour

Design was compliant with SMART and CREAM and the iterative cycles of AR, combined with a pre-step and a meta step of reflection on content, process and premise, ensured rigour in data generation, gathering, exploration and narration. Very close attention was paid to enabling ex-ante and ex-post evaluation, since this had been identified as a gap in the literature review.

Reflective

Some data were generated through empirical observation, in consultation with traffic survey experts, and based on the survey methods identified by Allen et al (2012). Some data were based on archival SAP purchasing analysis, which was developed using my own expertise as a qualified member of the Chartered Institute of Purchasing and Supply (MCIPS) and in co-operation with the Purchasing Manager. In the DMF, BMC and pilot processes, many of the data were mutually generated and were the result of active and purposeful collaboration. The quality of the relationships was key, and this was integrated and nurtured throughout: in DMF workshops, BMC co-generation, pilot planning meetings, pilot diary collation, and pilot drop-in sessions. The Senior Management Team was briefed and consulted regularly, and progress and results were disseminated, both through staff and into the wider region.

Relevance

The research design was driven by the aim to research and develop practical knowing that would support the Vice Chancellor's Coherent Campus Policy and reduce inbound freight vehicle intrusion and dis-benefits on campus. In parallel, the use of a systems approach socio-technical framing for the thesis element, run in parallel with the action element, allowed additions to scientific knowledge within that framing and the addressing of concepts with gaps in the literature review.

11.8.5. Narrative and outcomes

The essence

The narrative is detailed in terms of core action in Chapters 1, 6, 7, 8, 9, 10 and part of 12. The narrative as thesis is told in Chapters 1, 2, 3, 4, 5, 11 and part of 12. However, the meta learning is also narrated as pre-step and meta step sections at the end of Chapters 6, 7, 8 and 9. The intended project was to first and foremost address the University (and city/region/EU) desire to improve the sustainability of logistics on the Coherent Campus (RQ1). Stakeholders were identified to mutually define problems, and then objectives, and a proto-business model was generated. From this, a pilot was planned and enacted. Multiple evaluations identified various strategies and reported them to the Senior Management of the University. The pilot was operationally successful but did not achieve the desired operational scale before it was paused. A quantitative quasi-experimental impact model was developed, to assess future potential scenarios for impact.

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Rigour

The story is told extensively, with a mix of data types, supporting a plurality of knowing. Statistics, images, artefacts from workshops, agendas, webpages, email messages, and copies of problem/objective trees are all used to document the narrative. Narrative is presented as facts from data, with judgements or commentary kept to the relevant chapters, or to the pre-step and meta step comments in the chapters that describe the story.

Reflective

Whilst the thesis is written in the past tense, to set it contextually for future readers, the core of the narrative was co-generated in the present tense by the stakeholders, step by step, with each cycle allowing purposeful change from month to month. Some activities were actioned in the present tense, traffic surveys and SAP analysis were ongoing and iterated, but then further analysed in the past tense for the final thesis. Thus, the thesis is an evolution of several of the project deliverables or reports that were used and disseminated during the unfolding of the work.

Relevance

The narrative captures the majority of the main interventions in a holistic fashion. By the very nature of scoping, there were other interventions pursued elsewhere, but the text is already over length and these are best reported elsewhere. Good examples of data, and the collaborative processes that co-generated them, are evidenced, along with the mutual decision making that led to and from them. The outcomes are full detailed in Chapter 10 and the RQs answered in Chapter 12.

11.8.6. Reflection on the story and outcomes

The essence

The analysis of the story, and the reflections of same, are in the pre-step and meta steps of Chapters 6, 7, 8, and 9, as well as in the dedicated Chapter 11. Judgements are made on the processes. Outcomes are reported in Chapter 10 and reflected on in the dedicated Chapter 11.

Rigour

The narrative is described to the rigour expected of AR: a plurality of knowledge is supported, different forms of data and fact are presented, and supported by extensive evidence of the underlying mechanisms of the emergent socio-technical systems approach. The statistical analysis, using SPSS, is rigorous and has adopted a prudent and conservative approach to significance, with very high levels of analysis reported. The clear statement of methodological pluralism was then supported by a strong use of Triangulation, in the SMART/CREAM evaluation in Chapter 10, combining and looking for synergy or divergence between quantitative and qualitative data, from varying methodological sources.

Reflective

In the main body of the action, the meanings were created mutually in the DMF workshops, and the ZOPP process was based around two collaborative sessions: one creating, one reflecting. The BMC took this and reflected on it further, co-creating a proto-business model, using a different but compatible framing of the 5W+H approach. From there, the pilot planning was collaborative between Estates staff, Purchasing staff, Clipper Logistics actors, and myself and my group. This dialogue, about meaning and actions, between different organisational groups, units and communities of practice has been key and core to the entire work.

Relevance

The problems identified in Chapter 1, in the initial setting of rationale, contract and access, were chosen to be in alignment. That is not to say that a project which appears in alignment at the outset cannot move to disharmony and internal conflict along the process. When that happens, my experience shows it to be often due to the enforced use of purposive planning, where the purposes are defined at the proposal stage and then are rigidly stuck to for 3-5 years with no opportunity for dynamic change; this does not suit our VUCA world. Carefully choosing a systems approach for a 'mess', and a socio-technical framing that was itself based in the literature and then had the key appropriate concepts mapped to it, allowed meaning for the organisations; theoretical needs were able to flex and adapt as the work proceeded, keeping them relevant to all.

11.8.7. Discussion: Extrapolation to a broader context; Articulation of actionable knowledge

The essence

The story is linked to the theory in the pre-steps and meta steps in Chapters 6, 7, 8, and 9 and in the dedicated Chapter 11. The work generated practical knowing that had direct application in the real world: by the University, at a policy level, nationally and internationally, and in increased theoretical knowledge in key components identified in the semi-systematic literature review, including notable gaps. As it progressed, the action generated papers in peer-reviewed academic journals and, although the core items of novelty have not yet been published outside of the thesis, this is structured for publishability, with key components in preparation for papers detailed in Chapter 11.

Rigour

Practical knowing is actionable knowledge and also knowledge about action (Coghlan, 2019) and the work has had a direct impact on action, moving forward the EU agenda on clean urban logistics. It has raised the topic of sustainable procurement in logistics, by winning the THELMA award for Procurement Leadership, and has been further recognised by the award of a University prize at the annual Environmental Awards.

Reflective

The account is a true and accurate record of the quality of the AR process and the quality of the relationships involved. It is frank about failings and about when new data or ideas surprised me or us: e.g. 'kiss and drive' in dwell time analysis. Whilst not wishing to betray trust, the problems with purchasing conservatism have been described and I have tried to adopt an open reportage. I am very aware that this is my viewpoint, thus I have tried to mitigate this with a plurality of data sources - especially those that allow the actors to 'talk directly' with the reader.

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11.8.8. Relevance

The final proposal to the University was that, if a fully scaled up CCCC were implemented, using twin vehicles from a base 6-11km from the main campus, making 110 drops, this would reduce the number of freight vehicles delivering University freight on campus by 29.67%. This thesis has shown, in deep detail and with strong evidence and analysis, that the intervention known as the Coherent Campus Consolidation Centre scheme was an impactful way to improve sustainability on the Coherent Campus at Newcastle University. The thesis has added to scholarly knowledge on the research gaps of:

- higher education institutions (HEI) and freight (2015);
- barriers to sustainable procurement (2009);
- engagement with Action Research in purchasing and supply chain management (2016);
- private purchasing behaviour (2014);
- urban freight and procurement activity (2012);
- little or no theory development (2003); and
- the use of electric vehicles (EVs) in freight (2012).

11.9. Summary

This chapter reflected on the completed research, redefined the systems approach socio-technical framing, elaborated how the practical knowing generated addressed the concepts within that framing. The addition to scholarly knowledge and theory around urban freight has been detailed. The chapter addressed the contribution to scholarly knowledge by the work, the strategies, data generation, and difficulties, critiqued the underlying assumptions of the research, and reported how well actionable knowledge was generated.

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Chapter 12. Conclusion: Answers to Research Questions

This chapter concludes the work. In this chapter I shall provide my answers to the four Research Questions set at the beginning. The opportunities for dissemination of the results will be addressed, as will the novelty of the thesis and the associated datasets.

As detailed in Chapter 1, the rationale for the research was based upon the local and international needs of Newcastle University and the European Union. Locally it was driven by the Newcastle University Coherent Campus initiative, while at the EU level it was combined, by climate change imperatives and earlier mobility policy agendas, into a research, development and policy requirement for sustainable urban freight logistics.

12.1. Research Question 1

RQ1: How to improve the sustainability of logistics on the Coherent Campus at Newcastle University?

The work used DMF workshops to build Problem and Objectives Trees, through a series of stakeholder workshops. These Problem and Objectives Trees were mutually defined by those that had the interest, mandate and resources to bring about change in the sustainability of urban freight, first in Newcastle upon Tyne and then focused specifically on the Newcastle University campus. This stakeholder process led to five identified and agreed interventions being mapped onto the final Problem Tree - see Figure 49 on page 248.

These interventions were:

- A: Better signage and Delivery Maps
- B: Self-consolidation via Supplier
- C: Consolidation Centre
- D: University Coherent Campus Consolidation Centre
- E: Sustainable Catering Initiatives

All were followed up by the University, although C was subsumed into D. All were seen as well designed and developed and all involved stakeholders that were highly committed to the interventions.

This thesis reports the development of, the progress of, and the evaluation of D, now named the Coherent Campus Consolidation Centre (CCCC).

The analysis of context and observations utilised archival analysis, and empirical surveys, to collect data and to analyse and inform the process. This process was repeated in evaluation, complemented by a quantitative quasi-experimental model, and convergence observed with summative and formative evaluations. The purchasing data analysis showed that the University had four different purchasing systems, each recording to different degrees of granularity. There was a fragmented population of buyers, although about 80% of orders were raised by about 20% of active buyers (see section 10.5). The University expressed a very short lead-time to suppliers, and, in post pilot evaluation, this continued to be a median lead-time of 1 day, with a range of 1-7. Freight vehicles formed a high proportion of overall traffic, which may have been elevated by the University Travel policy suppressing car use, but at 19.33% it was notably higher than the 13% recorded by Newcastle City traffic counts in 2015.

Intervention D was designed to intercept incoming deliveries and reroute them to a consolidation centre, bundling them and delivering them to campus the same day. The value proposition to the University was: fewer vehicles on campus; centralised receipt tracking; lower carbon footprint; improved air quality; and pride in sustainability - all in line with its Coherent Campus policy, detailed further in section 8.7.

Sustainability is usually viewed as the ‘triple bottom line’, made up of economic, social and environmental factors. Therefore, the answer to RQ1 lies in the integrated evaluation detailed in Chapter 8, where the Triangulation of mixed methods converged - summatively (in the DMF) and formatively (in the BMC).

The research has shown that if a fully scaled up CCCC were implemented, using twin vehicles, from a base 6-11km from the main campus, making 110 drops, this would reduce the number of freight vehicles delivering University freight on campus by 29.67%. Of all the vehicles classified as freight type vehicles observed on campus, 16.17% would be removed - see Table 138. This would save 106t or 88.89% of CO_2e; 872kg or 89.09% of NO_2; and reduce PM_{10} by 1.186kg or 23.78%. Since the University bought all electricity from carbon neutral sources, it would be legitimate to view those micro-level campus savings as 119862kg (circa 120t) of CO_2e per annum and 979kg of NO_2. Since electric vehicles continue to emit PM_{10}, the decrease for particulates would be lower.

The summative DMF evaluation (Table 150) and the formative evaluation of the BMC (Table 151) showed the following to be key success factors: marginal costs ('elastic walls'); stakeholder workshops; customer feedback; a reliable transport chain; the University placing value on the service; and funding for the pilot.

The action achieved in this research was recognised by 2 awards in 2015, as detailed in Chapter 9 above. On 4th June 2015, the research won the "Best Environmental Initiative" at the Newcastle University Annual Environment Awards, that recognise projects and initiatives that demonstrate commitment to reducing the University's environmental impact and work towards achieving the University's sustainability objectives. On 18th June 2015, the University was awarded "Outstanding Procurement Team" at the (THELMA) Times Higher Education Leadership and Management Awards, for the collaborative work around the initiative to reduce delivery vehicles on campus and cut carbon footprint.

This thesis has shown, in deep detail and with strong evidence and analysis, that the intervention known as the Coherent Campus Consolidation Centre scheme was an impactful way to improve sustainability on the Coherent Campus at Newcastle University.

12.2. Research Question 2

RQ2: To what extent can sustainable HEI logistics only be achieved through sustainable procurement practices?

In order to develop an answer to this RQ, the case of Newcastle University from 2011 to 2016 needs to be summarised with regard to the effectiveness of an intervention based on sustainable procurement practices. Then the alternative interventions should be examined, and then the results compared with the somewhat limited theoretical knowledge extant in the literature, and how it fits into the socio-technical 5W+H framing.

I believe the literature and the case showed that there are variances in the type of HEI in the literature, the Universiteit en Hogeschool van Amsterdam (Balm *et al.*, 2016) was quite different to Newcastle University, the former had 15,000 different suppliers and 20 different locations in the city, the latter 5,000 and either 5 or over 200 depending on definition. The Vrije Universiteit Brussel (VUB) was more similar, with similar annual and weekly volumes but crucially still had a central warehouse function unlike Newcastle (de Radiguès, Verlinde and Macharis, 2019). Newcastle University can be surrounded with a cordon, others e.g. the University of Southampton, are porous with multiple independent entrances and exits. Ordering by telephone is not permitted at the University of Southampton but is permitted at others (e.g. the University of Newcastle) (Mcleod *et al.*, 2015).

As Quak et al, have commented, it is "difficult it is to determine the exact trips that result from public procurement behavior. First of all, procurement is often only used as an administrative activity and not used to achieve policy objectives. In most procurement activities and systems, the resulting footprint, nor the resulting transport activities are asked, let alone recorded. Procurement officers do have other incentives than to minimize the transport trips or the footprint, and therefore this is often not one of the select suppliers for goods or services" (Quak, Nesterova and Kok, 2019).

It is also worth noting that after the pilot, and as the University centralised, some of the key metrics changed. There was a small change in the lead time as the number of buyers processing orders fell and the function was co-located. This adds some credence to the assertion by Glas, Schaupp & Essig et al. (2017) - that centralised organizations adapted differently to strategy objectives than did decentralised organizations. They further found that centralised organizations perceived up-to-date strategic objectives to be more important than did decentralised organizations, that tended to focus on the immediate needs of their local users. This suggest that if one wants to change procurement behaviour, centralise.

Private purchasing is significant at Newcastle, and there is a similar student purchasing behaviour at the University of Southampton (Cherrett *et al.*, 2017). There is no formal prohibition on private purchasing for anyone at Newcastle University (Aditjandra and

Zunder, 2017) and 2.5%-5.6% of a revised total volume of goods ordered was private. These flows need to be taken into consideration into any receiver led intervention.

However, the Newcastle case has demonstrated that an intervention led from the perspective of the receiver, recognising the nature of a decentralised and fragmented system, and incorporating both potential power buyers, Estates staff, the Purchasing team, and the wider pool of end users, was able to develop an intervention that was operationally sound and could, with scaling up to an appropriate solution, make substantial impacts on the University's key goal of reducing intrusion onto the campus by freight vehicles. This is detailed extensively in the answer to RQ1 above.

Given that the stakeholders present in the DMF workshops were self-selected from a robust, well established and strong network in the North East of England, and that the transport operators declined to participate, it is reasonable to state that all with an interest, resources and mandate were present. Other proposed solutions in the literature formed key elements in the intervention, as detailed extensively in the final socio-technical framing elaborated in Chapter 11. Therefore this was not an intervention of purely procurement activity; self-consolidation by supplier as raised as Intervention B or as examined by Verlinde et al for VUB (2012).

Could sustainable HEI logistics, using any of the definitions discussed in Chapter 1, be achieved without procurement activity? **Yes**. A top down vehicle regulation by a suitable authority that banned or severely taxed unsustainable vehicles in cities could force the replacement of the entire freight fleet, effectively changing the baseline entry conditions for a logistics operator to function. This might lead to price pressure on deliveries akin to that which followed the introduction of MAUT HGV road pricing in Germany (Gustafsson, Cardebring and Fiedler, 2006), but that would not be an active procurement activity, but rather background noise to the usual purchasing activity.

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12.3. Research Question 3

RQ3: How effective were participatory research approaches in facilitating this improvement?

There were three participatory research approaches in this work, and these are reported in this thesis. The first was the overarching use of AR and the process of framing and scoping access and contract, as explored in section 5.7.1. This was partially participatory, in that the *access* and *contracts* had to be negotiated. The process then began with iterative cycles of Constructing-Planning-Action-Evaluation, consisting of four such loops, which seemed appropriate. The nature of AR is inherently participatory; it is democratic, in that all actors are sharing the power of knowledge production, and it is aimed directly at the pragmatic solution of problems - see section 5.6.1. This helped enable this research, not least because Universities are collegial and key staff involved in the work were empowered to make decisions autonomously. However, it would not be true to suggest that the process was egalitarian; as CSH suggests, power structures and boundary judgements lay beneath the meetings, workshops and outcomes of this AR. The complex relationships of commerce, and unofficial relationships in this work, made it a mix of 'complex pluralist' and commercially 'coercive': all parties in any discussion came with relationships, and technical competencies, within the context of time and place. Therefore, this AR was specific to this mix of:

- the society of actors involved (shippers, operators, receivers, government);
- the ensemble of techniques (technology, methods, regulations or systems); and
- the environment in which the system existed or would exist (geographic, geopolitical) (Zunder and Dellinger, 2005).

The opening workshops were very effective. Of note were the stakeholder analysis cards (Figure 43 on page 232) that clearly drew out and shared the name, interests, problems, resources and mandates of each participant. The mutual development of the Problem and Objective Trees – sections 7.4.4 & 7.7.2 above - was an excellent process for the mutual definition of problems, objectives, and measurable indicators. The process was highly dynamic and developed five well outlined interventions. As stated in

Chapter 9, I found the DMF somewhat unhelpful; any future process flow could move from the Trees and interventions directly to a CANVAS based business model generation, as detailed in Chapter 6. The need to mix up the participants further in the workshops was notable and the use of a World Café style rotation would have helped.

Since urban freight logistics has a problem with sustainable interventions that meet the triple bottom line, the use of a business model framework was key. The Business Model CANVAS worked well, the details from the DMF provided the core, and then the continued rounds of the AR cycle developed both a proto-business model and also the essentials of the pilot - a process that had not been immediately obvious at the commencement of the work.

Both the DMF and BMC provided excellent indicators and questions for evaluation, the first being summative and the second formative. The higher relevance of the BMC questions compared to the DMF indicators was probably due to chronological proximity to the pilot.

Both methods developed close teams, with shared understanding and goals, and a focus on action and delivery, with clear structures to plan and monitor that action. They combined well in the iterative AR cycles. The process delivered a working pilot and a clear understanding of value creation, value capture, and reward for value, which continued to drive the plans for a scaled-up CCCC. I would commend the use of ZOPP style workshops, with BMC or ULBMC business model generation, for such urban freight logistics work in future.

The participatory research processes were highly effective both as research for action and research for this thesis.

12.4. Research Question 4

RQ4: What novel approaches for policy and practice locally, nationally and at an EU level could be developed from this work?

As detailed in Chapter 1, there are four distinct areas in which this question needs to be answered. First, policy and practice at Newcastle University itself. Second, policy and practice locally by the councils and the (then) recently formed North of England

Combined Authority (NECA). Third, the policy initiatives of the UK government and, fourth, those of the European Union.

12.4.1. Newcastle University

The key *rationale* of this work was to support the Coherent Campus initiative of 2008. It addressed the lack of focus on freight in that policy. The work was pragmatic: a *contract* was agreed, and *access* given. My work has led to the University changing its purchasing policy, to support the development and implementation of a full-scale CCCC. The University actively pursued ERDF funding to support the start-up, with a fall-back of internal funding, if required.

Other policy changes have come from the research work. The University, having seen the fragmented nature of the purchasing system and the consequences I reported, moved to centralise the function in 2016 and, by 2018, the buyers had relocated to a central Hub, to enable better control of how demand was expressed to suppliers.

Some of the other interventions generated in the original workshops (Chapter 5) were also adopted. The University brought Catering back in-house and adopted an electric vehicle fleet to service it. It also proceeded with better signage and implemented traffic calming at the Sites that were most favoured by freight.

12.4.2. Local Government

The city councils of Newcastle upon Tyne and Gateshead, with the facilitation of NECA, expressed strong interest in the value of joining the CCCC as a shared service. Both shared purchasing data with me and the ERDF bid had actions dedicated to evaluating a sustainable business model for these two cities to join the CCCC.

Conversely, the evaluation in Chapter 8 also informed NECA that this scheme, in and of itself, had low macro-level city impact on the two key measures by which the government judged sustainable transport: CO_2e and NO_2. While the Government had recently placed a very high priority on air quality, and had repeatedly recommended consolidation, NECA took on board the message from this work, that other policies to reduce freight on the roads in areas of poor air quality may be more effective: policy and practice were to be adjusted accordingly. NECA took over the running of the regional Freight Partnership and I reported my findings to that group.

12.4.3. UK Government

As explained in Chapter 1, the UK had shown little policy interest in freight or logistics since the publication of "Sustainable Distribution: A Strategy" (DETR, 1999). By 2018 this had started to change, primarily due to the acknowledgement that air quality had deteriorated to a dangerous level in UK cities and the successful civil suits that the UK government lost to ClientEarth - on three separate occasions - when the ruling was that the government had failed to adequately plan to tackle the growing problem of air pollution. A ruling on 21st February 2018 would effectively "force ministers back to the drawing board in their efforts to clean up dirty urban air" (The Guardian, 2018). As a result of the ruling, if ministers failed to remedy the situation "lawyers have 'exceptional' leave to bring a judicial review without seeking further permission" (ibid.).

ClientEarth had won two previous rulings against ministers over air quality levels, forcing the government to draw up new plans for reducing nitrogen dioxide - much of which came from vehicles - to within legal limits. These plans entitled "UK plan for tackling roadside nitrogen dioxide concentrations" (DEFRA and DfT, 2017) effectively pushed responsibility to local authorities to solve the problem, with no detriment to owners of diesel vehicles. This led to the creation of a Clean Air Fund, launched in March 2018[39]. The document detailing the Government's response suggested freight consolidation as a solution for freight emissions, yet it exampled the defunct Bath and Bristol scheme that had proved to lack a viable business model (Bath & North East Somerset Council, 2016; DEFRA, 2018). It is fair to suggest that the UK had a pressing political and environmental problem.

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[39] *https://www.gov.uk/government/consultations/air-quality-additional-measures-to-support-individuals-and-businesses-affected-by-local-no2-plans*

There was a gap in the development of UK policy for urban freight logistics. The report "How can we improve urban freight distribution in the UK?", from the Independent Transport Commission (Niblett, Finney and Pryde-Saha, 2017), included the London Borough Consolidation Centre (LBCC) with which my work had shared much, but it was a slim document with no status. No clear UK government policy on urban freight logistics had emerged since 1999.

My suggestion from this work is that inbound and receiver-led consolidation centres do not make absolute savings in CO_2e and NO_2 to justify funding on a cost-benefit basis alone. They do, however, reduce the congestion at the sites they service and can form a coherent and valuable service for the recipients. Other policies to mitigate freight emissions, such as subsidies to cleaner vehicle uptake, may be preferable at a macro level. A very key policy point from this work is that public bodies underestimate the degree of control they have over commercial logistics operations, through the power of their collective purchasing spend, and how legal deployment can exercise change in inbound logistics.

12.4.4. European Union

The European Union had consistently produced active freight transport policies, since its landmark 2001 White Paper (European Commission, 2001b), but it was the 2006 Communication "Keep Europe Moving" (European Commission, 2006a) that started the development of a fully business-friendly and yet environmentally-driven Freight Logistics Action Plan (European Commission, 2007). The combination of freight policy, urban policy, and the overarching climate change goals of the 2020 Energy package (European Commission, 2010) meant that urban freight logistics remained a key policy focus.

The EU had funded multiple streams of research, development and innovation into urban freight logistics[40]. These developed multiple complementary and supplementary

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[40] *e.g. BESTUFS, BESTFACT, NICHES, SMARTFUSION, CITYLAB and many more, see https://goo.gl/UidVn3*

volumes of policy advice that, in the spirit of subsidiarity, the EU disseminated to cities - usually through the urban freight logistics groups of the CIVITAS initiative[41] - and elsewhere. As the EU itself stated: "The Commission will improve the dissemination of best practice, produce additional guidance documents and facilitate the procurement of clean vehicles through its Clean Vehicle Portal" [42]. This was not a federal, nor even national, matter for the EU, which had not used its extensive powers of derogation for breaches under the EU Air Quality Directives to intervene in urban freight logistics.

Given the high number of failed consolidation schemes funded by the EU, the clear policy advice from this work is to ensure that all such schemes are designed with a suitable business mode generation tool. Also, that the ex-ante and ex-post evaluation is carried out, but that it be based upon the individual characteristics of the scheme and the actual effect on both the traffic at the end customer(s) site(s) and also at the macro level.

If a very broad point were to be made, it might be that consolidation centres can be a solution for some sites, for some users, but quite often not for solving the problems one might expect.

12.4.5. Policy Recommendations

The key policy recommendations from this work are as follows:

- That an inbound logistics consolidation scheme can have significant effects on reducing freight traffic congestion and can be deployed within current legal frameworks.
- That any such consolidation scheme must be designed with a view to triple bottom line sustainability, using suitable business model generation, with commensurate ex-ante and ex-post evaluation.

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[41] *http://civitas.eu/measures/urban-freight-logistics*

[42] *https://ec.europa.eu/transport/themes/urban/urban_mobility/urban_mobility_actions/urban-logistics_en*

- There is a gap in UK transport policy on urban freight logistics that can be filled with the research outcomes of this and parallel work.
- That the impact of consolidation schemes may not always have a broad macro effect on CO_2e, NO_2 and PM_{10} commensurate to the cost of running them, when compared to other interventions. This may make such schemes less important to public policymakers with limited resources, whilst still being valid for the receiving organisation.
- That Newcastle University develop and implement a full scale CCCC in order to reduce freight vehicle intrusion on site.

12.4.6. Policy Recommendation Dissemination

In order that my recommendations to policy have impact, I have disseminated them and shall continue to do so. I present this activity in tabular format, as Table 152.

Action	University	Local	National	EU
Participate in policy forums	Newcastle City Futures group	North East England Freight Partnership; Local Chartered Institute of Purchasing and Supply (CIPS) group meetings; Chartered Institute of Logistics and Transport (CILT) group meetings	(CILT) freight forum	ALICE (logistics) and ERTRAC (road) European Technology Platforms; Open ENLoCC: European network of logistics competence centres
Publish popular articles		Planned submission of short article to CIPS “Supply Management” magazine	Planned submission of short article to CILT “Focus magazine”	Articles in Open ENLoCC Logistics review
Contribute to scholarly knowledge	Submission of up to four peer reviewed articles based upon this work.			

Table 152: Policy Recommendation Dissemination

12.5. Novelty and Contribution to Wider Knowledge

Finally, it is appropriate to draw out the key novelties in this work. This list is not exhaustive, the thesis is deep and contains insights as yet unnoticed.

The work is novel in that:

- It presents a novel deployment of Action Research in a novel context (urban logistics) and with methodologies novel to AR (DMF and BMC) within the overarching iterative cycle;
- The deployment of a logical framework approach to a developed world problem is novel, as its application to an urban freight logistics problem which was unique;

- The work deployed quite different methods to evaluate how an institution expressed demand from the previously deployed delivery and servicing plan approach, i.e. archival analysis of SAP data, and a procedural analysis of purchasing procedures, yielding new types of data that led to deep understanding and convergence;
- The work provides new data on the activities of freight vehicles on a site; the observation that 8.7% of all freight vehicles in 2015 were dropping off or collecting passengers is unique;
- The work provides a new and detailed analysis of how an institution expresses demand;
- The work adds to the understanding of the impacts of such an inbound logistics scheme, detailing an approach that adopts the lens of such an inbound scheme as opposed to that of a logistics operator;
- The work makes a contribution to the body of knowledge on the dwell time of freight vehicles in cities, in this case by vehicle class and location;
- The work makes an important incremental increase in the shared scholarly knowledge about a certain type of urban consolidation centre.

12.6. Opportunities for Further Research

The opportunities for further research from this work are multiple and include:

If the operational data from the LBCC – see sections 8.8 & 10.11 - were to be made available, then a full comparison could be made, using a mixed methods approach, or simpler quasi experimental modelling.

Future work could address the opportunity for supplier discounts/funding and the balance between value to the University and willingness to pay, which would in turn form the basis of continued research on the sustainability of current procurement policies.

Further research into the existence and role of power buyers and their potential importance in sustainable procurement with the use of a different systems approach such as CSH would merit investigation.

How to improve the sustainability of logistics on the Coherent Campus at Newcastle University?

The datasets collected could be augmented by continued surveying of the site, perhaps with continuous video and ANPR monitoring, enabling a time-series analysis of how traffic changes and informing ongoing modelling.

The combination of traffic surveying and emissions monitoring, either static on site or portable in vehicles, would potentially allow for further understanding of freight and emissions.

Development of the quantitative quasi-experimental model to include noise and safety impacts would lead to wider evaluation of impacts.

The deployment of qualitative methods such as questionnaires, focus groups, and perhaps other systems approaches, would allow Triangulation and convergence between the more quantitative methods above and people-based research.

The syncretisation of ZOPP style workshops with BMC or ULBMC business model generation for such urban freight logistics work in future would be a methodological novelty worth pursuing and of value to both researchers and practitioners.

The potential to develop and deploy the full scale CCCC as a piece of action research has to be an opportunity to again deliver research in action and provide data of a similar and yet different case study.

12.7. Conclusion

In this chapter I have provided answers to the four Research Questions. Some of the opportunities for dissemination of the results have been addressed, as has the novelty of the thesis and the associated datasets.

In short:

RQ1: How to improve the sustainability of logistics on the Coherent Campus at Newcastle University?

This thesis has shown, in deep detail and with strong evidence and analysis, that the intervention known as the Coherent Campus Consolidation Centre scheme would be an impactful way to improve sustainability on the Coherent Campus at Newcastle University.

How to improve the sustainability of logistics on the Coherent Campus at Newcastle University?

RQ2: To what extent can sustainable HEI logistics only be achieved through sustainable procurement practices?

The diversity of HEIs in the literature has been discussed. The fact that the Newcastle University case was not purely procurement driven has been noted. The criteria and factors to be taken into account have been discussed. However, a top down regulatory approach could also achieve more sustainable HEI logistics.

RQ4: How effective were participatory research approaches in facilitating this improvement?

The participatory research process were highly effective, both as research for action and research for this thesis. However, the DMF approach was less helpful than others and the use of ZOPP style workshops with BMC would have been preferable. The AR iterative cycles drove the work well.

RQ4: What novel approaches for policy and practice locally, nationally and at an EU level could be developed from this work?

A key policy point from this work is that public bodies underestimate the degree of control they have over commercial logistics operations, through the power of their collective purchasing spend. Also, that legal deployment of new policies can generate change in inbound logistics.

Appendix A: Script Specification and Resultant Perl Script

Script specification

```
The objective is to analyse the file of vehicles entering
and leaving multiple sites, match the IN time with the OUT
time, and write these to a '_good' file.
Some records will not be matchable and these need to be
written to a '_bad' file for further processing outside of
this coding project.

This will be run on a macOS 10.12.4 (Sierra) machine
running Perl 5.18.
If it is necessary, I can install Perl 5.24 and run it from
a user directory.
I may also run this on an Ubuntu Linux box, but I am happy
to assume portability.
I understand CPAN and can install Perl packages, and I am
fairly competent in the command line and can do most that's
needed but I'd prefer a clean well commented simple Perl
job that a non-expert like me can understand.
The script should take a file name as input, and output
that as two new filenames with '_good' and '_bad' appended
at the end. [This script should not append to any existing
files but replace them]

I have provided xls file for examples, and .csv files for
use.
The .csv files have had dos2unix run on them to assure they
are Unix compliant files.

The input file is a CSV with the headings:

date,plate,site,direction,time,class,logo

Each entry either has data or has blanks thus: [any blank
lines should be ignored]

Date,plate,site,direction,time,class,logo,enginetype
30.04.2012,XX55YYY,Site 1,OUT,08:00:00,L,LOGO,
30.04.2012,ZX02GFD,Site 1,OUT,12:28:00,,Euro 4

THIS DATA FORMAT CAN BE ADJUSTED FOR SEQUENCING IF
NECESSARY.
```

```
All IN records that match an OUT record on data and plate
and site should have parts of IN and OUT sets of data
written to a new '_good' file
This new file will have the original data but some
additional data, one a time calculation, and one a logical
one.

date,plate,site,direction_in,time_in,class_in,logo_in,direc
tion_out,time_out,class_out,logo_out,time_diff,class,logo

date, the date shared by IN and OUT, only one needed be
captured
plate, the plate shared by IN and OUT, only one needed be
captured
site, the site shared by IN and OUT, only one needed be
captured
direction_in, the original IN direction [this may seem
redundant but the field has other uses for us as well]
time_in, the original IN time
class_in, the original IN class [this may seem redundant
but the field has other uses for us as well]
logo_in, the original IN logo [this may seem redundant but
the field has other uses for us as well]
enginetype_in, the original IN engine type
direction_out, the original OUT direction [this may seem
redundant but the field has other uses for us as well]
time_out, the original OUT time
class_out, the original OUT class [this may seem redundant
but the field has other uses for us as well]
logo_out, the original OUT logo [this may seem redundant
but the field has other uses for us as well]
enginetype_out, the original OUT engine type
time_diff, the difference in time between time_in and
time_out
class, this is logical, if class_in has value, use
class_in, otherwise use class_out, even if also null
logo, this is logical, if class_in has value, use class_in,
otherwise use class_out, even if also null

This is an example of the '_good' file:

date,plate,site,direction,time,class,logo,enginetype
30.04.2012,XX56KMY,Site 1,IN,18:01:00,Light Goods
,UNIVERSITY,Euro 4
30.04.2012,XX56KMY,Site 1,OUT,18:02:00,Light Goods
,UNIVERSITY,Euro 4
```

```
30.04.2012,N54AYP,Site 1,OUT,17:52:00,Light Goods
,LOGO,Euro 3/4
30.04.2012,YY54AYD,Site 1,OUT,17:31:00,Light Goods
,LOGO,Euro 3/4
30.04.2012,UU06EUZ,Site 1,IN,16:46:00,Light Goods
,UNIVERSITY,Euro 4
30.04.2012,JJ08WGZ,Site 1,IN,16:50:00,Light Goods
,GLASS,Euro 4
30.04.2012,JJ08WGZ,Site 1,OUT,16:59:00,Light Goods
,GLASS,Euro 4
30.04.2012,IK05ADK,Site 1,OUT,16:03:00,2 Axle HGV,XYZ,Euro
III/IV
30.04.2012,KL55VJF,Site 1,OUT,16:16:00,Light Goods
,OFFICE,Euro 4
30.04.2012,MJ55VJF,Site 1,IN,16:14:00,Light Goods
,OFFICE,Euro 4
30.04.2012,NB55WWE,Site 1,IN,15:51:00,Light Goods ,NHB,Euro
4
30.04.2012,NB55WWE,Site 1,OUT,15:53:00,Light Goods
,NHB,Euro 4
30.04.2012,FI05ADK,Site 1,IN,15:56:00,2 Axle HGV, XYZ,Euro
III/IV
```

If a record in the input file does not match then it should be written to the '_bad' file in the same format as the original input.
We shall then manually edit it until it either does match, or we discard it, but that is not part of this coding.

The files will then be imported into Excel and as such there is a requirement that the resulting file are comma delimited files that import and look as the examples in this bundle.

The files may contain upto 7000 lines of data at a time, but not more.

It is a requirement that any problems in the logic above are pointed out and better solutions are suggested, the purpose is to process the data correctly and output the desired CSV files, I am not worried about being told I have made a mistake in my spec!!

Tom

Perl script [coded by Kumar S.]

```
#!/usr/bin/env Perl

use v5.14;
use warnings;

use Text::xSV;
use Time::Piece;

sub usage {
  say STDERR <<EOT;
Syntax: $0 <file.csv> ...

Reads an input CSV file and divides the records into 'good'
and 'bad'. The good
records are stored in a file named 'file_good.csv' and the
bad records in
'file_bad.csv', assuming the input file is named
'file.csv'. You may pass more
than one input file.
EOT
}

use constant GOOD_CSV_HEADERS => (
  qw/date plate site/,
  qw/direction_in time_in class_in logo_in enginetype_in/,
  qw/direction_out time_out class_out logo_out
enginetype_out/,
  qw/time_diff class logo enginetype/,
);
use constant BAD_CSV_HEADERS => (
  qw/date plate site direction time class logo enginetype
error/,
);

# Read the records from a CSV file and do some post-
processing:
# - Records are sorted by time
# - Records get some metadata added (_timestamp and maybe
_bad)
sub read_records {
  my ($filename) = @_;
  my $csv = Text::xSV->new( filename => $filename );

  # All records from the input CSV
```

```
  my @records;

  $csv->read_header;

  # Read all records from the CSV file. $csv->fetchrow_hash
returns a hashref
  # with the keys being the same as the values in the CSV
file header.
  while (my $record = $csv->fetchrow_hash) {

    # Remove leading and trailing spaces from all fields in
the record
    for my $key (keys %$record) {
      next unless defined $record->{$key};
      $record->{$key} =~ s/^\s+//;
      $record->{$key} =~ s/\s+$//;
    }

    # Check that this record has enough minimum
information. If not, add
    # information about the missing/invalid fields to the
'_bad' key.
    push @{$record->{_bad}}, 'date missing' unless $record-
>{date};
    push @{$record->{_bad}}, 'site missing' unless $record-
>{site};
    push @{$record->{_bad}}, 'plate missing' unless
$record->{plate};
    push @{$record->{_bad}}, 'unknown plate' if $record-
>{plate} eq '?';
    push @{$record->{_bad}}, 'direction missing' unless
$record->{direction};
    push @{$record->{_bad}}, 'invalid direction' unless
$record->{direction} =~ /^(IN|OUT)$/;

    # Parse the date and time and store the result in the
_timestamp key.
    # This allows easier date-time comparisons later on.
    if ($record->{date} and $record->{time}) {
      local $@;
      eval {
        $record->{_timestamp} = Time::Piece->strptime(
          $record->{date} . " " . $record->{time},
          "%d.%m.%Y %H:%M:%S"
        );
      };
```

```
      # If Time::Piece wasn't able to parse the date and
time, mark the
      # record as bad
      push @{$record->{_bad}}, 'failed to parse date and/or
time' if $@;
    }

    # If there was an error generating the timestamp, or if
the date or
    # time were missing, store a dummy timestamp, equal to
the Unix epoch
    $record->{_timestamp} = Time::Piece->new(0) if not
defined $record->{_timestamp};

    push @records, $record;
  }

  # Sort the records by timestamp
  @records = sort { $a->{_timestamp} <=> $b->{_timestamp} }
@records;

  return \@records;
}

# Write a record to the 'good' CSV file
sub write_good_csv_record {
  my ($csv, $in, $out) = @_;

  # Time difference in seconds
  my $time_diff = $out->{_timestamp} - $in->{_timestamp};

  # The output has information about both the IN and OUT
ins
  $csv->print_data(
    date    => $in->{date},
    plate   => $in->{plate},
    site    => $in->{site},

    direction_in => 'IN',
    time_in  => $in->{time},
    class_in  => $in->{class},
    logo_in  => $in->{logo},
    enginetype_in => $in->{enginetype},

    direction_out => 'OUT',
    time_out  => $out->{time},
    class_out => $out->{class},
```

```
    logo_out  => $out->{logo},
    enginetype_out => $out->{enginetype},

    time_diff => sprintf("%02d:%02d:%02d", $time_diff-
>hours, $time_diff->minutes % 60, $time_diff->seconds %
60),

    class   => ($in->{class} || $out->{class}),
    logo    => ($in->{logo} || $out->{logo}),
    enginetype => ($in->{enginetype} || $out-
>{enginetype}),
  );
}

# Write a record to the 'bad' CSV file
sub write_bad_csv_record {
  my ($csv, $record) = @_;

  # The output is equivalent to the input
  $csv->print_data(
    date    => $record->{date},
    plate   => $record->{plate},
    site    => $record->{site},
    direction => $record->{direction},
    time    => $record->{time},
    class   => $record->{class},
    logo    => $record->{logo},
    enginetype => $record->{enginetype},
    error   => join(" | ", @{$record->{_bad}}),
  );
}

# Process a CSV file and create 'good' and 'bad' output CSV
files. The 'good'
# CSV file has information about all IN and OUT records
that 'matched'
# according to the spec. The 'bad' CSV file contains all
records that couldn't
# go into the 'good' file.
sub process_file {
  my ($filename) = @_;

  # All records from the input CSV
  my @records = @{read_records($filename)};
  # Only the OUT records
  my @out_records = grep { $_->{direction} eq 'OUT' }
@records;
```

```
  # Set up the output files
  my $good_filename = ($filename =~ s/\.csv/_good.csv/ir);
  my $bad_filename = ($filename =~ s/\.csv/_bad.csv/ir );

  my $good_csv = Text::xSV->new(filename =>
$good_filename);
  my $bad_csv = Text::xSV->new(filename => $bad_filename);

  $good_csv->set_header(GOOD_CSV_HEADERS);
  $bad_csv->set_header(BAD_CSV_HEADERS);

  $good_csv->print_header;
  $bad_csv->print_header;

  # The actual processing of records to divide them into
'good' and 'bad'
  for my $record (@records) {
    # OUT records that have been matched with IN records
get marked as
    # 'done'. So, skip records that are already marked as
such.
    next if $record->{_done};

    if ($record->{direction} eq 'OUT') {
      # This is an OUT record without a corresponding IN
record since no
      # earlier IN record matched with this one. Thus, this
is 'bad'.
      push @{$record->{_bad}}, 'could not match an IN
record';
    }

    if ($record->{direction} eq 'IN' and not $record-
>{_bad}) {
      # This is an 'IN' record, which isn't yet known to be
'bad'.
      # Iterate over all OUT records in chronological order
to find a
      # match for this IN record.
      for my $out_rec (@out_records) {
        # Skip bad OUT records.
        next if $out_rec->{_bad};
        # Skip OUT records that were already matched with
other IN
        # records.
        next if $out_rec->{_done};
```

```
        if ($out_rec->{plate} eq $record->{plate} and
          $out_rec->{site} eq $record->{site} and
          $out_rec->{date} eq $record->{date} and
          $out_rec->{_timestamp} > $record->{_timestamp}) {

          # We've found the first valid OUT record that is
          # chronologically later than the IN record

          # Store the OUT record in the _out key
          $record->{_out} = $out_rec;

          # Mark the OUT record as 'done' so it is not
matched
          # with any other IN record
          $out_rec->{_done} = 1;

          last;
        }
      }

      # If we couldn't find a corresponding OUT record, set
the
      # IN record to be bad.
      push @{$record->{_bad}}, 'could not match an OUT
record' unless $record->{_out};
    } elsif (not $record->{_bad}) {
      # We should never reach here. die() just in case
future
      # modifications may cause this line to be executed.
      die "Unhandled condition: Record should have been
marked as 'bad', but isn't.";
    }

    if ($record->{_bad}) {
      write_bad_csv_record($bad_csv, $record);
    } else {
      write_good_csv_record($good_csv, $record, $record-
>{_out});
    }
  }
}

##### main #####

unless (@ARGV) {
  usage;
```

```
  exit 1;
}

for my $filename (@ARGV) {
  # Treat -h and --help arguments as special and print the
usage information
  # if we encounter them.
  if ($filename =~ /^(-h|--help)/) {
    usage;
    exit 0;
  }

  say "Processing $filename ...";
  die "ERROR: Cannot read from input file '$filename'\n"
unless -r $filename;
  process_file($filename);
}
```

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