FREIGHT TRANSPORT MODAL CHOICE IN NORTH WEST ENGLAND'S ATLANTIC GATEWAY

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Abstract

Overuse of the road network has led to greater levels of congestion, elevated levels of road surface wear and tear and an increase in transport related air pollution. When taken in combination with the failure of attempts to balance modal split the road network's continuing slide towards breaking point seems to be beyond question. However, circumstances have conspired to present one particular region of England with a tabula rasa for the development of new policies to influence the modal split of freight transportation.

England's economy is currently based around a London-centric model. The current move towards developing what has become known as a Northern Powerhouse is aimed at rebalancing the economy of the nation for the betterment of all of its citizens. The Atlantic Gateway is an integral part of these efforts. The devolution of powers and responsibilities from national government to regional authorities may provide an opportunity for positive change the likes of which has not be seen in the North of England since the beginning of the industrial revolution.

Different regions are influenced by their own geographical and infrastructure constraints. Devolution ensures that decisions are made locally and are therefore more able to meet local needs. A greater understanding of what influences modal choice within the Atlantic Gateway allows local policy makers to make better informed decisions on how to accommodate the increasing levels of freight transportation on the existing local transport infrastructure.

Two different multi-criteria decision making analysis tools are utilised in this study. The first model uses the Analytic Hierarchy Process (AHP) to determine the weights of a range of criteria identified as influencing modal choice. The second model combines AHP with the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to allow the modes of transport under consideration to be ranked. This AHP-TOPSIS approach was adopted to address the limited data made available by the freight transportation industry in support of this research and the inadequacy of the data which is publicly available from mainstream sources.

With billions of Pounds having been spent over many years to balance modal split it was disappointing to find that today, in the North West of England, road is still, by far, the preferred mode for transporting freight. The margin by which road leads the other modes within this geographical region shows the degree to which modal shift policy has so far failed. It also shows the amount of work needed to be done if modal shift is to be delivered in the future.

Acknowledgements

The completion of this thesis represents the culmination of eight years of hard work. None of which would have been possible without the assistance of my supervisors and the funding that was provided by the European Union.

It has been a long journey with more downs than ups along the way. Fortunately I have not had to make this journey alone. Over the years that have gone in to completing this work I have been fortunate to be accompanied by an extraordinary range of wonderful people. Each of these people has made the journey easier for their being involved.

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No set of acknowledgments would be complete without mentioning family, those people that are there through thick and thin. My wife and children have been essential in keeping me in touch with the real world during the long days and late nights that were worked to bring me to the end of this multi-year project. Thank you for not allowing me to lose heart during these tough times and thank you for not allowing me to forget what really matters.

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Abbreviations

AHP	Analytic Hierarchy Process
BBC	British Broadcasting Corporation
CAA	Civil Aviation Authority
CI	Consistency Index
CEF	Connecting Europe Facility
CO_2	Carbon Dioxide
CR	Consistency Ratio
DCS	Decision and Cognitive Sciences
DG-MOVE	Directorate-General for Mobility and Transport
DfT	Department for Transport
ER	Evidential Reasoning
EU	European Union
EUROSTAT	European Statistical System
GDP	Gross Domestic Product
HM	Her Majesty's
HGV	Heavy Goods Vehicles
IWW	Inland Waterway
LJMU	Liverpool John Moores University
LKW	Lastkraftwagen (German equivalent to HGV)
MCDA	Multi-Criteria Decision Analysis
MCDM	Multi-Criteria Decision Making
MoS	Motorways of the Sea
NIRP	Negative Ideal Reference Point
NIS	Negative Ideal Solution
NUTS	Nomenclature of Territorial Units for Statistics
OECD	Organisation for Economic Co-operation and Development

PIRP	Positive Ideal Reference Point
PIS	Positive Ideal Solution
PRIME	Platform of Rail Infrastructure Managers in Europe
RI	Random Index
RUS	Route Utilisation Strategy
SME	Small and Medium-sized Enterprise
SWOTH	Strength, Weakness, Opportunity, Threat.
TEN-T	Trans-European Networks in Transport
TEU	Twenty-foot Equivalent Units
TKM	Tonne Kilometres
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
UK	United Kingdom

Chapter One

Introduction

1.1 Background

The congestion and capacity problems associated with road freight transportation costs Europe about 1% of its Gross Domestic Product (GDP) every year (European Commission, 2011). The shift towards road as the principal means of transporting freight has been identified as a contributing factor in this (Garcia-Menendez and Feo-Valero, 2009). With the publication of its 2001 transport white paper (European Commission, 2001) the European Union set itself the goal of rebalancing modal split in Europe to 1998 levels.

Short sea shipping is seen as the only mode of freight transport that has been able to compete with the growth rates of road transport over the last few decades (Campbell, 2007). Compared to other modes of freight transportation, Short Sea Shipping has a largely unexploited capacity (Blonk, 1994), is particularly reliable, energy efficient, and has external costs seven times lower than road (Lowe, 2005). In recent years, despite some questions having been raised over the green credentials of the shipping industry (Hjelle, 2010), the EU has devised the Marco Polo (European Commission, 2013) and the Motorways of the Seas (European Commission, 2012) programmes as key elements of its policy to achieve a shift of freight away from roads and on to alternative modes of transport.

A major supporting point for the movement of more journeys away from the road is that shipping has a substantially better safety record than road. Annually less than one hundred people die in shipping related incidents within the EU (European Maritime Safety Agency, 2011). By comparison the EU has over thirty thousand people die annually in road related incidents (BBC News, 2007; Brandstaetter, 2012). Despite this the EU's goal of rebalancing modal split has not yet been achieved. It has been stated that this is in part due to the lack of a commonly agreed definition for Short Sea Shipping (Douet and Cappucilli, 2011).

Previous studies that looked at achieving a modal shift from road to sea have been undertaken using a variety of approaches. These include, but are not limited to: case studies (Torbianelli, 2000), cost benefit analysis (Paixao and Marlow, 2001) and SWOTH analysis (De Oses and Castells, 2008). Studies are typically carried out with a focus on a specific geographical region, such as occurred in: France (Gouvernal *et al.*, 2010), Spain (Feo-Valero *et al.*, 2011) and Canada (Brooks and Trifts, 2008). However, national boundaries often contain a variety of different problems. A more specific regional perspective would be of greater benefit.

1.2 Research Aim

The aim of this work is to investigate the modal choice decision making process (between road, rail, inland waterways) occurring within the freight transportation industry of North West England's Atlantic Gateway.

In acknowledgment of the necessity to adopt a region specific perspective, the research question upon which this thesis concentrates is focused on North West England's Atlantic Gateway. Within this region, policy makers have long sought to move the majority of freight away from the road network and on to rail and inland waterways. However, extensive advertising of the perceived benefits of these transport modes within the gateway have met with mixed results. As a result, policy makers are now asking "where to next?" Where best to spend their limited time and financial resources.

With this in mind, the hypothesis that this work takes as its starting point is as follows. It is possible to circumvent the limited amount of quantitative data that the freight transportation industry makes available to researchers. This can be achieved by analysing qualitative responses provided by key experts from within the logistics sector itself. The initial application of a qualitative approach will ultimately allow a novel quantitative model of the modal choice decision making process to be constructed and subsequently applied to the question of freight modal choice decision making that takes place in industry within the Atlantic Gateway.

If the hypothesis is proven to be true it will provide policy makers with a pathway for informing the development of transport policies that are more likely to achieve the desired modal shift of freight vehicles away from the roads.

1.3 Research Objectives

Simply using the selected experts to analyse the broader question of modal choice decision making would not be sufficient to test this hypothesis. As a result, the following research objectives were identified:

- **Identify the prevailing levels of modal split existing in the European Union's EU27.** An analysis of this data is required to identify any trends resulting from existing or previous EU policies geared towards producing a modal shift.

- **Identify regionally significant freight handling infrastructure in the North West region of England.** Trade does not occur in isolation. It requires a well-developed network of infrastructure to accommodate the enormous scale of continuously occurring transport activity. Identifying which elements of the infrastructure network are relevant to freight transportation is an important part of building a greater understanding of how variations in modal split occur.

- **Identify organisations that play a significant role in the present day freight industry of the North West region of England.** A wide range of companies play a variety of roles in the movement of freight. Identifying those organisations which play the most influential roles in the freight industry of the region is the key to understanding whose decision making needs to be influenced to deliver a more even modal share across transport modes.

- **Identify the most effective research methodology for assessing the modal choice decision making process of North West England's Atlantic Gateway.** To achieve this the advantages and disadvantages of a range of decision analysis, consumer expectation modelling, and forecasting techniques will be considered to arrive at a decision on which would be the best suited for use in this work.

- **Identify the key criteria that influence modal choice decision making within North West England's Atlantic Gateway.** To understand the process involved in making a modal choice the first major step is to determine the factors that influence the decision making process (D'Este and Meyrick, 1992). Previous work (Matear and Gray, 1993; Murphy *et al.*, 1997; Cullinane and Toy, 2000; Mangan *et al.*, 2001; Punakivi and Hinkka, 2006; Beuthe and Bouffioux, 2008; Garcia-Menendez and Feo-Valero, 2009) has identified an extensive list of potential factors. Having a firm grasp of these factors is fundamental to this research.

- **Develop a complete modal choice decision making framework specific to North West England's Atlantic Gateway.** By utilising the criteria identified as having an impact upon modal choice a concise framework can be established to model the modal choice decision making process.

- **Establish the weight of each criteria within the decision making framework.** The second major step in understanding the choice process is to determine the relative importance of the factors that influence decision making (D'Este and Meyrick, 1992). This can be done theoretically (Dial, 1979; Gursoy, 2010) or based on empirical evidence (Garcia-Menendez and Feo-Valero, 2009). Due to the lack of publicly available data it is necessary to ascertain the weights of each criterion through the opinions of industry experts.

- **Construct a simplified model.** Having identified the most heavily weighted criteria in the complete framework a more readily accessible, reduced size, modal choice framework based around the most influential criteria, can be produced. This can then be used to determine the ranking of the freight transport modes of most significance within the geographical region under consideration. Subsequently, the results can be made available for policy makers to utilise when developing modal shift transport policy for North West England's Atlantic Gateway.

1.4 Structure of Thesis

Beyond the introduction, this thesis contains eight chapters. These chapters are arranged as illustrated in Fig. 1.1 and are briefly described as follows:

Chapter Two: Literature Review

Chapter Two initially looks at the Atlantic Gateway of North West England and the devolution of power within the United Kingdom before going on to review European transport policy, including: the Trans-European Networks in Transport (TEN-T), Motorways of the Sea (MoS), and the Marco Polo Programme. Subsequently, the chapter considers the current state of the road network and links it to Malthusian population theory and Hardin's tragedy of the commons. Ultimately, Chapter Two goes on to review a series of approaches that have been pursued by academics as they attempt to model the modal choice decision making process within the EU.

Chapter Three: Research Methodology

This chapter lays the foundation for chapters five and six to build upon. Firstly, the methodologies of AHP, TOPSIS, Evidential Reasoning, SERVQUAL, and the Delphi method

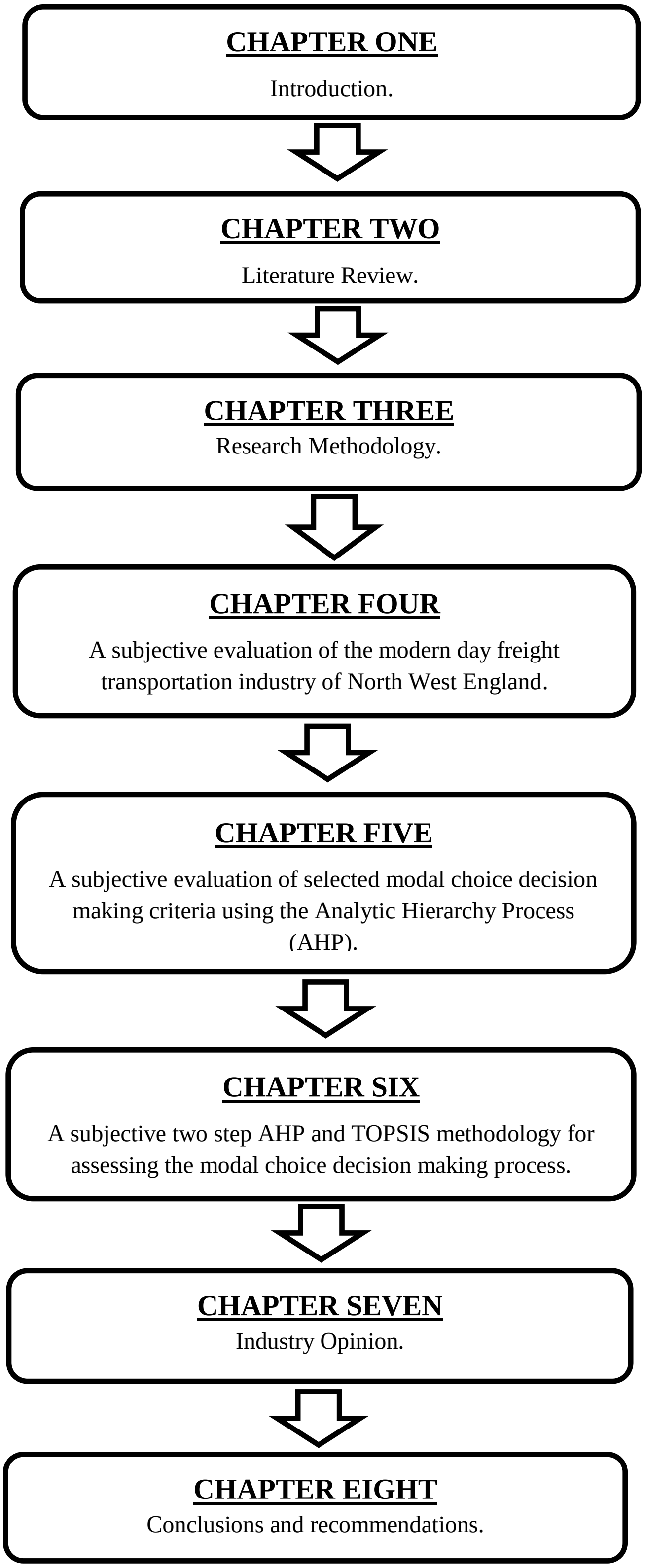


Fig. 1.1: Structure of the Thesis

are briefly explained. After this the advantages and disadvantages of each are considered before the approach that will be pursued in the following chapters is identified.

Chapter Four: A subjective evaluation of the modern day freight transportation industry of North West England

This is a core technical chapter that provides a deeper level of understanding of the freight transportation industry of North West England. Over the course of twelve months, data was gathered through a series of workshops that were geared towards identifying the significant stakeholders in the region's freight industry as well as the significant freight handling infrastructure and the environmental issues of relevance to the modern day freight transportation industry. The aim of this chapter is to define with a greater level of certainty the elements of the freight transport sector that play a role in the modal choice decision making process that occurs within the Atlantic Gateway.

Chapter Five: A subjective evaluation of selected modal choice decision making criteria using the Analytic Hierarchy Process (AHP)

This is a core technical chapter that develops a model for evaluating the importance of selected decision making criteria within the modal choice decision making process. The model utilises the subjective knowledge and judgement of experts in the field to provide data for analysis through the AHP methodology. The objective of this model is to identify the criteria which carry the greatest weight when a modal choice decision is being made.

Chapter Six: A Subjective two step AHP and TOPSIS methodology for assessing the modal choice decision making process

This is a core technical chapter that leads on from Chapter Five. With the most important criteria in the modal choice decision making process having been identified in Chapter Five, Chapter Six utilises AHP and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) to develop a model of the decision making process that can be utilised by industry.

Chapter Seven: Industry Opinion

In Chapter Seven, the issues raised through this research are discussed with leading figures in the field of European logistics.

Chapter Eight: Conclusions and recommendations

In this chapter the conclusions arrived at by this work are presented. Also, recommendations are presented for further research in the field of modal choice decision making within North West England's Atlantic Gateway and further afield.

Chapter Two

Literature Review

This chapter was derived from a systematic review of the existing literature of relevance to modal shift within the EU and more specifically the United Kingdom. Relevant keywords were used to search through various databases, journals, and the reference lists of a range of peer reviewed articles. The results of this search were then analysed and interpreted before being drawn together in to a narrative. Sources of dubious origin, including questionable data, or utilising a poor methodology were discounted so as to ensure the validity of the conclusions drawn.

Whilst this review considers the modes of road, rail, and inland waterway it does not include air which is typically used for the transportation of comparatively small amounts of specific cargoes whose nature lends itself to being transported by that mode. It also does not consider the United Kingdom's proposed new high speed (HS1 and HS2) network whose objective it is to extend the UK's existing high speed rail infrastructure (linking London's Saint Pancras International station to the Channel Tunnel) to additional cities; such as Birmingham, Manchester, Liverpool, Sheffield, and Leeds. At the time of writing this network had yet to be constructed and as its aim is to provide high speed passenger services it is of limited relevance to the modal shift of freight away from the country's road network.

2.1 Introduction

Fast and efficient transport underpins the European economy. At present, road is the preferred mode for freight transportation within Europe. However, the rising volume of both people and freight on European roads has led to higher levels of congestion, pollution, and infrastructure wear and tear. The various problems associated with road transport cost Europe 1% of its Gross Domestic Product (GDP) every year (European Commission, 2011). That is a figure of approximately one hundred and eleven billion pounds, equivalent to the cost of over one hundred hospitals or twenty two thousand primary schools. Unless the level of road use can be reduced, European taxpayers will go on paying this bill. Freight transport activity is projected to increase by around 40% by 2030 and by a little over 80% by 2050. Passenger traffic is also projected to grow but by slightly less than freight transport: 34% by 2030 and 51% by 2050 (European Commission, 2011).

In the United Kingdom (UK), as in mainland Europe, the carriage of freight over the latter half of the last century has been dominated by road transportation. The crumbling state of the nation's road infrastructure clearly demonstrates that this mode of transport cannot continue to meet all the demands placed upon it by the public sector, the private sector, and the general public (Asphalt Industry Alliance, 2013).

2.2 Freight industry leadership

It has been said that the freight industry rewards skill, brilliance, and daring amongst its decision makers (McGowan, 2017). However, anecdotal evidence points to this only being the case as long as the decisions being made generate increasing levels of profit for the companies' concerned (Knott, 2013). Logistics practitioners have suggested that the quality most naturally found amongst those at the top of their industry is megalomania. Their main goal being to concentrate as much power as possible in their own hands (Paraskevadakis, 2014).

It could be said that the freight industry has put power in the wrong hands, but that would miss the point. It is not that those at the top of the industry are the worst people, but rather that if those at the top wish to maintain their positions it depends upon them demonstrating certain kinds of behaviour. The moment an executive loses their focus on profit making they, or their company, are replaced by a more ruthless contender. In a world in which corporate decisions are governed by the necessity of producing good quarterly reports, individual managers are often powerless to make decisions that place anything before profit.

With this being the case, it can be seen that today's freight industry has adopted an out of sight, out of mind mentality (Linkola, 2011):

> "Like any major industry, it is only interested in profit. In terms of its morals, industry only worships money. Its gods are the bank and the market. The industry, as it is, increases its wealth by moving more and more freight. Most things in the world the industry doesn't understand, and the future is one of them. The industry's plans don't extend beyond the horizon"

Cleaner, safer, more efficient, more sustainable, more direct, and often cheaper alternatives to road transportation do exist but attempts to convince people to utilise them to their full potential are an ongoing struggle (Kenny, 2018). As a result, this work is aimed at assisting the efforts of policy makers rather than freight industry managers.

If the global economic crisis of 2008 taught us anything, it is the requirement to build in resilience and fail safe mechanisms to our systems. This is not reflected by the currently mono-modal orientation of the freight industry. In variety lies strength and opportunity. The modern freight transportation industry needs to embrace a truly multi-modal approach where the most sustainable mode of transport (in terms of both cost and environmental implications) for a given route is utilised to its full potential.

Overuse of the road network has led to greater levels of congestion, elevated levels of road surface wear and tear and an increase in transport related air pollution. When taken in combination with the failure of attempts to balance modal split the road network is continuing slide towards breaking point is beyond question. However, circumstances have conspired to present one particular region of England with a tabula rasa for the development of new policies to influence the modal split of freight transportation.

2.3 Devolution

England's economy is currently based on a London-centric model. The recent move towards developing what has become known as the Northern Powerhouse is aimed at rebalancing the economy of the nation for the betterment of all of its citizens. At the same time, the devolution of powers and responsibilities from national government to regional authorities may provide an opportunity for positive change the likes of which has not be seen in the North of England since the beginning of the industrial revolution.

2.3.1 The Northern Powerhouse

The Northern Powerhouse is a strategy aimed at addressing key barriers to productivity in the North of England and Wales by bringing together the great cities, towns and rural communities of the region to become a powerhouse for the UK's economy. It is anticipated that this will be achieved through a range of different actions. The most relevant to this work is the proposal to devolve significant powers and budgets to directly elected mayors to ensure decisions in the North are made in the North, for the benefit of the North (HM Government, 2017).

2.3.2 European equivalents to the Northern Powerhouse

The UK's Department for Transport states that their ultimately aim is for the Northern Powerhouse to rival successful regions elsewhere in Europe. As their targets, they have identified:

<u>The Randstad region of the Netherlands</u> – "Bounded by the four cities of Amsterdam, Rotterdam, the Hague, and Utrecht. This region has a population of almost eight million people and includes Schiphol airport, one of Europe's major airports, and Rotterdam port, one of Europe's major ports, which is also linked by a waterway freight corridor and dedicated freight railway to transport infrastructure with links to the rest of Europe" (Department for Transport, 2015). The Randstad region generates a GDP of approximately two hundred and twenty billion pounds per year, about half of the Netherlands' GDP (Eurostat, 2015).

<u>The Rhine-Ruhr region of Germany</u> – "Draws together twenty three million people, mainly from five large cities (Koln, Dusseldorf, Essen, and Dortmund) and ten smaller cities, but works as one economic area. The region has the most heavily used autobahn roads in Germany and a well-developed rail network. It has one major international airport at Dusseldorf, and Europe's largest inland port in Duisburg that supports heavy industry and distribution parks" (Department for Transport, 2015). The Rhine-Ruhr region generates around five hundred and forty billion pounds per year, representing about a quarter of Germany's GDP (Eurostat, 2015).

2.3.3 The Atlantic Gateway

The Atlantic Gateway is an integral part of the UK government's Northern Powerhouse strategy. Within this strategy, the Atlantic Gateway will serve as a "sustainable freight logistics gateway" (Department for Transport, 2015). A sustainable freight logistics gateway has been described as (Mid-West Regional Authority, 2014):

> "A region which features an efficient freight logistics system. The operation of which contributes both to the economic and social well-being of the region while having a limited and well understood impact on the environment".

Comprehensive, efficient, networks of transport infrastructure are also an essential part of a sustainable freight logistics gateway. As is the integration of services using road, rail, sea and inland waterways. This allows industry to maximise the benefits of each mode in the supply chain (Hjelle, 2010).

The Atlantic Gateway refers to the area of North West England that forms the corridor between Merseyside and Greater Manchester. It comprises the combined area of the Manchester and Liverpool City regions, including Warrington and northern parts of East and West Cheshire.

With Manchester and Liverpool combined having a population of over four million people the Atlantic Gateway accounts for over half of the North West's population. This represents the largest area of urban population in the United Kingdom outside of London (Atlantic Gateway, 2012).

The Atlantic Gateway has been targeted for fifty billion pounds of investment over the next fifty years. This investment is aimed at driving development and growth in urban areas by creating housing, jobs, improving connectivity, and upgrading transport and logistics infrastructure. It also provides an approach for informing policy development and establishing national priorities to rebalance the economy (Cheshire and Warrington Local Enterprise Partnership, 2014).

2.3.4 Transport within the Atlantic Gateway

At present, the United Kingdom relies on the transportation of freight by road. Much of this enters the country in ports on the south coast and is then transported the full length of the country to destinations in the north. As a result, England has some of the most congested roads in Europe. Using coastal shipping, the Port of Liverpool, and the Manchester Ship Canal to move goods into the heart of Northern England could go some way to alleviating this problem. The Manchester Ship Canal represents a viable alternative to road. It runs alongside Europe's largest industrial estate, Trafford Park (Trafford Council, 2014), and currently uses less than twenty percent of its freight capacity (MDS Transmodal, 2014). The problem lies in convincing freight businesses to utilise this alternative transport mode to road.

2.3.4.1 The Port of Liverpool

The Port of Liverpool is in a strongly competitive position. It is already the major Irish Sea roll on–roll off (Ro-Ro) port in the North West of England. With its location, deep water, infrastructure for handling both coastal and deep-sea shipping, proximity to the Manchester Ship Canal, as well as road and rail links to all regions of the United Kingdom, it is the west coast port in the best position to serve the whole of the UK market from a central point (Peel Ports Group, 2016). With sufficient investment, it could be a major sustainable distribution hub serving a nationwide hinterland through waterborne, rail and road freight transport.

2.3.5 Post devolution decision making

Different regions are influenced by their own geographical and infrastructure constraints. Devolution ensures that decisions are made locally and are therefore more able to meet local needs. A greater understanding of what influences modal choice within the Atlantic Gateway will allow local policy makers to make better informed decisions on how to accommodate the increasing levels of freight transportation on the existing local transport infrastructure.

The significance of Liverpool in the UK governments plans for the Northern Powerhouse cannot be underestimated. Especially as the construction of new road infrastructure, to alleviate the growing levels of congestion on the existing network, is a course of action which has long been established as being neither environmentally or economically viable. Indeed, in a worst-case scenario the construction of new roads or the improvement of the existing ones may result in increased congestion (Bellman, 1958; Pollack and Wiebenson, 1960; Falkenhausen, 1963).

2.3.6 Triple convergence

In 2005, Dietrich Braess identified what became known as Braess' Paradox (Braess *et al.*, 2005). It states that adding extra capacity to a network, when the moving entities are responsible for choosing their own route, can in some cases; reduce the overall performance of the network. As counter intuitive as this may seem Braess was not alone in his thinking. His paradox built upon the work of others (Mogridge, 1990; Downs, 1992). Downs (1992) had previously stated that expanding a road system as a remedy to congestion is ineffective and often even counterproductive, especially if the improvements make public transport less convenient or they result in investment shifting away from the public transport system.

However, the funding of public transport is not the only factor to consider. Every vehicle driver normally searches for the quickest route. These are typically limited access roads such as motorways or dual carriageways. If these are not congested, they are faster than local streets. Since most drivers know this, they converge on these 'best' routes from many different directions. It is logical to believe that if such a road were doubled in capacity, traffic would be able to flow unimpeded throughout the day, during both peak and off peak times, as the same number of vehicles would have twice as much road space. Unfortunately, Downs counters this belief with his theory of "triple convergence". Once it becomes evident that this road is now uncongested three things are expected to happen (Downs, 1992):

- Road users who had formerly travelled at a different time to avoid peak congestion would shift back into the peak period.

- Road users who had been using alternative routes would shift onto this, now uncongested, route instead.
- Some people who had been using public transport would start driving on this road during peak periods both at peak and off peak times.

Within a short time, this triple convergence upon the ‘improved’ road begins to make it as congested as before its expansion. More and more drivers begin to use the road during both peak and off peak hours and the traffic volume continues to rise. Before too long vehicles are once again moving at a crawl during the busiest spells.

Increasing road capacity does not fully eliminate peak-hour traffic congestion, or even reduce the intensity of traffic jams during the most crowded periods. This is not to say that expanding, or improving, the road network has no benefits, periods of maximum congestion may be shorter, and congestion on other routes may be less (Downs, 2004, Braess *et al.*, 2005). Equally, after expansion, the road can carry more vehicles per hour than before, no matter how congested it is (Mogridge, 1990). However, it is impossible to eradicate peak-hour traffic congestion on limited access roads once it has appeared within a community that is not shrinking in size (Downs, 2004). The construction of more road attracts more vehicles but if the road network were no longer developed then it would promote the use of other modes.

2.3.7 Modal shift without triple convergence

The EU’s original goal of attaining a modal shift away from road remains valid. However, the question remains, how to deliver such a shift whilst still using the existing transport infrastructure as the number of road vehicles in operation continues to increase (Statista, 2017; Department for Transport, 2017). Vehicles need to be removed from the road network. The construction of new roads, or the improvement of existing roads, will not address the issues of congestion and road surface wear and tear. So far, only road pricing and higher fuel taxes have been found to be exempt from the principle of triple convergence (Downs, 2004).

2.4 European Transport Policy

In recent years, the European Union (EU) has heavily influenced UK transport policy. However, with Brexit now a reality this looks set to change. Looking at the most recent EU transport policies that aimed for, but failed to deliver, modal shift is a useful way to decide where to start when composing transport policy for North West England.

In its 2001 transport white paper (European Commission, 2001) the EU proposed that measures be taken to rebalance modal split in Europe. The aim was to have the market share of each of the modes of transport return, by 2010, to their 1998 levels. Many believed that European Transport Policy faced a difficult task in achieving this whilst at the same time maintaining European trade flow competitiveness (Feo *et al.*, 2011). The measures proposed to address road congestion amounted to two trains of thought. The EU could either attempt to build its way out of the problem or it could attempt to manage its way out. To provide a building solution, the Trans-European Networks in Transport (TEN-T) programme was established to allow public sector financing to fund the construction of new transport infrastructure. To provide a management solution, the Marco Polo programme was devised to create an avenue for assisting private-sector transport providers make more sustainable use of the available transport infrastructure.

2.4.1 Trans-European Networks in Transport (TEN-T)

In the 1990s, the European Commission adopted the first action plans on trans-European networks in Transport. TEN-T stated that its principle objectives were: to improve economic and social cohesion by producing interconnecting and interoperable national networks of land, sea, air and inland waterway transportation; linking somewhat isolated regions of Europe to the rest of the continent, and promoting less polluting modes of transport (European Parliament, 1996).

2.4.1.1 The priority project approach

The initial approach to achieving TEN-T's goal was to identify priority projects of common European interest. These focused on upgrading the existing network where necessary but also constructing new infrastructure to fill the gaps in the existing transport network. Thirty projects were selected (European Commission, 2014). The projects that had the most direct implications for the North West of England were:

- Priority project thirteen - Road axis United Kingdom/Ireland/Benelux.
- Priority project fourteen - West coast main line.
- Priority project twenty one - Motorways of the Sea.
- Priority project twenty six - Railway/road axis Ireland/United Kingdom/continental Europe.

A deadline of 2020 was established for the completion of these projects and it was indicated that the completion of all thirty priority projects would result in significant benefits. These would include: time savings to journeys, reduced road congestion, improved performance of the rail network, and a reduction in the amount of CO_2 generated by the transport industry (European Commission, 2014).

2.4.1.2 The corridor approach

In 2013, the EU had a change of mind and announced details of the most radical overhaul of its infrastructure policy since its inception in the 1980s. Plans were set out to shift the focus of future transport infrastructure investment away from isolated individual projects to corridors (Fig. 2.1).

Source: Railway Gazette (2013)

Fig. 2.1: Map of the core TEN-T network corridors.

This focus on corridors aimed at removing bottlenecks, upgrading infrastructure and streamlining cross-border movement. The nine TEN-T corridors that were identified were expected to be completed by 2030 when they would provide a core network connecting ninety-four major ports with rail and road links and provide thirty-eight key airports with rail links to major cities.

2.4.2 Priority project twenty one: Motorways of the Sea (MoS)

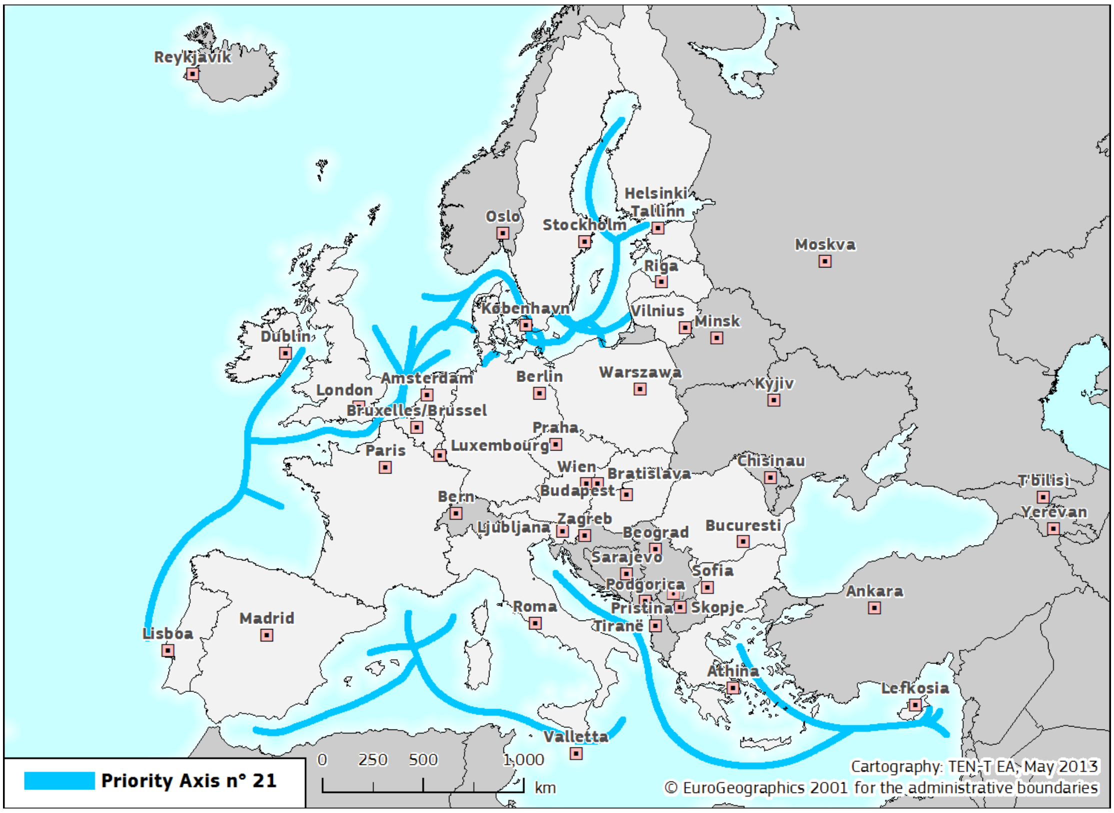
Despite this change in focus from priority projects to corridors, priority project number twenty-one "Motorways of the Sea" remained. This project was perceived as being different to the others. Short sea shipping was seen by some as the only mode of freight transport able to keep up with the growth rates of road transport (European Commission, 2003). In addition, compared to other modes of freight transportation, short sea shipping was advertised as having a largely unexploited capacity, being more reliable, being more energy efficient, and having external costs seven times lower than road (Hjelle, 2010). As a result, rather than building infrastructure it focused on promoting intermodality. Its aim was to do this by generating intermodal options that, based on short sea shipping; provided frequent, high quality alternatives to road transport.

The concept of "Motorways of the Sea" was to introduce new, fully integrated, intermodal, maritime-based logistics chains in Europe. It was anticipated that these chains (making use of underutilised maritime, rail and inland waterway infrastructure) would increase cohesion between the different transport modes, be more environmentally sustainable, more commercially efficient, and provide more efficient hinterland connections than road only logistics chains.

"Motorways of the Sea" were expected to be part of an integrated Trans-European network (TEN-T). The four corridors that were designated as "motorways" were identified by their location: Baltic Sea, Western Europe, South East Europe, and South West Europe (Fig. 2.2).

These corridors were to provide the "floating infrastructure" necessary to accommodate freight movements that would be shifted from the road network. It was anticipated that, in time, a fully-fledged network of motorways of the sea would develop utilising the vast transport potential of the European seas to connect different European regions, through ports that were each linked to inland modes of transport.

The end goal of the process was to concentrate freight flows on to sea-based logistical routes offering a door-to-door service combining short-sea shipping with other forms of transport. As a result, relief would be brought to the congested European road network. To achieve this would require partnership and co-operation through the involvement of organisations from both the public and private sectors. This was vital to accomplish the concentration of freight flows that were imperative for Motorways of the Sea to become viable.



Source: European Commission (2013)

Fig. 2.2: TEN-T project number twenty-one.

2.4.3 The Marco Polo programme

The purpose of the Marco Polo programme was straightforward. It was to help reduce traffic congestion on Europe's crowded roads and promote the use of more environmentally friendly means of transport. Its strategy was simple "shift as much freight traffic as possible from roads to other modes of transport. While roads are overused, rail, sea, and inland waterways often have spare capacity. They also pollute less". Grants from the programme were provided in a bid to make the difference between newly launched modal-shift projects being a success rather than a failure (European Commission, 2009).

Marco Polo was complementary to the Trans-European Networks existing Motorways of the Sea network. It emphasized the use of short-sea shipping to provide a management solution to the problem of congested roads. It aimed to bring about a change in modal split by shifting freight movements away from the road and towards more sustainable transport modes. Suitable alternative transport modes existed that made both economic and environmental sense. The aspiration was that by using these alternatives an annual volume of twenty billion tonne-kilometres of freight would be removed from the roads of Europe. This is the equivalent of more than seven hundred thousand trucks a year travelling between Paris and Berlin.

To achieve its objective, Marco Polo supported actions that contributed towards maintaining the distribution of freight between the various modes of transport at 1998 levels. This was to be achieved by shifting the aggregate increase in international road freight traffic (amounting to approximately twelve billion tkm per year) to short sea shipping, rail and inland waterways or to a combination of modes of transport in which road journeys were as short as possible. This action should decrease road traffic over time on a given corridor by shifting goods from road to short sea shipping operating on Motorways of the Sea.

2.4.3.1 Funding projects

Alternative forms of transport may well have been greener, cleaner and even cheaper over time, but producers, manufacturers and hauliers were reluctant to invest in change in what was a very competitive sector of the economy. To address this, Marco Polo co-funded new projects during the crucial start-up phase before they become profitable.

As of 2013, there had been two Marco Polo programmes, the first from 2003-2006, and the second from 2007-2013. The original Marco Polo (2003-2006) had a budget of seventy five million Euros whereas Marco Polo II (2007-2013) had a much higher budget of four hundred and fifty million Euros. Marco Polo II continued to make use of the proven mechanisms of the previous programme, but then went on to attempt to deliver the initial programmes goal over a larger geographical area. Ultimately, from its inception in 2003, up until 2013, Marco Polo funded over two hundred projects.

2.4.3.2 The end of Marco Polo

In 2013, a communication was issued (European Commission, 2013) on the results of the Marco Polo programme for the 2003-2013 period. It painted a picture that some described as “overly optimistic” (Macaulay, 2014). The communication went on to state that, although the Marco Polo programme had come to an end, in the next programming period (2014-2020), Marco Polo would be replaced by the Connecting Europe Facility (CEF).

2.5 Environmental Issues

It has been stated that environmental issues have been under-represented in previous modal choice decision making work (Meixell and Norbis, 2008). The exclusion of this factor represents a major oversight. If taken in isolation, this would not pose a problem to the transport industry pursuing a business as usual approach. However, consumers are increasingly becoming concerned about the environmental impact of the products that they buy. As a result, major retail companies have begun to attempt to prove their "green credentials" (Harvey, 2007) by holding their suppliers to account for a range of environmental issues that the transport industry is perceived as contributing towards (Neff and Thompson, 2007).

The interaction between the transportation industry and the environment is a vast and complicated subject. However, since the turn of the century, as supply chain managers have begun to understand that environmentally sound decision making can reduce the impact of their business on the environment, an increasing amount of interest in this field has developed (Coyle *et al.*, 2006; Markley and Davis, 2007; Srivastava, 2007; Hjelle and Fridell, 2012). Unfortunately, despite this level of interest, the transport sector has the fastest growing levels of pollution emissions of all sectors (Piecyk and McKinnon, 2013). With road transport being the largest contributor of pollution within the transport sector as a whole. Although environmental regulations have reduced emissions from individual road vehicles this has been offset by an increase in the total number of vehicles in operation (Eurostat, 2017).

Transport, both freight and passenger, plays a contributory role in many of the well-known contemporary environmental issues. The negative environmental effects produced by the transport sector as a whole are substantial (Rodrigue *et al.*, 2013). However, emissions vary greatly between transport modes. This has been one of the major contributing factors in the call for modal shift away from road to more sustainable modes of transport.

EU policy makers now state that "a modern transport system must be sustainable from an economic and social as well as an environmental viewpoint" (European Commission, 2011). In order to achieve this objective the EU has encouraged the development of fiscal policies aimed at integrating the external costs of transport so that the price of transport reflects its real cost to society.

2.5.1 Externalities

Transportation is a polluting activity and every mode of transport gives rise to environmental impacts and accidents. "An external cost, also known as an externality, arises when the activity of one group of people has an impact upon another group and this impact has not fully been accounted for, or compensated for, by the first group" (European Commission, 2003). Emissions of carbon dioxide, particulate matter, noise and congestion are commonly recognised external costs of the freight transport industry. In contrast to the benefits, the costs of these effects are generally not borne by the transport users.

The European Union has categorised a broad range of externalities. As shown in Fig. 2.3, the EU has grouped externalities in to seven major categories. These are (European Commission, 2003): human health (fatal), human health (non-fatal), effects on crops, effects on building materials, impacts upon ecosystems, changes caused by global warming, and amenity loss due to noise.

2.5.2 Internalising externalities

Modes of transport have dissimilar external costs. Therefore, some modes are more advantageous to society than others. The internalisation of external costs means making such effects part of the decision making process of transport users. One of the main modal split issues is that goods transportation generates external costs to society, such as pollution, noise, and congestion, which are often not part of the transports' costs as paid by the final consumer. A range of policies has been developed in an attempt to address this. These have been specifically aimed at minimising environmental impact. For example, increasing the use of cleaner fuels, such as liquid petroleum gas and compressed natural gas, to reduce emissions of harmful exhaust gases. The introduction of electric powered vehicles also offers the potential for further improvements in air quality, particularly in urban areas.

Authorities have also attempted to reintegrate external costs in to the final prices of each mode so that those that are the most costly to society, such as road freight, no longer benefit from externalising part of their costs. Theoretically, if external costs such as those identified in Fig. 2.3, were to be integrated in to each modes prices, when all costs have been taken in to account, this would better balance modal competition in favour of the modes that are least costly to society. Nations have so far struggled to produce fiscal policies that manage to successfully

Impact Category	Pollutant / Burden	Effects
Human Health – mortality	PM_{10} [a], SO_2 NOx, O_3	Reduction in life expectancy
	Benzene, Benzo-[a]-pyrene 1,3-butadiene Diesel particles	Cancers
	Noise	Loss of amenity, impact on health
	Accident risk	Fatality risk from traffic and workplace accidents
Human Health – morbidity	PM_{10}, O_3, SO_2	Respiratory hospital admissions
	PM_{10}, O_3	Restricted activity days
	PM_{10}, CO	Congestive heart failure
	Benzene, Benzo-[a]-pyrene 1,3-butadiene Diesel particles	Cancer risk (non-fatal)
	PM_{10}	Cerebro-vascular hospital admissions Cases of chronic bronchitis Cases of chronic cough in children Cough in asthmatics Lower respiratory symptoms
	O_3	Asthma attacks Symptom days
	Noise	Myocardial infarction Angina pectoris Hypertension Sleep disturbance
	Accident risk	Risk of injuries from traffic and workplace accidents
Building Material	SO_2 Acid deposition	Ageing of galvanised steel, limestone, mortar, sand-stone, paint, rendering, and zinc for utilitarian buildings
	Combustion particles	Soiling of buildings
Crops	NO_x, SO_2	Yield change for wheat, barley, rye, oats, potato, sugar beet
	O_3	Yield change for wheat, barley, rye, oats, potato, rice, tobacco, sunflower seed
	Acid deposition	Increased need for liming
Global Warming	CO_2, CH_4, N_2O, N, S	World-wide effects on mortality, morbidity, coastal impacts, agriculture, energy demand, and economic impacts due to temperature change and sea level rise
Amenity losses	Noise	Amenity losses due to noise exposure
Ecosystems	Acid deposition, nitrogen deposition	Acidity and eutrophication (avoidance costs for reducing areas where critical loads are exceeded)

Source: European Commission, 2003

Fig. 2.3: External costs of energy and transport: Impact pathways of health and environmental effects.

integrate externalities. However, road using charging is at the forefront of policy makers. In particular, the EU states that "…as a general rule, all transport users should pay the full cost, internal and external, of the transport services they consume" and road user charging most definitely has a role to play in this (European Commission, 1996).

2.5.2.1 Road user charging

One solution that would internalise externalities and at the same time address road congestion is road user charging, also known as tolls. At some point, most services that are free of charge at the point of use experience a problem with managing access. Like it or not, in the end politicians will have to come back to charging road users for their use of the road. Road pricing is not only the most sensible way of regulating traffic in congested areas, but the best way to avoid gridlock in the future (Raphael, 2012).

British traffic jams have a heavy economic cost. By 2025, the cost of congestion will rise to thirty-five billion pounds annually in the UK (Raphael, 2012). The Eddington Transport Study (Eddington, 2006) noted that a 5% reduction in travel time for all business travel on the roads could generate two and a half billion pounds in savings. Deterring 10% of vehicles from using the road during peak hours could make the difference between near-gridlock and free flowing traffic. However, "the political dilemma for policy makers is that road users prefer to queue rather than pay. Queueing is admittedly an egalitarian approach, but it is also the most inefficient form of rationing" (Raphael, 2012).

Within the UK, road charging has been considered as a means of managing demand on the road network. However, it has met with mixed results. London has embraced the idea (BBC News, 2004) whereas Manchester has rejected it (BBC News, 2008). Externalities are rarely internalised in the pricing of road use. As a result, a shift towards doing so enters unknown territory and it is therefore difficult to predict how the public will respond. The UK is divided on the issue but many European governments agree that the heavy demand on road use in Europe, compounded by the under-priced, fixed-cost-based, supply of road infrastructure, is a critical factor in the creation of a number of significant problems particularly with regard to congestion, safety, and the environment. These nations anticipate that shifting the emphasis towards a "variable cost" approach to the pricing of road use, in line with the user pays principle, will, in the long term, make competition among transport systems fairer and more efficient (European Commission, 1996). The Eurovignette system was the EU's flagship project for achieving this.

2.5.2.2 Eurovignette

Eurovignette was introduced on 1st January 1995 as a road user charge system (toll system) that is common across its user nations. Originally, these nations were the Netherlands, Luxembourg, Sweden, Denmark, Belgium and Germany. The principle of the system is that vehicles (excluding buses) with a gross vehicle weight of over twelve tons have to buy the Eurovignette if they wish to use motorways and some national roads within the participating countries. The price of the toll depends upon the number of axles of the vehicle, the vehicle's emission class and, the period for which the vignette is purchased. This can range from one day to one year. Since 2008, the Eurovignette is stored electronically on a central database and there is no need for users to possess paper proof of purchase or display stickers on the window of their vehicle. The Eurovignette is accepted in all Eurovignette countries, if a vehicle travels through several of these nations only one valid Eurovignette is required.

Unfortunately, the Eurovignette countries are now limited to Denmark, Luxemburg, the Netherlands and Sweden. In Belgium and Germany, Eurovignettes were in force until they devised their own toll systems (Germany in 2005 and Belgium in 2016). In contrast to the Eurovignette, the German (LKW-Maut) and Belgian (Viapass) systems base their toll on the distance of the journey that is undertaken rather than a period of time, as is the case with Eurovignette. The disagreement between the original Eurovignette nations on how to structure the toll system serves to demonstrate another example of the lack of agreement on how best to proceed with a view to addressing the question of modal shift. Tolling may serve as a method for internalising externalities but, perhaps more importantly, it also serves as an additional source of income for governments that adopt this approach. This second point may be why some countries are so attracted to the idea.

A pricing policy similar to Eurovignette, if ever implemented across the entirety of the UK, would without a doubt make long-haul road transport considerably more expensive. However, the experience of the nations that originally formed the basis for Eurovignette are a valuable indicator as to what the result of a UK system would be. Germany is a good case in point.

In Germany, toll revenues in excess of the systems operating costs provide funding for transport infrastructure improvements (Wieland, 2005). The German scheme has provided freight companies with an incentive to purchase vehicles with lower emission rates. This lowers the emissions of carbon dioxide and other pollutants on German roads. A limited shift from road to rail freight transportation has also been identified as a result of implementing the system. The only negative consequence of LKW-Maut has been the re-routing of some trucks away from toll roads and onto other roads, resulting in additional noise and congestion on those routes (UK Commission for Integrated Transport, 2007*)*. However, despite this, the road infrastructure of Germany is still considered to be congested.

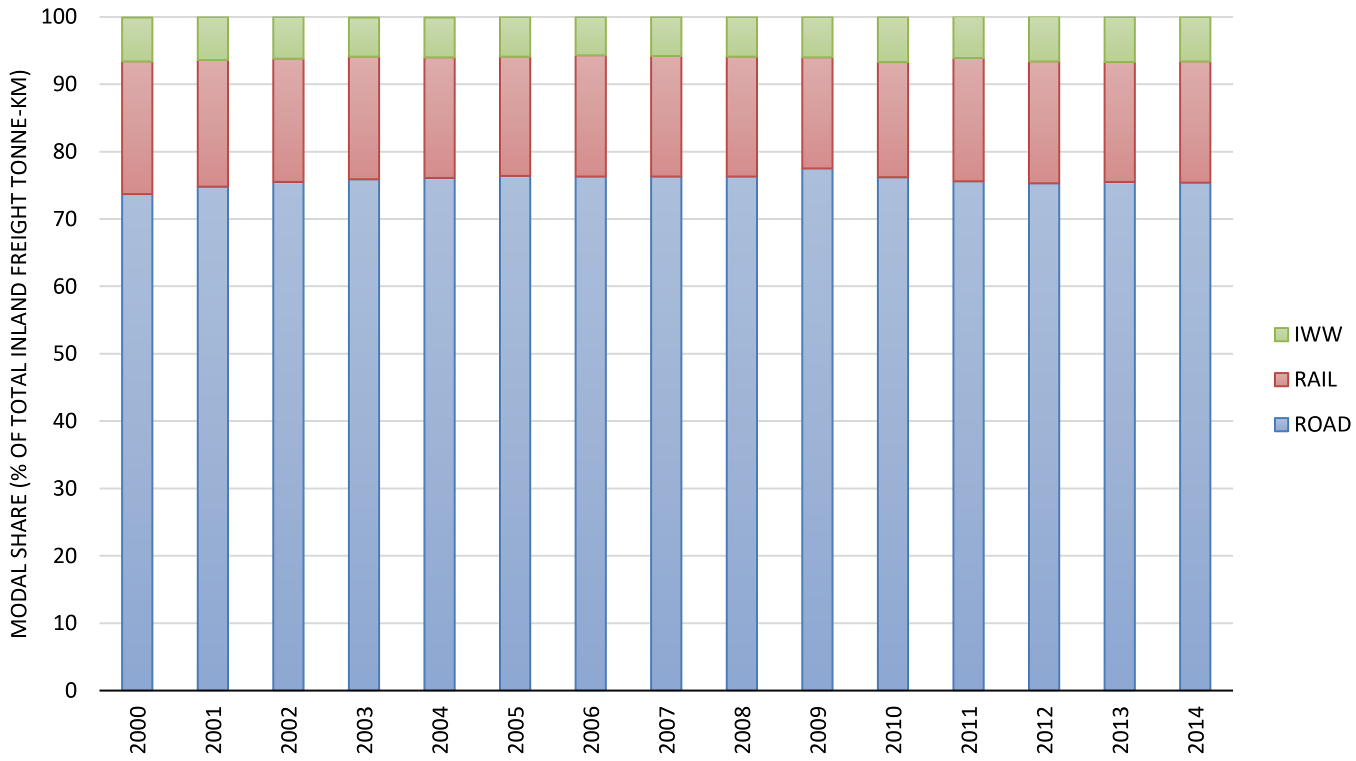
Tolls may internalise the cost of externalities but they do not remove heavy vehicles from the road. Other attempts have been made to achieve this, these include: bringing in weekend, night time or Sunday driving bans to prevent the uninhibited operation of trucks during certain specified periods (Lowe, 1998); maximum speeds for heavy vehicles being capped in some countries by either lowering national speed limits or by the extending outwards of urban speed limit zones; the compulsory fitting of speed limiters on trucks; and more rigorous law enforcement such as increasing the number of speed cameras. It has been claimed that each of these approaches are able to lessen the daily range of trucks, complicate logistics schedules and, as a result, reduce the competitiveness of road haulage against other modes over certain routes (Beresford, 1999). However, after years of employing them the problem of congested road infrastructure remains.

2.6 The result of fourteen years of EU transport policy

No figures exist for modal share in North West England's Atlantic Gateway. However, if we consider the figures that the European Union has compiled then the impact of their policies and programmes that have so far been outlined in this work can be seen (Fig. 2.4). The ongoing expenditure of large amounts of taxpayer's money, based on the EU's own data, has met with limited success. The modal share of each mode has remained similar throughout the last fourteen years.

The movement of freight away from road to produce a significant modal shift never occurred. It has been stated (Paixao and Marlow, 2014) that the desired levels of modal shift were not produced because of:

- A lack of understanding of the characteristics of each mode.
- A lack of interest within the freight transportation industry.
- The actions of vested interests in preservation of their monopolies.
- The inability of the industry to move to a more efficient, greener, sustainable business model.



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
ROAD	73.7	74.8	75.5	75.9	76.1	76.4	76.3	76.3	76.3	77.5	76.2	75.6	75.3	75.5	75.4
RAIL	19.7	18.8	18.3	18.2	17.9	17.7	18.0	17.9	17.8	16.5	17.1	18.3	18.1	17.8	18.0
IWW	6.5	6.4	6.2	5.8	5.9	5.9	5.7	5.8	5.9	6.0	6.7	6.2	6.7	6.7	6.6

Source: Own representation of data from Eurostat (tsdtr220).

Fig. 2.4: Modal split of freight transport in the EU-27 from 2000-2014

However, a lack of understanding of the characteristics of each mode is an unlikely reason for modal shift not occurring as much work has been done on this topic, and the specific strengths and weaknesses of each mode identified (Department for Transport, 2010). The results of the Department for Transport's work is briefly summarised in Table 2.1.

Equally, companies prioritise profit, therefore if there was profit to be made by industry operating in a more efficient, greener, sustainable business model then they would already be doing so (Knott, 2013). More likely, the reason that a modal shift did not result is that there is a lack of interest within the freight transportation industry and vested interests are acting in preservation of their monopolies (Paraskevadakis, 2013).

The fact that the Marco Polo programme was brought to an end demonstrates what the EU thought of the results that it achieved with its budget of five hundred and twenty five million Euros. That alone should identify whether the EU held Marco Polo to be a success or a failure. The CEF continues to fund projects with a view to stimulating the competitiveness of combined transport when compared against exclusively road transport. However, the difference between Marco Polo and the CEF is that the latter has a seven-year budget of twenty four billion Euros for transport related projects between 2014 and 2020. That is over forty five times the Marco Polo budget and with four years less to spend it in. The year 2020 will show whether twenty four and a half billion Euros spent over seventeen years can deliver the level of modal shift required to alleviate the pressure on the EU's roads.

2.6.1 The flaw in EU modal shift policy.

In 2018, after years of input from EU policy makers, European countries are still not equal when it comes to freight transport. Huge dissimilarities remain between nations in the modal split of inland freight transportation. In particular, the geographical circumstances of a given country are a major contributing factor towards these differences. Countries that are isolated from the rest of the continent, on islands or peninsulas, tend to have a much larger share of inland freight transport by road. This is because road is the least costly mode for short distances. EU transport policy from the 1990s to today has not been robust enough to overcome this (Organisation for Economic Co-operation and Development, 1997).

Table 2.1: Analysis of strengths and weaknesses of road, rail and water modes.

	STRENGTHS	WEAKNESSES
ROAD	- Flexible, door-to-door service. - Many alternative routes. - 'Turn up and go' network access. - Suited to ad hoc flows. - Low regulatory and financial entry barriers. - Low unit operating costs for small volumes.	- Open access to infrastructure leads to network congestion. - High unit operating costs for large volume flows. - High environmental and social impacts per tonne kilometre.
RAIL	- Hauls large volumes in a single trainload. - Low unit operating costs for large volumes. - Timetabling generally avoids congestion and delays. - Suited to regular, predictable flows. - Automated loading and unloading is often possible. - Low environmental and social impacts.	- Limited network coverage. - High costs of infrastructure provision and maintenance. - Route capacity and capability constraints. - Road use is often required at one or both ends of a rail leg. - Transhipment costs and risks. - Regulatory and financial entry barriers for new operators.
WATER	- Moves a large volume in a single vessel. - Low unit operating costs for large volumes. - Automated loading and unloading is often possible. - Uses natural transport corridors. - Low environmental and social impacts.	- Limited network coverage. - Low operating speeds. - Road use often required at one or both ends of a water leg. - Transhipment costs and risks. - Regulatory and financial entry barriers for new operators. - High cost of terminal infrastructure and vessels. - Tidal constraints. - Sea transport is susceptible to weather conditions.

Source: Department for Transport (2010)

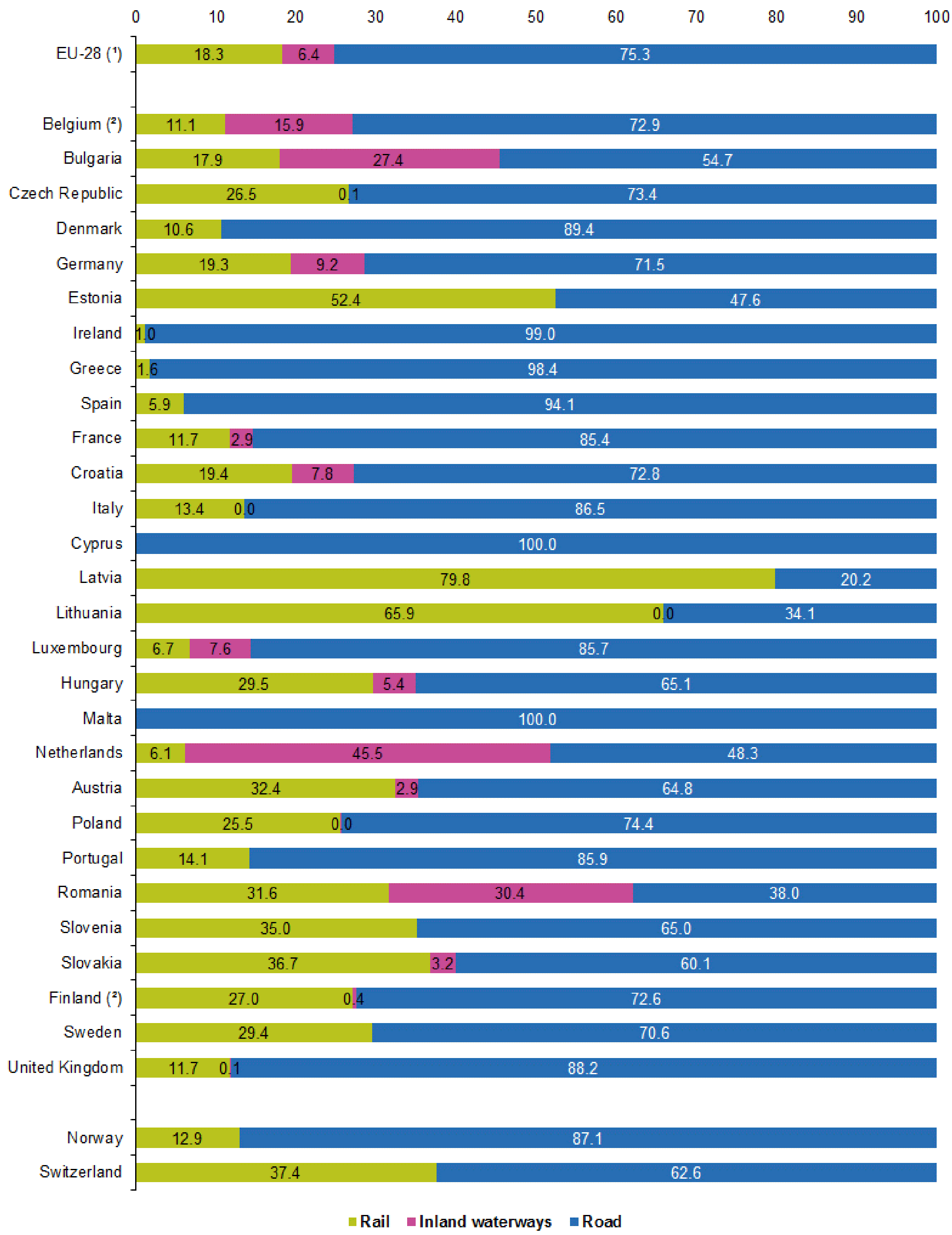
2.6.1.1 Road

In 2015, one year after the end of the Marco Polo programme, the importance of road in the transportation of freight across Europe is still apparent (Fig. 2.5). It is the main inland mode of freight carriage for almost all countries and has a monopoly or near monopoly in many countries: Malta (100%), Cyprus (100%), Ireland (99.0%), Greece (98.4%), Spain (94.1%), Denmark (89.4%), United Kingdom (88.2%), Norway (87.1%), Italy (86.5%), Portugal (85.9%), Luxembourg (85.7%), and France (85.4%).

These countries present some common characteristics. Many of them are relatively small, geographically isolated, possess long coastlines that give them access to the sea, or have most of their territory on peninsulas that are isolated from the rest of the continent by mountain ranges (Fuchs, 2010).

Although, not all of these countries are islands, it is no coincidence that small islands display the largest road shares. Malta and Cyprus have 100% of their inland freight transported by road whereas Ireland has 99%. The size of the islands means that inland journeys take place over comparatively short distances. Within Ireland, the largest of these islands, it is 266 kilometres (166 miles) between Dublin and Cork, and 166 kilometres (103 miles) between Dublin and Belfast. These distances are all far below the level at which rail becomes profitable (Rich *et al.*, 2011; European Commission, 2006) and explains the competitiveness of road transportation on smaller islands.

The United Kingdom is larger than Ireland (Fig. 2.6), with the distance by road between Land's End and John o' Groats being 1,406 kilometres (874 miles). However, at 88.2%, the share of road is still the most significant. Whilst some journeys, such as: London to Liverpool at 354 kilometres (220 miles), London to Manchester at 336 kilometres (209 miles), London to Edinburgh 647 kilometres (402 miles), are larger than those undertaken in Ireland, the share of rail is still low (11.7%). The UK finds itself in exactly the same situation as the smaller islands. Although, from end to end, the nation surpasses the distance considered competitive for rail, any point within the nation is within easy travelling distance of the coast by road. As a result, it should not be surprising that road dominates inland movements of freight. For shipments entering the UK through the south coast, road is the most competitive mode of transport to destinations as far North as Liverpool, Manchester, and Hull. However, for destinations further North than this, a shipment can be brought by sea to a Northern



(¹) EU-28 includes rail transport estimates for Belgium, inland waterways transport estimates for Finland and does not include road freight transport for Malta (negligible). Figures may not add up to 100% due to rounding.

(²) Estimated values.

Source: Eurostat (2017); rail_go_typeall (rail), iww_go_atygo (inland waterways), road_go_ta_tott (national road transport), road_go_ca_c (cabotage road transport), and Eurostat computations (international road transport).

Fig. 2.5: Modal split of inland freight transport (% of total tkm)

port before being unloaded and transported inland to its destination over a much shorter distance by road. This situation also holds true for many of the larger countries of mainland Europe (France, Italy, Spain) as each of them has a long coastline with a wide range of ports available for use.

Source: Own. Amended from Demis Mapper 6

Fig. 2.6: A range of significant locations within the United Kingdom and Ireland.

2.6.1.2 Rail

Geography plays a role in modal share but so does politics. Within Europe, countries which historically had their economies managed through a rigid regime of central planning, as is the case with the eastern European countries that were formerly members of the Soviet Union, then the higher the share of rail transport the country is likely to have (Fuchs, 2010). The larger the role governments play in the economy, the more inclined they are to invest in public transportation infrastructure such as railway. This does not mean that there is no investment in road, but that the political will to develop the rail network is stronger. This is most evident in Latvia (79.8% rail), Lithuania (65.9% rail), and Estonia (52.4% rail). Railways require a larger involvement from the state, not only to realise the investment in infrastructure needed but also to organise their management. In these nations "the high market shares held by railways were as a result of public planning and design rather than the economic efficiency of the railway companies" (Fuchs, 2010). However, since joining the EU, formerly planned economies, such as: Poland, Hungary, and Slovakia; which formerly had a high rail share, have subsequently demonstrated a convergence with the Western nations of the EU and road has become increasingly important in goods transportation (Fuchs, 2010).

In the UK, Atkins, the British Engineering company, estimated that in an environment with a less rigid regime of central planning, rail becomes profitable compared to road for journeys longer than 440 kilometres (273 miles). This is similar to the 500 kilometres (311 miles) mentioned by Rich *et al.* (2011). In addition, the European Commission confirms that road "can provide flexible services regarding departure time and destination, and it is the fastest transport mode for distances up to about 500 kilometres (311 miles) (European Commission, 2006). The UK has a small but significant quantity of freight moved by rail (11.7% rail), this is understandable as the Channel Tunnel connects its rail network to the continent and this makes rail journeys with other countries possible. However, the UK is still an island and, as a result, has a very large share of road transport due to the majority of journeys undertaken being less than 500 kilometres, the magic distance for the competitiveness of rail. Rail is simply not held as being economically competitive over shorter distances.

2.6.1.3 Inland Waterways

Inland waterways (IWW) are a minor mode in terms of inland freight transportation within Europe. As was the case in 2001 (European Commission, 2001), today IWW transport remains the poor relation of road and rail, even though it is a mode which is not expensive and does less damage to the environment than road transport.

Unfortunately, IWWs are only important to some specific areas. Where a nation has a significant sized navigable network of both man made and naturally occurring IWWs joining a major river then they tend to have sizeable inland navigation shares. Therefore, the prevalence of use of IWW in these countries does not come as a result of EU transport policy but entirely as a quirk of geography. The River Rhine and the River Danube are the key pieces of IWW infrastructure in Europe:

> *The Rhine* – Amongst the nations of Europe, the Netherlands clearly has the biggest share of inland freight transport moved on inland waterways (45.5%). This is possible as a result of its geographical position on the Rhine Delta, the well-developed canal infrastructure that connects much of the country to the Rhine River provides a good connection to a large European hinterland.
>
> It is interesting to note that three of the Netherlands neighbours (Belgium, Germany, and Luxembourg) have respectively the second, third, and fourth largest shares of inland freight transport taking place on Western Europe's inland waterways. In addition, France, another nation having access to the Rhine has a small but significant share of freight transport on inland waterways.
>
> *The Danube* – Other countries that have a significant share of their freight transported on inland waterways benefit from access to the Danube. These are Germany (9.2%), Austria (2.9%), Slovakia (3.2%), Hungary (5.4%), Croatia (7.8%), Romania (30.4%), and Bulgaria (27.4%). This increases the further downstream the nation is located, with the greatest amount transported in Romania and Bulgaria. As they are the nations closest to the delta of the Danube, they benefit from the economy of scale provided by the larger vessels that can access the lower portions of the river.

With this being the case, rail and road remain the two main inland modes in all of countries of Europe except: the Netherlands, Bulgaria, Romania, Luxembourg, and Belgium. These nations are all located on or in close proximity to major inland waterways that the majority of other countries simply do not have.

Fortunately, the United Kingdom has its own custom-made inland waterway specifically designed for the transportation of freight between Liverpool and Manchester. With the existence of the Manchester Ship Canal, it is not beyond the realms of possibility that IWW freight transportation could take on the same level of importance to the Liverpool – Manchester corridor that the River Rhine and the River Danube have to their surrounding regions.

Unfortunately, there is a significant factor that appears to stand in the way of this happening. Upon the unloading of cargo from a vessel on the Manchester Ship Canal, to reach the end customer, it is still necessary for end haulage by road over a short distance. Due to the short distance, the per kilometre price is higher than for long distance road transport (Nierat, 1997). This is off putting for many companies. As a result, it appears that the very success of the road network is what leads to its deterioration. It is a victim of its own success.

2.7 The tragedy of the roads

Hardin (1968) neatly describes how commons (resources that are perceived as belonging to the whole of a community) ultimately come to be destroyed from over use. Whilst Hardin described the problem confronted by farmers utilising a pasture for agricultural purposes, the same thinking can be applied to today's road network.

Roads were occupied by vehicles for many years and everyone could keep as many vehicles on the road as they could afford to. This arrangement worked for a long time as the number of road vehicles in use was well below the carrying capacity of the existing road network. However, as the number of vehicles on the road increased, a problem arose. As a rational being, each person, be they an individual or owner of a freight transportation company, sought to maximize their own gain. Although they may not have realised, they each asked themselves "What is the utility to me of adding one more vehicle to the road". In their minds, the result of their decision had one negative and one positive component.

Since the owner receives the benefits of the positive aspects of having the vehicle, to them, the positive utility of putting another vehicle on the road is nearly +1. However, the cost of the negative effects of one more vehicle on the road (such as pollution, road surface wear and tear, and the need for more roads to be constructed) are shared by all road users, and many none road users. As a result, the negative utility for any particular decision making person is only a tiny fraction of -1.

If the component utilities are compared then the rational person concludes that there is only one sensible course of action to pursue, to add another vehicle to the road network. In time this will be followed by another and another and another. Unfortunately, this is the conclusion that every person with access to the road network also arrives at. Each person is locked in to a system that compels them to increase the level of use of the road network.

How to solve this is the very question that people have now been asking for many years and a workable answer has proved elusive. Indeed, it has been easier to identify what is not the solution.

2.7.1 No technical solution

As was the case with TEN-T and Marco Polo, it is often assumed that a solution can be found to any problem through relevant developments in technology and the application of a large enough amount of money. Technical solutions are always welcome but sometimes it has to be recognised that a desired technical, or financial, solution is not possible. Wiesner and York (1965) found this when they concluded, during the cold war, that the dilemma of the nuclear arms race "has no technical solution" as "both sides are confronted by the dilemma of increasing military power but steadily decreasing national security". In addition, Hardin (1968) also recognised this when he stated that overpopulation could not be solved by technology or money. The same can now also be said of the problem of road congestion, road surface wear and tear, and transport related pollution.

Since then, it has been argued (Steltemeier, 2012) that the conclusions reached in Wiesner, York and Hardin were incorrect. However, whether they were right or wrong in apportioning the status of "no technical solution problems" to the cold war or overpopulation is not the concern of this work. Instead, the concern here is that they identified a new class of problems referred to as "no technical solution problems".

A technical solution has been defined as "one that requires a change only in the application of techniques of the natural sciences, demanding little or nothing in the way of change in human values or ideas of morality" (Hardin, 1968). As an extension of this, a problem with no technical solution can be defined as one that, although it may require the application of technology, cannot be solved without a matching change in related human values or ideas of morality.

Many of the people that consider the problem of the over congestion of the road network attempt to identify methods of avoiding the problem without relinquishing any of the privileges enjoyed. They believe that building more roads, upgrading existing roads, creating traffic management systems, developing autonomous vehicles, and the platooning of heavy goods vehicles will solve the problem through technological means (Gallop, 2014). It is not possible to solve a "no technical solution problem" in a technical manner (Hardin, 1968). Wiesner, York, and Hardin are not the only people that thought along these lines.

2.7.2 Caught in a trap

It has been stated that population grows exponentially (Malthus, 1798; Slavov *et al.*, 2014). In a finite world, this means that the per capita share of available resources must decrease as population increases. If the same logic applies to congestion on the road network then it would be seen that as the number of road vehicles in existence increases the individual's 'share' of the existing resources (in this case the road) must decrease. This is an accurate reflection of the present day situation experienced by users of the road network.

Malthus (1798) observed that an increase in a nation's food production improved the well-being of the populace, but the improvement was temporary because it led to population growth, which in turn restored the original per capita level. In other words, humanity tends to use the abundance of a resource to generate growth in the population rather than produce a higher standard of living for the existing population. This dilemma has become known as a "Malthusian trap".

2.7.2.1 Malthus on the road

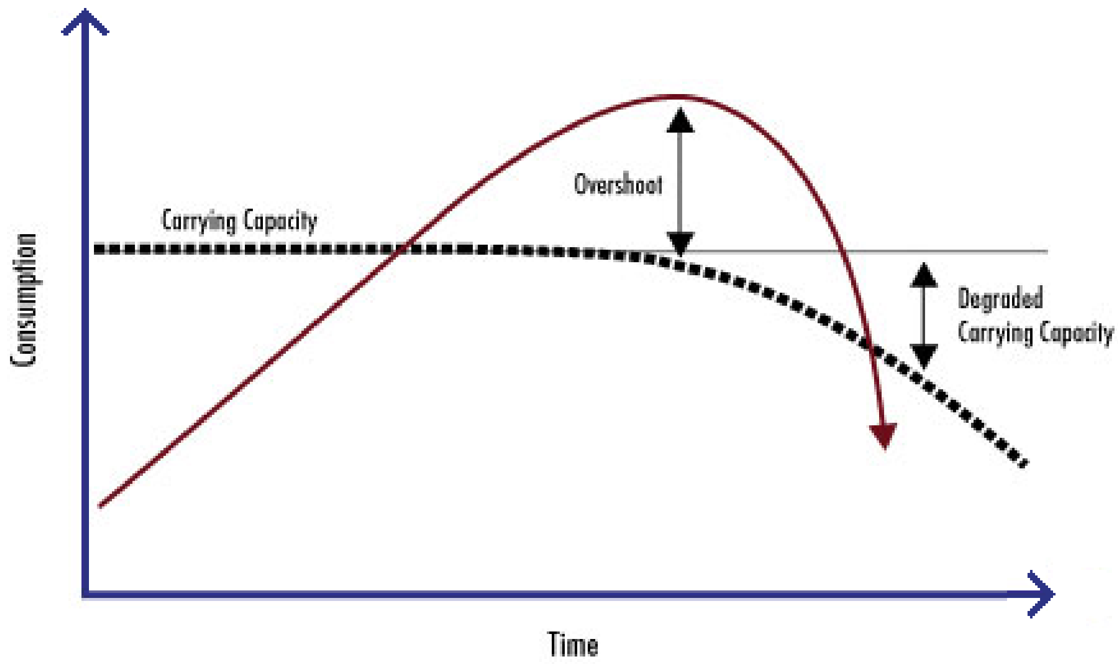
When the number of vehicles on the road reaches a problematic level, action is taken to alleviate the situation. This is usually either achieved through the construction of new roads, or existing roads being made able to accommodate more vehicles. Rather than solving the problem this then allows additional vehicles to utilise the road until, at some point in the future, the upgraded network once again becomes congested.

In the case of the road network, as the quantity of available road increases, the resource abundance encourages more vehicles on to the roads. Over time, this brings the per capita supply of road back to its original level. This being the case it could be said that the road network is caught in a Malthusian trap.

2.7.2.2 Escaping the trap

Unlike many other assessments of the problem Malthus provided an indication as to the direction in which the solution lay. He stated that the power of population is only repressed by moral restraint or misery (Malthus, 1798). In terms of its application to the current day road network, Malthus's position could be taken as stating that road congestion will only be reduced by fewer people using the road network (moral restraint). Alternatively, it could equally be taken as stating that the increasing number of road users leading to longer, more frequent traffic jams, the deteriorating condition of the road surface, and increased levels of air pollution (misery).

A finite road network can only support a finite number of vehicles. Therefore, the growth in the number of road users must eventually reach zero (Fig. 2.7). With this in mind it can be taken that the optimum population of a system is less than its maximum possible population. Although, the difficulties associated with ascertaining the capacity of any system are significant (Knott, 2012) little progress can be made towards establishing the optimum population size for a system (transport or otherwise) until a long shadow that is cast upon the modern world is removed.



Source: Kolankiewicz (2010)

Fig. 2.7: The road network's Malthusian trap

2.7.3 Smith the destroyer

The Wealth of Nations (Smith, 1776) popularised the idea of the "invisible hand". The idea that an individual who "intends only his own gain" is "led by an invisible hand to promote … … the public interest". This belief has since hindered the efforts of those attempting to rationally analyse and find solutions to a range of problems, including road congestion, with the tendency to assume that, political or industrial decision makers will make decisions that benefit society as a whole.

If this assumption is correct, it justifies the continuance of the present range of laissez faire transport policies. If it is correct, we can assume that people will control their own actions to bring about reduction in the level of road usage to an optimal level. Unfortunately, this assumption is obviously not correct. If any further evidence were needed as to why this is not the case, look no further than the economic crisis of the 1930s (Jorda *et al.*, 2011; Kinderberger and Aliber, 2011) along with the more recent economic crisis of 2008 (Havemann, 2009; The Economist, 2013).

An important theme that persists throughout the world is the idea that the economic system is automatic, and, when left with substantial freedom, it is able to regulate itself. However, in reality, the ability to self-regulate and to ensure maximum efficiency is limited by externalities, monopolies, tax preferences, lobbying groups, and other 'privileges' extended to certain members of the economy at the expense of others. As a result, to 'fix' the economic system we need to re-examine our individual freedoms to see which are sustainable. The same applies to the road network.

No technical solution can rescue us from the misery of congested roads. Unlimited freedom to use the road network will bring it to ruin. At present, to avoid having to make hard decisions the expectation is that individual conscience will eventually kerb its use. Relying on an appeal to the consciences of individuals is doomed to failure and the longer that a problem is left unresolved, and allowed to get worse, the more severe will be its solution (Linkola, 2011).

Hardin (1968) agreed with this when he stated that it is a mistake to believe that we can control the actions of other people by an appeal to their conscience. The failed EU transport policies of the first fourteen years of the twenty first century provide additional evidence of this.

Both Hardin's and Malthus's arguments are made in the context of the question of overpopulation but the principles that they expound apply equally to any instance in which society appeals to an individual that is exploiting a commons to restrain themselves for the general good.

2.7.4 No longer a commons

Recent history is replete with examples of similar problems (Yelling, 1977; Lindsey, 2004; Fairlie, 2013; Bawden, 2015; Appleby, 2017; Fox, 2017) when the methods that worked successfully in the past have simply been repeated, even though they were no longer effective, or had in some cases become counter-productive. We have become trapped on a "methodological treadmill", limiting ourselves to tried and tested methods that, because they succeeded in the past, are considered safe. We have forgotten that the same goals, with the passage of time, often require new methods in order to achieve them (Linkola, 2011). We have also forgotten that it is not possible to solve a problem using the same thinking that lead to it in the first place.

Today, this could certainly be taken to be the case. The safe methods that have so far been used to deliver modal shift have not achieved their goal, so an alternative approach must be taken. To be able to influence the people that make these decisions the decision making process that is followed when making a modal choice needs to be modelled. Fortunately, this has been an ongoing process for many years.

2.8 The academic's approach to modelling modal choice

The earliest academic paper considered here is McGinnis' commonly cited 1979 study into the attitudes of shippers towards freight transportation choice. By 1979, the issue of modelling transportation choice had already been under consideration for many years and McGinnis (1979) refers to some of these earlier studies.

2.8.1 In the beginning

McGinnis identifies earlier analyses that were carried out by Meyer *et al.* (1959), Ballou and DeHayes (1967), Neuschel (1967), Balmour and Vinod (1970). The objectives and methodologies of these studies varied widely. As a result, a lack of comparability exists between them. This precludes any comparison beyond general statements.

As such, initially, Meyer *et al.* (1959) found that transportation and inventory costs are important determinants of transportation choice. Subsequently, Ballou and DeHayes (1967) conclude that the impact of transportation reliability upon inventory levels is an influential factor upon transportation selection. Neuschel (1967) states that the logistics concept requires the economics of transportation to be balanced with company policies and customer satisfaction. Finally, the Balmour and Vinod (1970) model of transportation choice considered cost, speed, reliability, loss and damage to be the most important factors of concern when studying modal transport selection.

2.8.2 Shipper attitudes towards freight transportation choice

Much like the objectives of this work, McGinnis (1979) aimed to assist policy makers in their attempts to influence modal choice. To collect a data set, a random sample of one thousand traffic executives, within the United States of America, were sent a questionnaire. This covered a broad range of topics believed to influence transportation choice.

Unfortunately, the approach adopted by McGinnis is potentially flawed. As the respondents to his questionnaire were self-selecting, the data collected is highly likely to be an unrepresentative sample of the industry in question (Vardi, 1985). Statistical confidence in research findings is damaged by non-random samples, such as self-selecting respondents (Jacobs *et al.*, 2009). These respondents can be completely unrepresentative of the target group as a whole (Vardi, 1985). This undermines the subsequent data analysis and, ultimately, produces one-sided results that reveal more about the nature of the respondents than shippers' attitudes towards freight transportation choice (Jacobs *et al.*, 2009).

Fortunately, within the boundaries of this thesis the specifics of the data collection process followed by McGinnis is not the main focus. Technically speaking, research is described as 'valid' if it measures what it is supposed to measure (Cronbach and Meehl, 1955; Kendell and Jablensky, 2003). McGinnis's work clearly identifies freight rates, loss and damage, inventories, speed and reliability as factors of influence upon the attitude of shippers toward transportation choice.

However, the effect on the decision making process of company policy, customer influence, market competitiveness, and external market influences was less clear. Due to their nature, these factors suggest that organisations other than the management of distribution companies have influence over the transportation decisions made.

McGinnis found that the construct of speed and reliability that he suggested for his model was clearly the most important factor, followed by freight rates and damage. However, McGinnis hedges his bets by stating that all three of these factors are of great importance and at any given time, any one of these may take priority. He states that with this being the case, it is unlikely that any one would constantly dominate the others for a prolonged period.

McGinnis went on to suggest that future research in the areas of freight transportation choice should "be careful about making conclusions based on the ranking of variables without considering their relative importance". Conclusions and policy recommendations based on the ranking of variables may be misleading if those variables are all highly important (or of low importance) despite differences in rank. Despite the potentially flawed nature of data collection, these final conclusions remain valid. They were taken in to account throughout the development, data collection, and analysis process of this work.

McGinnis considered the thoughts of the shipper but other parts of the freight transport industry are of equal significance. Carriers are considered next.

2.8.3 Differences between shippers and carriers

The consideration of shippers and careers individual perspectives was considered extensively throughout the 1970s and 80s (Bardi, 1973; Evens and Southard, 1974; Jerman *et al.*, 1978; McGinnis, 1979; Krapfel and Mentzer, 1982; Baker, 1984; Chow and Poist, 1984; Granzin *et al.*, 1986). Until 1991, when Abshire and Premaux examined a selection of this previous work, no comprehensive study had addressed the issue of mode selection variables from the perspective of both shippers and carriers.

It was logical for Abshire and Premaux to draw from the previous work in selecting the criteria to be included in their own survey. Thirty five selection criteria were isolated for inclusion. A stratified random sample of traffic managers (employed by various manufacturing, whole sailing, and retailing organisations) and motor carrier sales managers (drawn from motor freight trucking companies) provided the survey group for their study. Each individual was asked to rate the importance of each of the criteria on a five point scale, with a ranking of one being "not important" and a ranking of five being "most important". The ultimate goal being to determine if a difference exists between the perceptions of shippers and carriers. A mean score was calculated for each of the factors for both carriers and shippers and these values were then compared.

Analysis of the degree of variance indicated a statistically significant difference in the perceptions of shippers and carriers for nineteen of the thirty five selection criteria. This finding demonstrated that "the carriers do not appear to be in tune with the needs of shippers" (Abshire and Premaux, 1991). In terms of prioritising the criteria, the top two selected by the shippers and the carriers where reliability of on-time delivery and reliability of on-time pickup but beyond that the subsequent criteria were subject to variation. Carriers respectively prioritised carrier reputation for dependability, carrier cooperation with shipper's personnel, and carrier representative's knowledge of shipper needs. In contrast, shippers preferred total transit time for the shipment, carrier response in emergency situations, and financial stability of the carrier.

The findings of Abshire and Premaux did not come entirely as a surprise. Earlier indications existed that pointed to the possibility of a disconnect in prioritise between shippers and carriers (Jerman *et al.*, 1978; Burdg and Daley, 1985). It is interesting to see that different elements of the supply chain perceive criteria differently. Structuring a service system that places too much emphasis on the wrong criteria and de-emphasizes certain selection criteria that are important to shippers, may lead to shipper dissatisfaction and subsequent loss of business. This is promising when attempting to promote modal shift. It demonstrates that other modes may be able to generate a movement away from road if they have a better understanding of shippers' priorities.

This all seems very straight forward but it is not as simple as that. Subsequent work followed in the late 1990s (Murphy *et al.*, 1997) and early 2000s (Evers and Johnson, 2000) on the question of whether shippers and carriers agree was performed. Following the same approach as Abshire and Premaux; Murphy *et al.* (1997) found that mean score comparisons indicate a number of important differences between shippers and carriers. However, they also identified that the main short coming of many shipper-carrier selection studies is that the analyses rely solely on mean score comparisons. Therefore, Murphy *et al.* (1997) goes on to perform a further statistical analyses of the criteria rankings generated thorough shipper and carrier responses. Contrary to previous findings, this analyses indicated a high degree of similarity between the two groups. As a result, Murphy *et al.* claims that under certain statistical analyses and comparisons the perspectives of shippers and carriers indicate a high degree of similarity.

With mean score comparisons showing a high degree of difference between shippers and carriers (Abshire and Premaux, 1991) and other forms of statistical analyses showing a high degree of similarity between shippers and carriers Murphy *et al.* (1997) there is clearly demonstrated a methodologically influence upon the results. This has yet to be resolved. In addition, Murphy and Hall (1995) points out that both the absolute and relative importance of long standing selection variables, such as: cost, transit time, reliability, flexibility; can fluctuate over time. Therefore, when taking in to account the findings from these previous studies, and with more recent research choosing to avoid the issue (Kannan *et al.*, 2011; Lu, 2003), indications are that after over forty years of research aimed at identifying and quantifying the degree of difference between the perspective of shippers and carriers the end outcome is that further research is required. “In short, the question still remains: do shippers and carriers agree, or not?” (Murphy *et al.*, 1997)

These initial attempts to consider what influences modal choice are very interesting. However, they attempt to assess the problem as a whole, independent of context. This is unwise as the available transport infrastructure, modes of transport selected, length of route, and geographic considerations are all factors that must be considered. Within the EU, there are a number of examples of academic researchers taking these factors in to account. Some of the more relevant examples of this will now be considered.

2.8.4 The broader issue of modal choice

Academics within the EU have pursued two distinct approaches to the issue of modal choice. In a similar way to that originally pursued by the EU itself, some academics have followed an individual case study approach, like TEN-T’s initial priority projects, whereas others have followed a corridor approach, in line with TEN-T’s post 2013 programme. Examples of these differing approaches are considered in the remainder of this chapter. This section considers academic papers that examined the following:

- Individual locations (priority projects) within the EU (Port of Genoa, Port of Antwerp)
- A long distance international corridor within the EU (Greece – United Kingdom)
- A short distance international corridor within the EU (Switzerland – Italy)

2.8.4.1 Individual locations (priority projects) within the EU (Port of Genoa, Port of Antwerp)

Grosso (2011) stated that “modal choice is a complex decision that shippers and freight forwarders take according to their preferences and to the available services supplied in the market”. Whilst this may be true, Grosso then went on to state that two main typologies of variables exist. These are costs related to the transport, and other service attributes. It is a gross oversimplification to state this to be the case.

Despite disagreement over Grosso’s initial statements, his attempt to capture freight forwarders preferences regarding modal choice is an interesting piece of work. Taking as a starting point the findings of the existing literature a questionnaire was developed and interviews conducted with freight forwarders in the areas of Antwerp and Genoa (Fig. 2.8). The main objective of these interviews was to capture the most important criteria that are taken in to consideration when selecting a mode of transport in either Genoa or Antwerp. Unfortunately, the organisations approached were predominantly freight forwarders and this somewhat limited the scope of the feedback as shippers, carriers, or other categories of organisations were not included. However, a data set was gathered and this allowed conclusions to be drawn.

For Genoa, the main origins and destinations of shipments were limited to: Italy (81%), Germany (2%), Spain (2%), and 15% to other destinations. In addition, the results showed that containerised transport was the most popular with a share of 77%. Followed by general cargo (6%), roll on – roll off (5%), with the remainder being undisclosed (12%). Further breaking this down, container transport was carried by: road (71%), rail (26%), air (2%), and short sea shipping (1%). Whereas, general cargo was carried by road (97%) and rail (3%).

Source: Own. Amended from freeworldmaps.net

Fig. 2.8: The geographical locations of Antwerp and Genoa

For Antwerp, the main origins and destinations of shipments were Belgium (43%), Germany (18%), France (13%), The Netherlands (8%), and 9% to other destinations. Containerised transport was the most popular with a share of 59%. Followed by general cargo (22%), dry bulk (2.5%), and liquid bulk (0.14%). Further breaking this down, container transport is carried by: road (72%), rail (11%), inland waterway (10%), and short sea shipping (0.1%). General cargo is carried by: road (74%), rail (15%), inland waterway (10%), and short sea shipping (1%).

Both Antwerp's and Genoa's respondents expressed similar opinions in relation to the topics presented in Grosso's questionnaire. Ultimately, the results of the investigation showed agreement amongst the majority of respondents in the ranking of the key criteria that the operators consider when making a modal choice decision. These were, in varying order: reliability, possibility to have losses or damages, customer services, cost, and flexibility. This was the case for both ports. Frequency of the service, transport time, or environmental issues were not ranked very highly.

Beyond the restrictions of the questionnaire, some qualitative considerations also emerged during interviews. For both Genoa and Antwerp, road transport was the preferred mode of transport. Feedback found that it was preferred on the grounds of its flexibility, frequency, transport time, and customer services. Although the operators recognised that alternatives to road transport could provide a solution to environmental concerns, this is only "taken in to consideration and a decision adjusted for it, if an economic benefit can be obtained" (Grosso, 2011). This shows a worrying lack of imagination, especially if the end goal is to promote modal shift.

The work of Grosso follows the initial, individual case study approach, which was pursued by the EU. However, other academics have pursued a corridor approach, in line with the EU's later thinking.

2.8.4.2 A long distance international corridor within the EU (Greece – United Kingdom)

In 1999, Beresford identified that there had already been a considerable amount of research carried out into the factors affecting modal choice for freight transport under different scenarios. He states that a shortcoming of these previous works was that the majority of them considered national rather than international movements. This was a mistake on his part, as specific geographical areas have their own constraints and factors to consider. However, Beresford acknowledges that the large-scale movement of freight by road in Europe has contributed to worsening traffic congestion and deteriorating transport conditions in general. In doing this, he identifies that almost twenty years ago academics were attempting to find a solution to the problem of road congestion.

As the problem of road congestion still exists today, historical efforts to address the issue appear to have not met with overwhelming success. However, the approach that were adopted in the past, along with the criteria selected for inclusion within previous models, may offer valuable information that can be used to inform today's efforts towards effective transport policy formulation.

Beresford identifies that the tendency of goods to be transported by road over steadily longer distances has brought about severe congestion and negative environmental consequences, especially over certain routes. He also explains how, in a similar fashion to today, a number of policy initiatives of the time sought to address this problem by encouraging the use of rail or sea transport, especially over longer distances. To increase the depth of understanding of the problem, Beresford (1999) proposed that a simple cost-distance model would be most suitable for modelling both national and intercontinental movements of freight. This sort of model was commonly in use at the time (Fowkes *et al.*, 1989*;* Hayuth, 1992; Banomyong, 2000). He then goes on to propose a transport cost model that highlights the factors affecting the choice of transport mode and test it against real conditions in what he refers to as the Greece-UK transport corridor (Fig. 2.9).

Source: Own. Amended from ABC News (2016)

Fig. 2.9: The Greece-United Kingdom freight transportation corridor.

Beresford states that the model that he uses is "flexible enough to be applied to …. a supply chain of any length" (Beresford, 1999). This seems to be a somewhat unreasonable assertion to make, as the factors that a decision maker considers when making a choice on freight transport mode over a distance of tens of miles will be different to those considered for a supply chain of over thousands of miles.

However, in an attempt to make the model useable over a broader area, Beresford only considers a limited number of attributes. These are total distance, transit time, and cost. Beresford himself accepted the shortcomings of his model when he stated that he hadn't attempted to redesign a simple cost-distance model, similar to the one used by Dial (1979), to fit the more complex multimodal transport operations that he was considering. It was also found that a shipper reaches a judgement on the likelihood of respective modes meeting their necessary delivery requirements based upon a complicated decision making process including cargo value-density ratio, perishability, and whether or not the consignment forms part of a manufacturing or assembly process (Evans *et al.*, 1995).

The larger the area considered under a modal choice study the more artificial the results will be. A much better approach than Beresford's would have been to focus in on a smaller region to generate data of more relevance to the decision making process that takes place as a customer or shipper reaches a judgement on the likelihood of a respective transport mode meeting their stipulated delivery requirements.

With all this in mind, the most obvious next step is to consider a shorter distance international corridor within the EU. A corridor that crosses a single national border, within a more geographically homogenous region than that considered by Beresford. Fortunately, work on this has already been completed.

2.8.4.3 A short distance international corridor within the EU (Switzerland – Italy)

In 2001, Bolis and Maggi presented the results of their microanalysis of freight transport modal choice within a corridor connecting Italy and Switzerland (Fig. 2.10). As no existing data was available for them to draw conclusions from, they had to generate their own. At the time, the application of Stated Preference on the question of mode choice was an established approach (Bates, 1988; Fowkes and Tweedle, 1997). Bolis and Maggi simply applied an adapted form of Stated Preference by way of embedding it in qualitative interviews. This allowed them to collect their own data from a number of the logistics managers of firms operating within the geographical area in question.

The objective of their work was to "produce behavioural parameters based on empirical research in to shippers' valuation of freight transport services with a view to making realistic estimates of the determinants of service choice" (Bolis and Maggi, 2001). Their efforts allowed them to identify relative monetary values to attach to the most important qualities of freight transport. This was performed in the hope that the results obtained would be of use in guiding the strategies pursued to promote the increasing transportation of freight by rail within the transalpine context.

Their findings confirmed the results of similar research carried out in the context of other locations within Europe (Blauwens and Van de Voorde, 1988; Wynter, 1995; Fowkes and Tweedle , 1997; Jong (de) *et al.*, 2000). Generally speaking, factors such as reliability, travel time, price, and lead-

Source: Own. Amended from BootsnAll Travel Network (2018)

Fig. 2.10: The transalpine freight transportation corridor between Lucerne (Switzerland) and Rome (Italy).

time were found to play a significant role in the choice made to select a particular mode of freight transport. More specifically, the results demonstrated that, within this geographical area, the service provided by road freight hauliers was considered to be qualitatively superior to the services that made use of rail or combined transport. Interestingly, improvements made to the road network were found to have a weaker impact on the modal share of road than similar improvements to rail or combined transport.

Bolis and Maggi go on to break their results down in accordance with the nationalities (Swiss and Italian) of those who responded to their survey. In doing this, they identified that the Italian sample had no significant preference for a particular mode of transport. However, in contrast, the Swiss sample reveals a clear preference for rail when transport service quality is equal across each available mode. In addition, within the Swiss sample the cost of a service is not significant, whereas the quality is. Swiss shippers are more concerned with the quality of a service than the price (Bolis and Maggi, 2001).

The results generated are interesting in that, at the time, the efforts being made to influence modal share in transalpine freight transportation where focused on cost, not quality. This being the case, a disconnect existed between the perceptions of policy makers and the reality of the situation. In addition, it is also concerning that despite these clear results the EU still pursued a priority project approach within the TEN-T programme where tens of millions of pounds were spent on road related projects.

It is also worth noting that the Swiss sample finds that flexibility is more important than frequency while for the Italians the opposite is the case (Bolis and Maggi, 2001). Therefore, it is shown that the factors influencing modal choice vary from nation to nation. However, to accept the nation as a basic unit within which to collate data is a misguided approach. Any given nation is composed of a variety of regions within which an assortment of different circumstances prevail. It is short sighted to believe that an entire nation can be accurately represented through one data set. Therefore, the logical next step is to consider a short corridor within a single nation of the EU and that is the intention of this work.

2.9 Conclusion

This chapter serves to introduce a number of issues of relevance to the modern day freight transportation industry and the modelling of modal choice decision making. Perhaps most importantly, it looks at the EU's failed efforts to promote a shift away from the haulage of freight, over long distances by road, towards other modes of freight transportation that are perceived as being more sustainable. The key elements of the transport policy that were adopted by the EU to deliver modal shift (TEN-T, Marco Polo, Motorways of the Sea) are considered so that reasons for their shortcomings can be identified.

This chapter goes on to look at the external impacts of freight transportation upon the environment and identifies the methods that have been pursued (Eurovignette, Toll Collect) in a bid to internalise them in to the overall cost of using a given mode of transportation. Another important subject mentioned in this chapter is the strengths and weaknesses that have been identified for the different transport modes. This information is critically important when considering how to make the most efficient use of each available mode in an attempt to accommodate the necessary movements of freight from the ports where it enters a country to the consumer centres of the cities, where the finished products are finally sold.

Having taken all this in to account a gap in the existing research is clearly identified. In recent years, modal shift research has been performed across the world in a range of locations of widely differing characteristics. Despite this no such work has been conducted within the increasingly important economic area of North West England's Atlantic Gateway. This lack of research strengthens the case for this work. It lends credence to the argument that the UK government being housed in London is a weakness in its efforts towards delivering effective policy outside of the capital. It is out of touch with the needs of the rest of the country.

When constructing a model it is important to ensure that the environment surrounding the problem as well as the participants associated with the problem are identified. Equally, it is necessary to represent the problem as thoroughly as possible and identify the attributes that may contribute towards its solution. This has been touched upon in this chapter as a number of attempts to model modal shift from the perspective of an academic have been considered. Each of these important points will be addressed again in later chapters. However, the following chapter identifies the methodology that will be followed to generate a model of the modal choice decision making process occurring within the freight transportation industry of North West England's Atlantic Gateway.

Chapter Three

Research Methodology

The purpose of this chapter is to briefly consider the origin, applications, methodology, advantages and disadvantages of the research techniques that were considered most suitable for this work. Having done this the chapter then goes on to state which of these techniques were selected to be utilised within this research.

3.1 Introduction

It was essential that the methodology utilised in this work be academically rigorous whilst at the same time remaining as transparent and intuitive as possible. Over twenty possible procedures were initially identified as being suitable. However, a number of these were removed from the list as they were considered to be too data intensive or impractical as a result of what some representatives of industry perceived as being an over reliance on computers. Subsequently, due to issues of: ease of use, reliability of results, transparency of process, and capacity to re-do the study to validate the results the list of suitable methodologies was reduced further.

Ultimately, it was considered that utilizing a different approach to the established Logit (Rich *et al.*, 2009), Probit (Wang *et al.*, 2013), and Utility (Guo *et al.*, 2016) methodologies in combination with the specific geographical constraints of this work would represent a departure from the existing literature and in that regard provide a novel contribution to existing knowledge. With this in mind a shortlist of possible research methodologies was compiled. From this list, the techniques considered most able to deliver the best outcomes were selected.

3.2 Possible Methodologies

In alphabetical order, the methodologies considered most able to deliver the best outcomes from this research were:

- Analytic Hierarchy Process (AHP)
- Delphi
- Evidential Reasoning (ER)
- SERVQUAL
- The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

3.2.1 Analytic Hierarchy Process (AHP)

AHP is an established methodology for multiple criteria decision making. The concept of AHP was devised by Thomas L. Saaty (Saaty, 1980) and has been extensively studied and refined since then (Saaty, 2000). AHP is defined as a procedure for combining both subjective and objective assessments and perceptions into an integrated framework based on ratio scales from pairwise comparisons (Song and Yeo, 2004). Through the use of pairwise comparisons AHP determines the priority of a set of alternatives and the relative importance of attributes in a multiple criteria decision making problem (Wei *et al.*, 2005).

3.2.1.1 Previous applications of AHP

Since its inception AHP has been extensively applied towards the modelling of unstructured problems in a variety of study areas. These include: risk assessment (Mustafa and Al-Bahar, 1991), marketing (Dyer and Forman, 1992), resource allocation (Ramanathan and Ganesh, 1995), location decision making (Atthirawong and McCarthy, 2002; Tzeng *et al.*, 2002), accounting (Apostolou and Hassell, 1993), manufacturing (Rangone, 1996), IT outsourcing (Udo, 2000), information security (Bodin *et al.*, 2005), personnel assignment (Korkmaz *et al.*, 2008), franchisee selection (Hsu and Chen, 2008), conflict resolution (Saaty and Peniwati, 2008), weapon selection (Dagdeviren *et al.*, 2009), and benchmarking (Salem, 2010).

3.2.1.2 Transport specific applications of AHP

Within the transport industry AHP has been used to address a range of issues, including: shipping policy (Frankel, 1992), bus performance (Tzeng and Wang, 1994), fuel transportation (Poh and Ang, 1999), airline competitiveness (Chang and Yeh, 2001), shipping company performance (Chou and Liang, 2001), airport expansion (Vreeker *et al.*, 2002), liner shipping competition (Kumar, 2002), hydrogen fuelling systems (Winebrake and Creswick, 2003), port selection (Ugboma *et al.*, 2006), transport policy (Berrittella *et al.*, 2007), and logistics outsourcing (Grewal *et al.*, 2008).

3.2.1.3 AHP Methodology

AHP decomposes a decision problem into its constituent parts and constructs a hierarchy of criteria. This allows the importance of each criterion to be established (Macharis *et al.*, 2004). The AHP method can also support group decision making by using the calculated mean of a collection of individual pairwise comparisons (Zahir, 1999).

The collection of data for use in AHP is done through a series of pairwise comparisons. To complete a pairwise comparison questionnaire an expert is required to use their experience to provide a judgement as to which of two separate criteria is more important and by how much.

In the application of AHP, Riahi *et al*. (2010) quantified judgements on pairs of attributes (A_i and A_j) in the form of an n-by-n matrix (D). In this, the entries a_{ij} are defined by the following entry rules:

Rule 1 If $a_{ij} = \alpha$, then $a_{ji} = 1/\alpha$, $\alpha \neq 0$

Rule 2 If A_i is judged to be of equal relative importance as A_j, then $a_{ij} = a_{ji} = 1$

Equation 3.1 shows the constitution of comparison matrix D using a_{ij}

$$D = a_{ij} = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix}$$

$$i, j = 1, 2, 3, \ldots, n \qquad (3.1)$$

Each a_{ij} represents the relative importance of attribute A_i to attribute A_j.

Having recorded the quantified judgments of comparison on pair (A_i, A_j) as the numerical entry a_{ij} in the matrix D, the next step is to assign to the n contingencies $A_1, A_2, \ldots, A_n$ a set of numerical weights ($w_1, w_2, \ldots, w_n$) that reflect the recorded judgements (Riahi *et al.*, 2010). These weights can be calculated using equation 3.2 where a_{ij} represents the entry of row i and column j in a comparison matrix of order n (Pillary and Wang, 2003):

$$\omega_k = \frac{1}{n}\sum_{j=1}^{n}\frac{a_{kj}}{\sum_{i=1}^{n} a_{ij}} \; (k = 1,2,3, \ldots, n) \qquad (3.2)$$

The weight vector of the comparison matrix provides the priority order but it does not confirm the consistency of the pairwise judgement. The AHP provides a measure of the consistency of the pairwise comparisons by computing a Consistency Ratio (CR) (Riahi *et al.*, 2010). The CR is devised in such a way that a value less than 0.10 is deemed consistent in the pairwise judgement. A decision maker should review their pairwise judgements if the resultant value is more than 0.10.

Table 3.1: Value of *RI* versus matrix order (Saaty, 1990)

Size of matrix (n)	1	2	3	4	5	6	7	8	9	10
Random Indices (RI)	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

The CR value is calculated according to the following equations (Anderson *et al.*, 2008):

$$\lambda_{max} = \frac{\sum_{j=1}^{n}[(\sum_{k=1}^{n} w_k a_{jk})/w_j]}{n} \tag{3.3}$$

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{3.4}$$

$$CR = \frac{CI}{RI} \tag{3.5}$$

In formulae 3.3, 3.4 and 3.5 *CI* is the Consistency Index, *RI* is the average random index (Table 3.1), *n* is the matrix order and λ_{max} is the maximum weight value of the *n-by-n* comparison matrix D.

3.2.1.4 Advantages of AHP

AHP benefits from the following advantages over other techniques (Saaty, 1990; Rangone, 1996; Ramanathan, 2001; Millet and Wedley, 2002; Ugboma *et al.*, 2006):

- AHP is a commonly used and widely accepted decision making tool.
- It is able to derive a scale for factors where measures may not ordinarily exist.
- As a result, it is able to compare quantitative and qualitative criteria in a common framework.
- AHP decomposes an unstructured problem in to a reliable hierarchical structure.
- The hierarchy structure can easily be adjusted to fit many different sizes of problem.
- The process of collecting judgements is not data intensive. Judgements can be elicited from a select group of qualified and experienced decision makers rather than a larger group of less suitable individuals.
- Multiple inputs from several individuals can be combined to generate a consolidated outcome.
- Upon the generation of results a method is included in the process to verify their consistency.

3.2.1.5 Disadvantages of AHP

AHP suffers from the following disadvantages over other techniques (Zahedi, 1986; Wei *et al.*, 2005; Dyer, 1990; Ishizaka and Labib, 2009):

- Making pairwise comparisons is an artificial way of making comparisons.
- Decision makers often approach a decision in a much less rational and logical way.
- It can be a challenge to follow the concept and perform the evaluation process using pairwise comparisons and the recommended scale.
- If multiple criteria exist, preferences between these criteria must be established. This makes the resulting decision inherently subjective.
- Responses made in accordance with the pairwise comparison scale are highly subjective and implicitly require the user to establish a reference point on the scale. The choice of this scale ultimately influences the results.
- Difficulties can arise if too many attributes leads to numerous paired comparisons having to be made. This results in the process becoming inefficient.
- It has been suggested that the scale used for comparisons should be multiplicative or exponential rather than linear.
- Often more than one criterion will be of importance and when this is the case various criteria may conflict with one another. Such interdependence between criteria and alternatives can lead to inconsistencies between pairwise judgments and the subsequent ranking of criteria.
- Under certain circumstances the results generated by the AHP process can experience rank reversal.
- If the consistency index is found to be too high problems can result when requesting participants to reconsider their inputs.

3.2.2 Delphi

Delphi provides a structured communication process in which a group of experts input, discuss and defend their opinions until a mutual consensus is achieved (Li, 2005). Its origins are rooted in efforts to forecast the future. As a research method, Delphi was known as early as the 1920s, but its current form dates back to the 1950s when it was utilised by Olaf Helmer, Norman Dalkey and Nicholas Rescher of the RAND (Research and Development) Corporation (Scheibe *et al.*, 1975). Delphi is based on the assumption that an expert is better at forecasting the future than a person who does not possess the same amount of knowledge, experience and qualifications. As a result, it has been stated that under 'normal circumstances' the opinions of a small number of experts should be valued more than a much larger group of non-experts (Helmer and Rescher, 1959; Klee, 1972; Oh, 1974). When the experts' views have been gathered, they are processed by a facilitator before being sent back to the same experts for re-evaluation. This procedure is repeated for an agreed number of rounds until the experts have reached a pre-established level of agreement on the issue under consideration (McAllister, 1992). Delphi relies on ensuring the anonymity of participants to each other as the group attempts to establish a consensus (Cuhls, 2005).

3.2.2.1 Previous applications of Delphi

Since its inception Delphi has been extensively applied towards the modelling of unstructured problems in a variety of study areas, these include: communication and public relations (Preble, 1983), family planning (Niero and Robertson, 1996), curriculum development in health care and social work training (French, 1997), identifying national park selection criteria (Kuo and Yu, 1999), developing a taxonomy of organisational mechanisms (Nambisan *et al.*, 1999), developing rules for a ceramic casting process (Lam *et al.*, 2000), identifying the traits and behaviours of top performing software developers (Wynekoop and Walz, 2000), software development project risks (Keil *et al.*, 2002), health education and health promotion campaigns (Meyrick, 2003), improving the quality of IT security audits (Pieko, 2005), and computer forensics legal issues (Brungs and Jamieson, 2005).

3.2.2.2 Transport specific applications of Delphi

Within the transport industry Delphi has been used to address a range of issues, including: transport facility alternatives (Scheibe *et al.*, 1975), air travel and aircraft technology (English and Kernan, 1976), fourth party logistics (Cheng *et al.*, 2008), bicycle industry supply chains (Cheng and Tang, 2009), forecasting long-term trends in road freight related carbon dioxide emissions (Piecyk and McKinnon, 2013), bus safety (Cafiso *et al.*, 2013), railway freight transportation (Zitz and Matopoulos, 2014), decarbonizing road freight (Liimatainen *et al.*, 2014), maritime transport in the Gulf of Bothnia (Pekkarinen and Repka, 2014), constraints on future size large container ships (Paz *et al.*, 2015), and international multimodal transport networks (Wang and Yeo, 2016).

3.2.2.3 Delphi Methodology

The Delphi method involves a number of cycles of anonymous written discussion and argument, managed by a facilitator. The experts involved do not meet, or even necessarily know who else is involved. The facilitator controls the process, and manages the flow and consolidation of information. Ultimately, the objective is to identify a properly thought through consensus of opinion or determine the most important issues with regards to a given topic.

These stages are typically completed in a series of established steps (Rowe *et al.*, 1991; European Commission, 2006; Hsu and Sandford, 2007; Cheng *et al.*, 2008; Chang *et al.*, 2010):

Select a facilitator - The most important part of any Delphi study is the selection of a suitably qualified and experienced individual to be the facilitator. It is critical that the individual selected has a neutral position on the area that is to be investigated. They must also have strong administrative skills. These will be essential for the task of compiling the data collected in the various survey rounds in to the source material for the subsequent round's discussion.

Select the experts - The recruitment of experts, to form a panel, is a fundamental stage of Delphi. Experts should be chosen, not so much for their title, function or position, but for their familiarity with the field, capability to envisage future perspectives, and willingness to engage in the process.

Frame the area of investigation - It is important to accurately define the field of investigation. To do this either a document must be put together to reflect the specific issue of interest or a questionnaire needs to be drawn up according to certain rules. The questions can either be precise and quantifiable or open ended to provide the opportunity to find alternative, original suggestions. The facilitator is a critical part of this process where they will have to determine both how best to frame the question and also how many survey rounds will be undertaken.

Conduct the first round of a questionnaire survey (collecting the primary data from expert participants) - In the first round the experts selected give their statements or express opinions on the provided document. The experts involved are separated from each other to ensure their anonymity from one another. Their opinions are collected in such a way as to ensure their anonymity. In this way it is ensured that the real opinions of each expert are obtained and not an opinion that has been falsified, to a greater or lesser extent, by peer pressure.

Conduct the second round of a questionnaire survey (clarifying opinions and seeking consensus) - In the second round, the experts are provided with the results of the first round. This allows them to alter their original assessments if they choose to or stick to their previous opinion if they see fit. If they feel that there is a serious degree of divergence between their own view and the group consensus they are invited to comment on this.

Conduct the third round of a questionnaire survey (defining more specific opinions and reaching consensus) - In the third round, each expert is asked to comment again on the arguments of the counter proposal or proposals that differ from the group consensus.

If it is deemed necessary, the third round of the survey can be followed by additional questionnaire rounds until a consensus is reached (Delbecq *et al.*, 1975). However, the Delphi process is often limited to three rounds as it is typically found that after this there is usually little variation in the opinions expressed (Ludwig, 1994). Whilst earlier Delphi studies insisted on unanimity, absolute unanimity is no longer considered desirable, since it may lead to the loss of important information (Weatherman and Swenson, 1974).

3.2.2.4 Advantages of Delphi

Delphi benefits from the following advantages over other techniques (Martino, 1983; Rowe *et al.*, 1991; Stitt-Ghodes and Crews, 2004; Cuhls, 2005; European Commission, 2006):

- By emphasising consensus, Delphi encourages experts to seek a common view.
- Rather than face to face interviews, or group discussions, Delphi participants interact anonymously. As a result, nobody 'loses face' from expressing their opinions, differing ideas and opinions are more freely offered, and extreme opinions can be brought up for discussion.
- All opinions, even those that are in a minority, are equally valuable and under review.
- The back and forth of the discussion process facilitates a higher level of participation from those involved than is the case in many other research methods.
- The repetitive approach gives the experts involved time to think issues through properly, refining and testing their own arguments until they are robust and have been fully considered. It also provides time for the experts to rigorously critique the arguments of others.
- The geographical remoteness of the experts from each other reduces the impact of strong personalities or particularly charismatic speakers that could otherwise lead to cases of groupthink as the experts seek to find consensus.

- The editing of responses by the facilitator avoids early respondents to a survey round achieving undue prominence. Also, inflammatory statements provided by experts can be toned down.
- Delphi permits an easy coupling of quantitative and qualitative research methods.
- When combined with more than one other research method (triangulation) the reliability of the results obtained increases.

3.2.2.5 Disadvantages of Delphi

Delphi suffers from the following disadvantages over other techniques: (Scheibe *et al.*, 1975; Stitt-Ghodes and Crews, 2004; Cuhls, 2005; European Commission, 2006; Skulmoski *et al.*, 2007

- It can be difficult to determine who is sufficiently expert to be on the panel.
- The selection of experts and guidance on how many experts are required is vague. The numbers have been as low as three and as high as one hundred and seventy one.
- Delphi is time consuming. For a large study with a wide range of fields, numerous participants, and many rounds of survey results to review at least one year should be allowed.
- There is a tendency for experts to over-rate the importance of fields in which they have personally been active. Especially for those that they were involved in by way of employment.
- The reliability of Delphi based research is questionable.
- Formulation of the questions in the first round is essential. If the area of investigation is poorly framed at this stage then the results of the subsequent survey rounds will not address the desired issue.
- Low participant response rates may result if there is a lack of personal contact between the facilitator and the members of the panel.
- The repeated distribution of questionnaires can also result in low response rates as the study progresses.
- Experts may avoid bringing their own opinions to the foreground so as not to give away their own research focus.
- There is no single method for analysing the data obtained through the rounds of questionnaire surveys.
- Replication of the study with a view to duplicating results can be problematic.

- Interpretation of the results derived from the multiple survey rounds can be inconsistent. Different facilitators arrive at different conclusions about the same material. Equally, the opinions of experts tend to change with time.
- It is not stated what level of agreement should be considered to be consensus amongst the experts.

3.2.3 Evidential Reasoning (ER)

ER takes an individual's knowledge, expertise and experience and represents them in the form of numerical belief functions (Xu *et al.*, 2006). In the 1960s the Theory of Evidence was devised (Dempster, 1967). This theory was then further developed in the 1970s (Shafer, 1976). As a result it is now commonly referred to as the Dempster-Shafer Theory. Dempster-Schafer Theory was originally utilised as an approximate reasoning tool (Buchanan and Shortliffe, 1984; Gordon and Shortliffe, 1985; Lopez de Mantaras, 1990). In the 1990s (Yang and Singh, 1994) Dempster-Schafer Theory was used as the foundation for the development of Evidential Reasoning (ER). The algorithm which makes up the heart of the ER process has been updated (Yang, 2001) and further modified (Yang and Xu, 2002) in the years since its emergence.

3.2.3.1 Previous applications of ER

Since the 1990s the ER methodology has been utilised in a variety of study areas. These include: failure diagnosis (Gertler and Anderson, 1992), evaluation of engineering products (Yang and Sen, 1997), organisational self-assessment (Yang *et al.*, 2001; Siow *et al.*, 2001), contractor selection (Sonmez *et al.*, 2001), GIS data classification (Peddle and Ferguson, 2002), land cover classification (Lein, 2003), object recognition (Binford and Levitt, 2003), combat identification (Chen and Blyth, 2004), transformer assessment (Tang *et al.*, 2004), dissolved gas analysis (Spurgeon *et al.*, 2005), safety analysis (Wang *et al.*, 1995; Liu *et al.*, 2005), environmental impact assessment (Wang *et al.*, 2006a), water quality (Sadiq *et al.*, 2006a), information security (Nordstrom, 2008), new product design (Chin *et al.*, 2009), and the prediction of a system's reliability (Hu *et al.*, 2010).

3.2.3.2 Transport specific aplications of ER

ER has also been used to assess a range of transport related issues, including: general cargo ship design (Sen and Yang, 1995), retro-fit ferry design (Yang and Sen, 1994b), map building for autonomous vehicles (Pagac *et al.*, 1998), road incident detection (Byun *et al.*, 1999; Zhang and Taylor, 2007), motorcycle assessment (Yang and Sen, 1994a; Yang, 2001), urban traffic management systems (Zhang *et al.*, 2007), bridge condition (Wang and Elhag, 2007), maritime security (Yang *et al.*, 2009), ship hull vibration (Godaliyadde *et al.*, 2010), and intelligent transport systems (Faouzi *et al.*, 2011).

3.2.3.3 ER Methodology

ER was devised to address Multiple Criteria Decision Making (MCDM) problems under uncertainty (Beynon *et al.*, 2000). Uncertainty is typically defined as the effects of ignorance, incomplete data (Wang *et al.*, 2006b), imprecise assessments, time pressure, and/or shortcomings in expertise (Sonmez *et al.*, 2001). The original ER algorithm is explained as follows (Yang and Xu, 2002):

$m_{n,i}$ is the probability representing the degree to which the ith attribute e_i agrees with the hypothesis that y is assessed to the nth grade H_n. In addition, $m_{H,i}$ is the remaining probability unassigned to any grade after all of the *N* grades have been assessed for the attribute as far as e_i is concerned. $m_{n,i}$ is calculated as follows (Yang and Singh, 1994; Yang and Xu, 2002; Wang *et al.*, 2006b):

$$m_{n,i} = w_1 \beta_{n,i} \qquad n = 1, 2, \dots, N \tag{3.6}$$

In this equation w_1 has yet to be normalized. $m_{H,i}$ is given by:

$$m_{H,i} = 1 - \sum_{n=1}^{N} m_{n,i} = 1 - w_i \sum_{n=1}^{N} \beta_{n,i}. \tag{3.7}$$

$E_{I(i)}$ is defined as the subset of the first i basic attributes as follows:

$$E_{I(i)} = \{e_1 \;\; e_2 \;\; \cdots \;\; e_i\} \tag{3.8}$$

$m_{n,I(i)}$ is the probability that is defined as the degree to which all the i attributes in $E_{I(i)}$ agree with the hypothesis that when y is assessed to the grade H_n.$m_{H,I(i)}$ it provides the remaining probability unassigned to a grade after all the attributes in $E_{I(i)}$ have been assessed. $m_{n,I(i)}$ and $m_{H,I(i)}$ can be generated by combining the basic probabilities $m_{n,j}$ and $m_{H,j}$ for all n = 1, 2, … , *N*; $j = 1, 2, \dots, i$ (Yang and Sen, 1997; Yang and Xu, 2002).

With the previous equations being taken in to account the original Evidential Reasoning algorithm can be summarised as follows (Yang and Xu, 2002):

$$m_{n,I(i+1)} = K_{I(i+1)}\left(m_{n,I(i)}m_{n,i+1} + m_{n,I(i)}m_{H,i+1} + m_{H,I(i)}m_{n,i+1}\right)$$
$$n = 1, 2, \dots, N \tag{3.9}$$

$$m_{H,I(i+1)} = K_{I(i+1)}m_{H,I(i)}m_{H,i+1} \tag{3.10}$$

$$K_{I(i+1)} = \left[1 - \sum_{t=1}^{N}\sum_{\substack{j=1 \\ j\neq t}}^{N} m_{t,I(i)}\, m_{j,i+1}\right]^{-1}$$
$$i = 1, 2, \dots, L-1 \tag{3.11}$$

$K_{I(i+1)}$ is a normalizing factor that allows $\sum_{n=1}^{N} m_{n,I(i+1)} + m_{H,I(i+1)}$ to equal 1. That being the case it is also the case that $m_{n,I(1)} = m_{n,1}$ (n = 1, 2, … , N) and $m_{H,I(1)} = m_{H,1}$.

It is important that the numbers applied to the basic attributes in E are done so in an arbitrary fashion. If this is the case then the results $m_{n,I(L)}$ (n = 1, 2, … , N), and $m_{H,I(L)}$ will not depend on the order in which the basic attributes are aggregated.

Ultimately the combined degree of belief β_n can then be found by (Sonmez *et al.*, 2001; Yang and Xu, 2002):

$$\beta_n = m_{n,I(L)} \qquad n = 1, 2, \dots, N \tag{3.12}$$

$$\beta_H = m_{H,I(L)} = 1 - \sum_{n=1}^{N}\beta_n \tag{3.13}$$

In this equation β_H is the degree of belief that has been left unassigned to an evaluation grade after all the L basic attributes have been assessed. β_H represents the degree of incompleteness resulting from the assessment. If all the assessments are complete, then β_H will equal zero (Wang *et al.*, 2006b; Yang and Xu, 2006).

3.2.3.4 Advantages of ER

The benefits of Evidential Reasoning over other multi-criteria decision analysis methods are (Yang and Singh, 1994; Yang and Sen, 1994a; Murphy, 2000; Yang, 2001; Yang and Xu, 2002; Xu and Yang, 2005; Wang *et al.*, 2006; Xu *et al.*, 2006):

- ER takes an individual's knowledge, expertise and experience and represents them in the form of numerical belief functions.
- ER has the ability to model the uncertainty that is inherent in the process of decision making.
- The algorithm is able to utilise both incomplete and vague data as well as complete and precise data.
- It also provides a great degree of flexibility by allowing the use of both quantitative and qualitative judgment.
- ER provides a rational and reproducible methodology whose procedure prevents a loss of information when converting a distribution value in to a fixed single value.
- The results of the analysis can be determined through the use of proven Intelligent Decision System (IDS) computer software.

3.2.3.5 Disadvantages of ER

ER suffers from the following disadvantages over other techniques (Yang and Sen, 1994a; Sonmez *et al.*, 2001; Yang and Xu, 2002; Mokhtari *et al.*, 2012):

- ER is not particularly intuitive, easy to understand or to implement.
- The computation process is not perceived as being straightforward.
- The ER aggregation process may not be rational or meaningful if it is not able to follow suitable synthesis axioms.
- Under certain circumstances the process followed to achieve the normalization of weights within the algorithm leads to it being unable to fully satisfy a given consensus axiom.
- Under certain circumstances the ER algorithm is also unable to fully satisfy a completeness axiom.

- Although the degree of completeness of the available data can be determined by the algorithm there is no method included in the process to verify the consistency of the results that are generated.

3.2.4 SERVQUAL

SERVQUAL is believed to be the most complete attempt to conceptualize and measure service quality (Nyeck *et al.*, 2002). When it was originally created the SERVQUAL instrument was devised to measure quality in the service sector (Parasuraman *et al.*, 1985). Since then it has been used to study quality in a wide range of other sectors (Nyeck *et al.*, 2002). In SERVQUAL the difference between customers' expectations of a service and their expereinces of the service are measured (Parasuraman *et al.*, 1988). It relies upon the assumption that service quality can be conceptualised and, through its modelling, "gaps" can be identified (Ladhari, 2009).

3.2.4.1 Previous applications of SERVQUAL

The SERVQUAL methodology has been applied in the measurement of the quality of service provided by: physicians (Brown and Swartz , 1989), hospital acute care units (Carman, 1990), retail chains (Teas, 1993; Parasuraman *et al.*, 1994), dental surgeries (McAlexander *et al*., 1994), AIDS service agencies (Fusilier and Simpson, 1995), fast food (Lee and Ulgado, 1997), banking (Lam, 2002), hotels (Markovic and Raspor, 2010), Higher Education providers (Yousapronpaiboon, 2014), post offices (Chatzoglou *et al.*, 2014), and academic libraries in developing countries (Asogwa *et al.*, 2014).

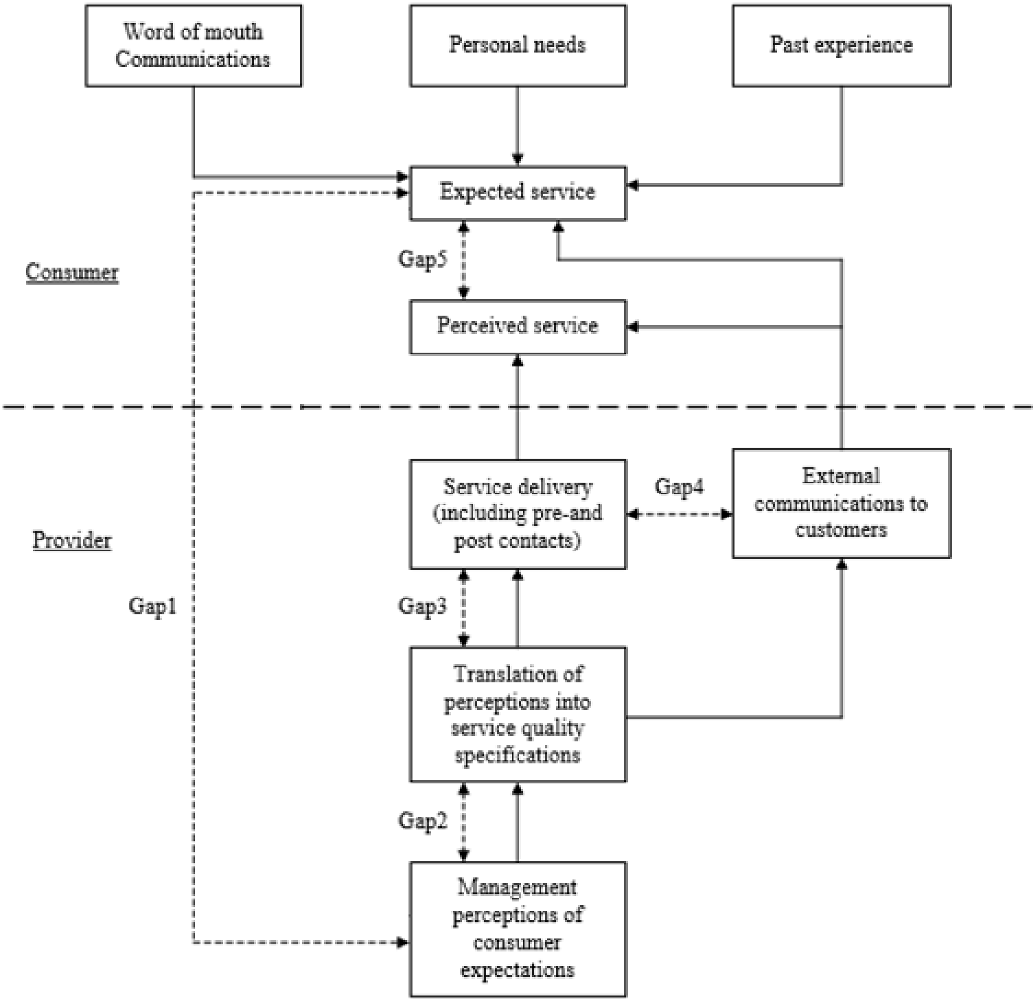
3.2.4.2 Transport specific aplications of SERVQUAL

Transport related utilization of SERVQUAL has been limited to assessing the quality of service provided by: tyre stores (Carman, 1990), rail freight (Shainesh and Mathur, 2000), passenger rail transport (Cavana *et al.*, 2007), container terminals (Wiegmans *et al.*, 2008), passenger airlines (Huang, 2010), urban bus transportation (Barabino *et al.*, 2012), highway passenger transportation (Pakdil and Kurtulmusoglu, 2014), public transportation (Randheer *et al.*, 2011; Muthupandian and Vijayakumar, 2012; Govender, 2014; Mikhaylov *et al.*, 2015), and Dry Ports (Pour and Yousefi, 2015).

3.2.4.3 SERVQUAL Methodology

A model of the identified service quality gaps can be seen in Fig. 3.1. The various gaps in the service quality model are described as (Parasuraman *et al.*, 1988; Ladhari, 2009):

Gap One – The 'management perception gap', also known as the 'knowledge gap'. This represents the difference between customer expectations and management's perceptions of customer expectations.



Source: Parasuraman *et al.*, 1985; Curry, 1999; Luk and Layton, 2002.

Fig. 3.1: Model of service quality gaps

Gap Two – The 'standards gap' also known as the 'service specification gap'. This represents the difference between management's perceptions of customer expectations and the translation of these perceptions in to service quality specifications.

Gap Three – The 'service performance gap' also known as the 'service delivery gap'. This represents the difference between the service actually delivered by frontline service personnel and the specifications set by management.

Gap Four – The 'communications gap', also known as the 'market communication gap'. This represents the difference between service delivery and what is promised to consumers in external communications, such as advertising.

Gap Five – The 'service quality gap', also known as the 'perceived service quality gap'. This represents the difference between customer expectations (of a service that they have yet to experience) and customer perceptions (of the same service once they have experienced it). This gap is the result of the combination of gaps one to four.

The SERVQUAL instrument is specifically designed to capture Gap Five. It is composed of five dimensions, often referred to by the acronym 'RATER', these are (Parasuraman *et al.*, 1988; Govender, 2014):

- Reliability – The ability to perform the promised service in a dependable and accurate manner.
- Assurance – The knowledge and courtesy of employees and their ability to convey trust and confidence.
- Tangibility – The physical evidence of the service, such as the appearance of the personnel and physical facilities, and equipment used to provide the service.
- Empathy – The caring, individualized attention provided to customers.
- Responsiveness – The readiness and willingness to help customers in providing prompt, timely services.

The five 'RATER' dimensions that make up the SERVQUAL instrument are examined by way of a twenty two point questionnaire. This was specifically developed to measure a customers' expectations (referred to as E) and subsequent perceptions (referred to as P) of a service (Parasuraman *et al.*, 1985).

The first part of the questionnaire is composed of five items relating to the reliability dimension, whereas the second part of the questionnaire has four items relating to the assurance dimension. The third and fourth parts have four items and five items that relate to the tangibles and empathy dimensions respectively. Finally, the fifth part, with four items, relates to the responsiveness dimension. (Ladhari, 2009).

These items are composed of a series of closed questions. The response to each of these is generally measured using a five point Likert scale of agreement. On such a scale (Parasuraman *et al.*, 1985; Govender, 2014):

1 = Strongly disagree
2 = Disagree
3 = Neither agree nor disagree
4 = Agree
5 = Strongly agree

Whilst a five point Likert scale is the most widely utilised, successful results have also been achieved through the use of a seven point Likert scale (Cui *et al.*, 2003).

As SERVQUAL relies on the assessment of the gap between customers' expectations of a service and their experiences of that service it is necessary for the twenty two point questionnaire to be administered twice. Initially, it is used to measure the expectations of customers prior to using a service. Subsequently, it is used to measure customers' perceptions of their experiences of that service (Buttle, 1996). Service quality can then be found through the following equation:

$$SQ = P - E \quad (3.14)$$

where SQ is service quality, P is the individual's perception of the delivery of a service, E is the individual's expectations of the delivery of a service.

Quality is delivered when customers rate their experiences of a service as equal to, or greater than, their expectations. However, if the expectations of customers are greater than their experiences of a service, then there is a perceived lack of quality. If left unaddressed this can lead to customer dissatisfaction (Parasuraman *et al.*, 1994; Chatzoglou *et al.*, 2014).

3.2.4.4 Advantages of SERVQUAL

SERVQUAL benefits from the following advantages over other techniques (Carman, 1990; Asubonteng *et al.*, 1996; Buttle, 1996; Wiegmans *et al.*, 2008; Mikhaylov *et al.*, 2015):

- SERVQUAL is widely used by both academic and industry practitioners.
- It enables the quality of a provided service to be assessed from the customer's perspective.

- Using SERVQUAL, customer expectations and perceptions can be tracked over time, together with the discrepancies between them.
- The SERVQUAL model can be used in various service sectors.
- It can be adapted to fit the specific attributes of a particular organization.
- The gap analysis approach utilised is a logical and straightforward concept to understand.
- The questionnaire employed by SERVQUAL for data collection can be adapted as needed to meet the requirements of a range of different surveys.
- As a result of extensive field testing and refinement SERVQUAL is considered to be a statistically valid instrument.
- SERVQUAL is applicable across different nations and cultural backgrounds.
- The SERVQUAL model can be used comparatively for benchmarking purposes.

3.2.4.5 Disadvantages of SERVQUAL

SERVQUAL suffers from the following disadvantages over other techniques (Carman, 1990; Cronin and Taylor, 1992; Buttle, 1996; Oliver, 1996; Dyke *et al.*, 1997):

- There is little evidence that customers assess service quality in terms of Perception/Exception gaps.
- The validity of representing service quality as a gap has been questioned.
- SERVQUAL focuses on the process of service delivery, it does not focus on measuring the outcomes of the service encounter.
- It has been argued that SERVQUAL measures customer satisfaction rather than service quality.
- SERVQUAL's five dimensions (RATER) are not universal, and the model fails to draw on established economic, statistical, and psychological theory.
- Despite SERVQUAL having originally been designed to provide a generic measure it often needs to be customized to the particular service context being assessed: ARTSQUAL (art museum context), EDUQUAL (education context) HEALTHQUAL (hospital context), RAILQUAL (railway context). This demonstrates the inability of the basic model of SERVQUAL to meet the needs of all service contexts.

- SERVQUAL's developers tested the original scale for reliability and validity. Attempts to modify the scale to meet the requirements of specific industries undermines the reliability and validity of the instrument.
- Respondents to the survey are asked to retrospectively consider their expectations of a service. The process of experiencing a service influences the respondent's recollection of their expectations. Therefore, the survey does not accurately capture the true customer expectations of a service. Only forecast expectations are genuine expectations.
- Expectations change over time as customers gain experience with a particular product or service.
- Subtle changes to the wording of a SERVQUAL survey can elicit very different responses. If the survey instrument is asking for 'ideal' expectations then the experienced service quality will always fall short of meeting expectations.

3.2.5 The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

TOPSIS is a multiple criteria decision making tool for use in identifying solutions from a finite set of alternatives (Buyukozkan and Cifci, 2012). The underlying logic of TOPSIS was initially proposed in the early 1980s (Hwang and Yoon, 1981) but the TOPSIS methodology itself was further developed in the 1980s (Yoon, 1987) and 1990s (Hwang *et al.*, 1993; Chen and Hwang, 1992). Hwang and Yoon (1981) stated that the purpose of TOPSIS is to define the ideal solution and the negative ideal solution (Liang, 1999) to a problem. The chosen alternative should not only have the shortest distance from the positive ideal reference point, but also have the longest distance from the negative ideal reference point (Hwang and Yoon, 1981).

3.2.5.1 Previous applications of TOPSIS

The TOPSIS methodology has been successfully applied across a range of study areas, including: selection of grippers in flexible manufacturing (Agrawal *et al.*, 1992), financial investment in advanced manufacturing systems (Kim *et al.*, 1997), robot selection (Parkan and Wu, 1999; Chu and Lin, 2003), comparing company performance (Deng *et al.*, 2000), selecting an expatriate host country (Chen and Tzeng, 2004), quantifying priorities in healthcare (Mullen, 2004), evaluation of water management scenarios (Srdjevic *et al.*, 2004), evaluating treatments for migraine (Ferrari *et al.*, 2005), material selection for the construction of gears (Milani and Shanion., 2006), evaluation of bids for manufacturing enterprises (Hao and Qing-sheng, 2006), credit scoring (Wu and Olson, 2006), customer driven product design (Lin *et al.*, 2008), weapon selection (Dagdeviren *et al.*, 2009), treatment of chronic plaque psoriasis (Guibal *et al.*, 2009), service quality in the health care industry (Buyukozkan and Cifci, 2012), and public crisis management (Jiang and Yu, 2012).

3.2.5.2 Transport specific aplications of TOPSIS

TOPSIS has also been used to address issues in the transport industry, including: performance evaluation of highway buses (Feng and Wang, 2001), evaluation of High-Speed Rail, Transrapid Maglev and Air Passenger Transport in Europe (Janic, 2003), outsourcing of logistics services (Bottani and Rizzi, 2006), bridge risk assessment (Wang and Elhag, 2006), automobile transport system analysis (Jakimavicius and Burinskiene, 2007), evaluating initial training aircraft (Wang and Chang, 2007), hazardous material transportation (Yan *et al.*, 2009), traffic police centres' performance (Sadi-Nezhad and Damghani, 2010), urban public transport competitiveness (Sun *et al.*, 2010), selection of logistics centre locations (Li *et al.*, 2011), and bus route evaluation (Soltani *et al.*, 2013).

3.2.5.3 TOPSIS Methodology

The TOPSIS approach is a multi-criteria decision making method for the arrangement of preferences in relation to an ideal solution (Hwang and Yoon, 1981; Gomez-Lopez *et al.*, 2009). The basic principle of TOPSIS is that the chosen alternative must have the shortest distance to the positive ideal solution and the farthest distance to the negative ideal solution (Garcia-Cascales and Lamata, 2007; Gomez-Lopez *et al.*, 2009). The mathematical procedure of TOPSIS is quite straightforward.

The TOPSIS method requires a decision matrix to be established to capture the data that is collected through a questionnaire. Formula 3.14 demonstrates how this matrix is formed:

$$D = \begin{bmatrix} x_{11} & x_{12} & x_{13} & \cdots & \cdots & x_{1n} \\ x_{21} & x_{22} & x_{23} & \cdots & \cdots & x_{2n} \\ x_{31} & x_{32} & x_{33} & \cdots & \cdots & x_{3n} \\ \vdots & \vdots & \vdots & \cdots & \cdots & \vdots \\ \vdots & \vdots & \vdots & \cdots & \cdots & \vdots \\ x_{m1} & x_{m2} & x_{m3} & \cdots & \cdots & x_{mn} \end{bmatrix} \tag{3.14}$$

Within this formula the decision matrix contains *n* alternatives and *m* evaluation criteria. Meanwhile, x_{ij} denotes the performance of the *i*-th alternative in terms of the *j*-th criteria (Triantaphyllou, 2000).

Normalizing the decision matrix is a key step in TOPSIS. Normalizing means transforming the dimensions of the various criteria into non-dimensional attributes. These non-dimensional attributes allow direct comparisons to be made across the attributes. The formula for normalizing the decision matrix is as follows (Onder and Dag, 2013):

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \;\; ; \;\; \mathrm{i} = 1, 2, 3, \ldots, \mathrm{n} \; ; \quad \mathrm{j} = 1, 2, 3, \ldots, \mathrm{m} \tag{3.15}$$

The weighted normalized decision matrix is calculated by mulitplying the values found in the normalized decision matrix by weights that have been generated for each criterion. This is shown in equation 3.16 (Kumar, 2008):

$$v_{ij} = r_{ij} \times w_j \;\; ; \;\; \mathrm{i} = 1, 2, 3, \ldots, \mathrm{n} \; ; \quad \mathrm{j} = 1, 2, 3, \ldots, \mathrm{m} \tag{3.16}$$

In this formula V_{ij} is the weighted normalized matrix, r_{ij} is the normalized matrix and W_j is the weight ascertained for the j^{th} criteria.

The Positive Ideal Solution, represented by A^+, and the Negative Ideal Solution, represented by A^-, are determined by finding the maximum and the minimum values in each column of the weighted normalized decision matrix (Kumar, 2008). The positive ideal solution (PIS) and the negative ideal solution (NIS) for each criterion are found using formulae 3.17 and 3.18 (Kumar, 2008):

$$A^+ = \left\{ \left(\max\ v_{ij} \,\middle|\, j \in J\right), \left(\min\ v_{ij} \,\middle|\, j \in J'\right) \,\middle|\, i = 1, 2, \ldots, m \right\} = \{v_1^+, v_2^+, \ldots, v_n^+\} \tag{3.17}$$

$$A^- = \left\{ \left(\min\ v_{ij} \,\middle|\, j \in J\right), \left(\max\ v_{ij} \,\middle|\, j \in J'\right) \,\middle|\, i = 1, 2, \ldots, m \right\} = \{v_1^-, v_2^-, \ldots, v_n^-\} \tag{3.18}$$

The separation distance of each alternative from the PIS and NIS is found by calculating the Euclidean distance of the alternatives from the ideal solutions. This is done through formula 3.19 (Triantaphyllou, 2000):

$$S_i^{+} = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - v_j^{+}\right)^2} \;\; ; \;\; i = 1, 2, 3, \dots, m \;\; ; \;\; j = 1, 2, 3, \dots, n \tag{3.19}$$

In this formula S_i^{+} represents the Euclidean distance of a solution to the Positive Ideal Solution. In turn, the following formula is applied to find the Euclidean distance of a solution to the Negative Ideal Solution which is represented by S_i^{-} (Triantaphyllou, 2000):

$$S_i^{-} = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - v_j^{-}\right)^2} \;\; ; \;\; i = 1, 2, 3, \dots, m \;\; ; \;\; j = 1, 2, 3, \dots, n \tag{3.20}$$

Both of these formulae are applied to the results found in formula 3.16, where the weighted normalized decision matrix were calculated, and formula 3.17 and 3.18, where the Positive Ideal Solution (PIS) and the Negative Ideal Solution (NIS) were determimed.

The relative closeness to the ideal solution is calculated using the following equation (Chen, 2011):

$$C_i^{*} = \frac{S_i^{-}}{S_i^{+} + S_i^{-}} \;\; ; \;\; i = 1, 2, 3, \dots, m \;\; ; \;\; 0 \leq C_{i+} \leq 1 \tag{3.21}$$

In this formula C_i^{*} represents the relative closeness of an alternaitve to the positive ideal solution. This equation is applied to the results derived from formula 3.19 and 3.20. where the seperation distance of each alternative to the PIS and NIS was determined.

By ranking in to descending order the values that were calculated in formula 3.21, the highest value of C_i^{*} (the value closest to 1) represents the optimal alternative. This reflects it having the closest distance to the Positive Ideal Solution (Kumar, 2008).

3.2.5.4 Advantages of TOPSIS

TOPSIS benefits from the following advantages over other techniques (Bottani and Rizzi, 2006; Kandakoglu *et al.*, 2009; Yang *et al.*, 2011; Vavrek *et al.*, 2014):

- TOPSIS is intuitive, easy to understand and to implement.
- The computation process is straightforward.
- The process followed is logic, rational and understandable.
- It is a method which allows working with different scales and types of information e.g. subjective or objective, quantitative or qualitative.
- It is able to consider a non-limited number of alternatives and criteria in the decision making process.
- The number of steps remains the same regardless of the number of attributes.
- Criterion are measured against both a positive solution and a negative solution.
- TOPSIS allows the straight linguistic definition of weights and ratings under each criterion, without the need of cumbersome pairwise comparisons and the risk of inconsistencies that this brings.
- TOPSIS yields a highly reliable preference order.

3.2.5.5 Disadvantages of TOPSIS

TOPSIS suffers from the following disadvantages over other techniques (Shih *et al.*, 2007; Kandakoglu *et al.*, 2009; Garcia-Cascales and Lamata, 2012; Vavrek *et al.*, 2014):

- The criteria should be independent of each other.
- Each criterion or sub-criterion must have either monotonically increasing or monotonically decreasing utility.
- The importance weight of each criterion must be incorporated into the comparison process from an external source.
- Any input which is expressed in a non-numerical form must be quantified through an appropriate scaling technique.
- It is difficult to weigh each criterion and also keep consistency in judgment.
- The absence of a process for checking the consistency of results generated by the process.
- TOPSIS suffers from the problem of ranking reversal (the final ranking can swap when new alternatives are included in the model).

3.3 Discussion of selected methodologies

Members of industry had requested an academic piece of work to consider the issue of modal choice within the freight industry of North West England's Atlantic Gateway. As a result, it was critical for the acceptance of the outcome of this work and for its subsequent application in real world situations that the results generated be embraced by the representatives of industry which had been involved. A big step towards this was for the involvement of industry representatives in the selection of the methodology.

Based on their previous experience of working with academia the members of industry that were involved at this stage were keen for the methodology utilised to be academically rigorous whilst at the same time being as transparent and intuitive as possible. The work that makes up the main part of this chapter was presented to those representatives of industry that were involved. The document was produced with the objective of prompting an extended discussion on the strength and weaknesses of each of the proposed methods.

None of the methods considered are perfect. They all have advantages and disadvantages. It quickly became apparent that ease of use, reliability of results, transparency of process, and capacity to re-do the study to validate the results where the most valued traits amongst the industry representatives. As a result, it was felt that the most suitable option for this work would be to utilise a combination of TOPSIS and AHP.

In brief, the main reasoning behind this decision was that both SERVQUAL and Delphi were considered too vague in their application and too unreliable in their results. In turn, ER was not considered to be particularly intuitive, easy to understand or implement. Equally, the computation process of ER was perceived as being overly complicated. These factors amounted to significant problems. If the freight industry felt that results had simply been plucked out of thin air then they were unlikely to buy in to any potential changes to their industry that were suggested.

However, it was clearly demonstrated that both AHP and TOPSIS have been applied towards a wide range of problems in many different fields. In addition, either alone or in combination with other techniques, they have a proven track record in aiding decision makers to address transport related issues. TOPSIS was the preferred approach to this work due to the advantages that were stated earlier in this chapter (see 3.2.5.4). However, the disadvantages of TOPSIS (see 3.2.5.5) were cause for concern. Therefore, after some discussion it was felt that a better path would be to use an integrated AHP and TOPSIS approach. Such a methodology would possess the advantages of both methods and the perceived limitations of TOPSIS could be remedied through the application of AHP.

In itself this approach is not a novel one, it has been adopted in a range of other areas of study in the past, including: hazardous waste transportation (Gumus, 2009), thirty party logistics providers (Percin, 2009), nuclear power plants (Yang *et al.*, 2010), automotive companies (Shahroudi *et al.*, 2011), supplier selection (Fazlollahtabar *et al.*, 2011), green supply chains (Muralidhar *et al.*, 2012). However, a combined AHP and TOPSIS approach hasn't been applied to the study of modal choice in North West England's Atlantic Gateway before. This is where the novelty of this work lies.

Typically, the form that a combined AHP/TOPSIS methodology takes is that a range of qualitative data is initially collected by way of pairwise comparisons that convert it in to a quantitative form. The AHP utilises this quantitative data to calculate weights for a range of relevant criteria. The TOPSIS is then used to calculate rank a range of alternative options. This approach met with the approval of experts as the outcome, a distance away from an ideal solution, was easier to accept than the apparently arbitrary numbers generated by the other methods considered.

The two short comings of TOPSIS that caused the most concern amongst industry representatives were its lack of ability to incorporate weights for each criterion and the absence of a process for checking the consistency of results that it generates. The effect of each of these can be limited by the relevant advantages of AHP (see 3.2.1.4). Specifically, AHP is able to analyse both quantitative and qualitative criterion, provide weights for each criterion and check for inconsistencies in the results generated. It was this last trait, the ability of AHP to verify their consistency of the results that it generates, which was of particular interest to industry representatives.

3.4 Conclusion

This chapter briefly considered a number of possible approaches to assessing modal choice in North West England's Atlantic Gateway. The methodologies covered were Analytic Hierarchy Process, Delphi, Evidential Reasoning, SERVQUAL, and Technique for Order Preference by Similarity to Ideal Solution. After consultation with freight transport industry representatives it was decided that a combined AHP and TOPSIS approach would be the preffered methodology for completing this study.

The details of the models that were developed and utilised to this end are covered in Chapter Five (AHP) and Chapter Six (AHP and TOPSIS). In the first model (Chapter Five) the Analytic Hierarchy Process is used to produce a model for determining the weights that each criterion carries in the modal choice decision making process of the freight industry of North West England's Atlantic Gateway. In the second model the Analytic Hierarchy Process is combined with the Technique for Order Preference by Similarity to Ideal Solution to analyse and rank the alternative modes of transport (road, rail, water) under consideration within the geographical area under consideration.

However, before going on to construct a model of the modal choice decision making process it is essential to develop a greater depth of understanding of the industry that is being modelled. This deeper understanding of the freight industry will be achieved by identifying the key stakeholders in the freight transport industry, the available infrastructure for use in the carriage of freight and the current opinion within the freight industry of their ability to deliver more sustainable freight transportation solutions. A number of workshops were organised specifically to address these issues. The organisation of these workshops along with the data collection process and the analysis of this data are covered in more detail in the following chapter.

Chapter Four

A subjective evaluation of the modern day freight transportation industry of North West England

4.1 Introduction

The focus of this chapter is on gaining a greater understanding of the significant stakeholders, infrastructure and environmental sustainability issues of relevance to the logistics industry of North West England. This will be of use in later chapters as a model is developed to reflect the modal choice decision making process that occurs within the region.

This chapter is based around three sessions of informal interviews that were attached to larger, more formal, more prestigious workshop events with which Liverpool John Moores University was involved. The larger events that were selected were chosen because they were attended by decision makers from freight transport and infrastructure management organisations. Their presence allowed access to be gained to some of the key actors and decision makers in the freight industry that would otherwise be hidden behind the gatekeepers of their organisations.

The process of collecting data from industry can potentially be very drawn out and overly complicated. To avoid this a plan of the structure of the work that was to be undertaken was produced (Fig. 4.1). This plan is briefly explained as follows.

Initially it was necessary to establish the geographical region within which the attendees were to base their judgements. Having a firm grasp of the issues to be discussed and also the geographical region to be considered, it was then essential to determine which events would be best suited to host a workshop.

Once the preferred events had been selected a list of the expected attendees was sourced and they were contacted with a pre-workshop survey. The results from this survey were received back before the workshop itself took place. Each workshop was then carried out to discuss a selected issue.

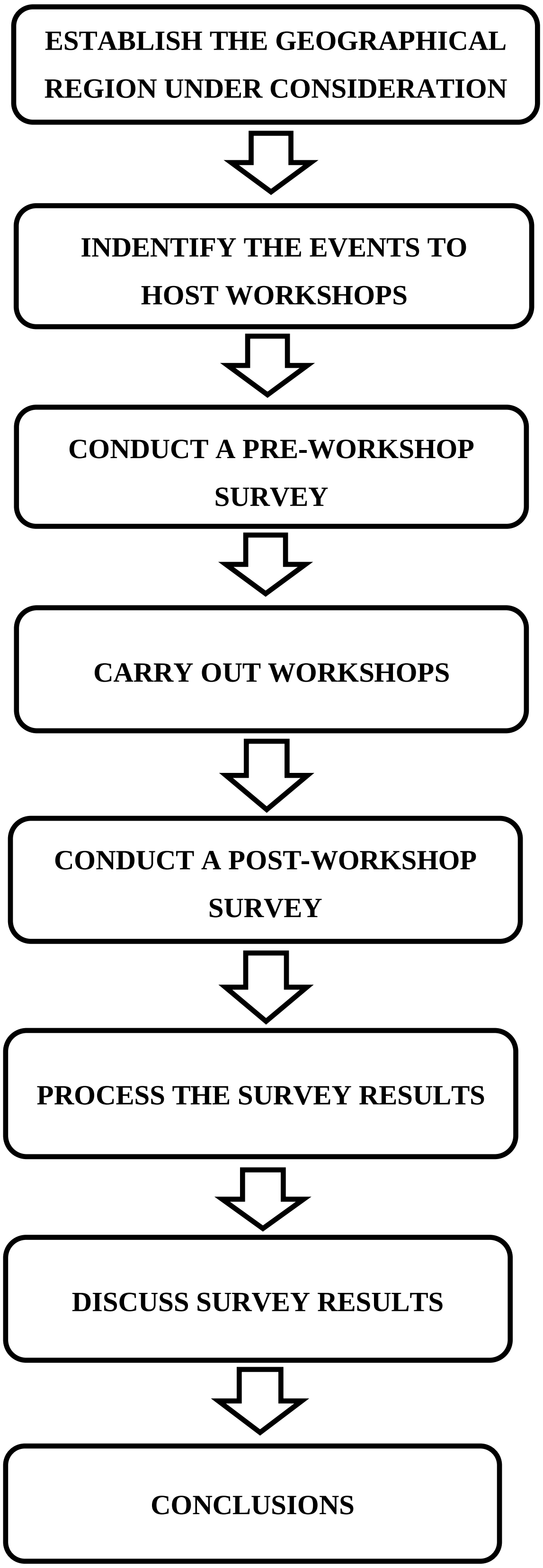


Fig. 4.1: The structure of work undertaken in this chapter

Upon reaching the end of each workshop a period of time was allowed to pass before the attendees were again contacted. This time they were asked to complete a post-workshop survey. Upon receipt of their completed post-workshop surveys the results of both surveys and the workshops themselves were collated, processed and discussed before conclusions were drawn from the process.

4.2 The region in question

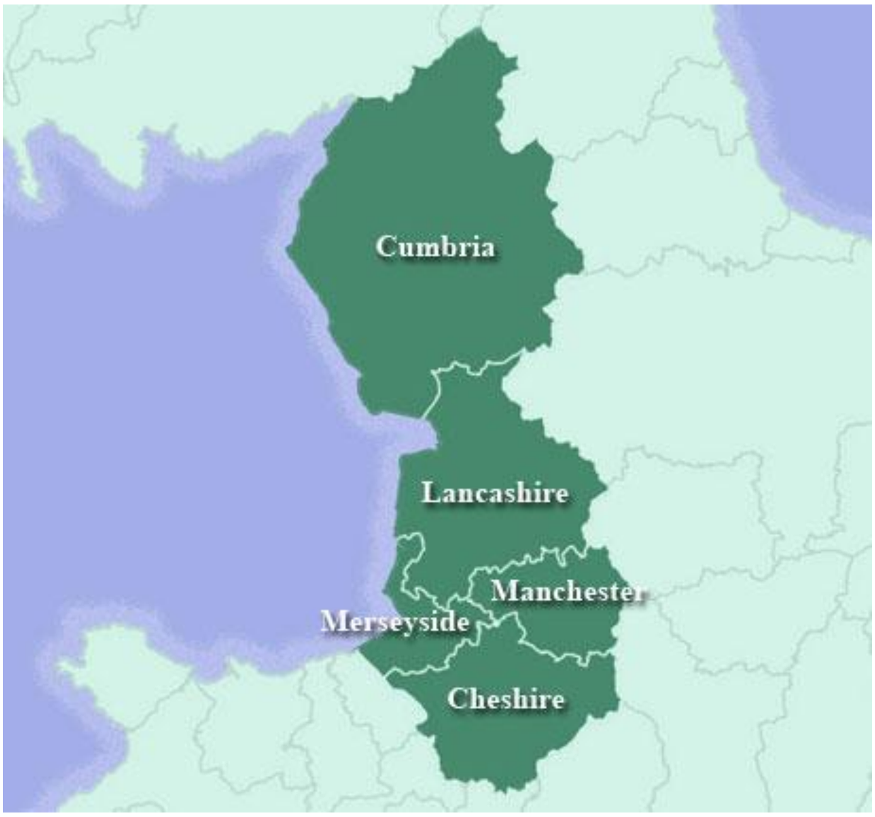
England is composed of nine regions (Fig. 4.2). These are, in alphabetical order: East, East Midlands, Greater London, North East, North West, South East, South West, West Midlands, Yorkshire and the Humber.

Source: Youth Dance England (2014)

Fig. 4.2: Regions of England

This work focuses on North West England (NUTS 1 code – UKD). The North West of England is divided in to five counties (Fig. 4.3). These are, in alphabetical order: Cheshire, Cumbria, Greater Manchester, Lancashire, and Merseyside.

The North West of England is surrounded by: Scotland (to the North), The Irish Sea (to the West), Staffordshire, Shropshire, and the Peak District (to the South), The Peak District, and Pennines (to the East). The counties of Cumbria, Lancashire, and Cheshire are predominantly rural. Large urban areas cover the counties of Greater Manchester and Merseyside.



Source: PicturesofEngland.com (2012)

Fig. 4.3: Counties of North West England

4.2.1 Population

According to the Office of National Statistics the population of England in 2017 was 55,619,430. Of this total number 7,258,627 (13%) resided in the North West region of England. This makes the North West the third most populous region after London, and the South East.

During 2017, of the total population of the North West, 4,205,024 (58%) resided in the two smallest counties (Greater Manchester and Merseyside). The remaining 3,053,603 (42%) were spread across the much larger areas of Cheshire, Cumbria, and Lancashire.

4.2.2 Industry

The North West of England produces approximately 60% of the UK's industrial output, a significant proportion of which is exported. This movement of freight makes the infrastructure of the region key to the economic well-being of the nation as a whole. The main modes of freight transportation used in the North West of England are Aviation, Maritime, Rail and Road.

4.3 The events to host workshops

The selection of the events that would be used to host workshops was the most important part of the work carried out in this chapter. The events that were selected were chosen because they were attended by decision makers from the manufacturing industry as well as freight transport and infrastructure management organisations. Their presence allowed access to be gained to some of the key actors and decision makers in the freight industry that would otherwise be hidden behind the gatekeepers of their organisations.

4.3.1 Workshop One – Environmental Issues

With a period of time now having passed since the publication of the Department for Transport's (DfT) local transport white paper "Creating Growth, Cutting Carbon" an event was set up to discuss whether any progress has been made towards delivering the DfT's agenda. At the time of the white paper's publication its goals were considered to be quite challenging. This event aimed to determine whether attempting to simultaneous deliver both an environmental agenda and a growth agenda was an unachievable dream.

The panel of high profile speakers provided a range of perspectives on this topic. They spoke from both a national and regional angle, and gave their thoughts on the key challenges facing the transport profession over the coming months and years. The speakers were:

1. A Professor whose specialization was Sustainable Transport and Sustainable Development. At the time they had professional links to LJMU, the University of York and the Stockholm Environment Institute. They ran a consultancy company where their work included developing a zero carbon transport plan for the UK of 2050. They also edited the journal "World Transport Policy and Practice".

2. A Professor with links to the University of Huddersfield whose specialization is in Transport and Logistics. They are a well-known rail professional with thirty-five years' experience in a range of positions in industry. They also founded the Association of Community Rail Partnerships and at the time they were the convenor of a northern-based lobby group aiming to stimulate debate on devolved government for the North of England.

3. A chartered architect with extensive experience in advising public and private sector clients on large capital infrastructure programmes. They had a specialization in Low Carbon Vehicles and Infrastructure and at the time they were leading the Greater Manchester Electric Vehicle Scheme and were seconded to lead its delivery body, The Manchester Electric Car company.

4.3.2 Workshop Two – Freight Transport Infrastructure

This security workshop was aimed at demonstrating to stakeholders in the international shipping industry how current maritime security research can help improve the performance of their businesses. More specifically the workshop addressed: security risk estimation models, prevention measures for minimizing maritime risks in uncertain environments, effective training for port facility personnel, container security, evaluation based resource allocation and maritime security decision making.

The panel of speakers had strong links to academia. Their presentations were geared towards demonstrating to representatives of industry where the cutting edge of current academic thinking was with regards to supply chain security. The speakers were:

- A senior university lecturer in Marine Engineering. In 1986 they received a first class BEng with honours from the Marine Engineering College, Calcutta, India. They then sailed for sixteen years on board a wide range of ocean-going vessels, serving as a Chief Engineer between 1996 and 2003. They received an MSc in Maritime Technical Operations (2007) and a PhD in Maritime Safety (2010) from Liverpool John Moores University. Their research is currently in the areas of risk assessment and security modelling of maritime supply chains.

- A Naval Architect who is currently working with the International Maritime Organisation (IMO) in London. In this capacity they are a member of the Maritime Safety Division (MSD) which is a sub division of the Maritime Security and Facilitation department.

- A Professor whose current research is in the area of decision making under uncertainty, and its application in consumer preference identification, supplier selection, environmental impact assessment, and sustainability management. A co-designer of the Windows based decision support tool called IDS (Intelligent Decision System) and several web based interactive tools. IDS is now used by researchers and practitioners from over thirty countries in the world, including organizations such as NASA, PricewaterhouseCoopers, and General Motors.

- A university lecturer in Decision Sciences. Prior to their current appointment they were a postdoctoral research associate at the Decision and Cognitive Sciences (DCS) research centre of Manchester Business School and a research fellow at Hong Kong Baptist University. Their current research interests are in multiple criteria decision analysis under uncertainties, modelling and optimization of complex systems, and risk analysis in supply chains.

4.3.3 Workshop Three – Freight Transport Industry Stakeholders

For more than a century, the Port of Liverpool and The Manchester Ship Canal were arch rivals competing with each other for cargo coming from or going to every corner of the globe. However, times have changed and with Peel Ports now owning both organisations a Mersey Ports Master Plan is being devised to provide a twenty year strategy of growth for the Port of Liverpool and The Manchester Ship Canal as a combined entity.

This meeting was organized to provide a glimpse into the world of Peel Ports and provide a setting for discussion to take place regarding the proposed developments that will occur to deliver 20 years of growth. The presentation which formed the backbone of this event is posted online and can be found at:

http://www.ciltuk.org.uk/Portals/0/Documents/Regions/NW/GM/PeelPorts0412.pdf

For an issue such as this, involving the decisions made by an individual organization it was necessary for a representative of that organization (Peel Ports) to give their thoughts on the key challenges that will need to be overcome to achieve their goal. The speaker was:

- The Managing Director of Mersey Ports, which covers the Port of Liverpool and the Manchester Ship Canal. They had held this role since 2008. Originally qualifying as a Mechanical

Engineer, they had previously been an Operations Manager at Thorn EMI (a domestic appliances manufacturer), a Senior Manager at Philips Electronics (a manufacture of Cathode Ray Tubes for TV production) and a Director at Thorn Lighting (a UK market leader and significant global player in the manufacture and sales of professional lighting systems).

During their time at Thorn Lighting, they were appointed Operations Director for Asia and were subsequently based in Guangzhou, South East China and put in charge of the development of a manufacturing and logistics base that would ultimately serve Asian, Australian, and European markets.

4.4 Methodology

This research was aimed at examining the logistics industry's opinion of itself. This was done by organising three workshops. Each of these workshops was linked to a particular event.

4.4.1 Workshop Questions

After the speakers had delivered their presentations and answered questions from the audience, informal interviews were performed with some of the attendees. During these interviews a single question was posed. The question was decided in advance and aimed at addressing an issue of relevance to the transport industry whilst at the same time taking in to account the likely qualifications, experience and fields of interest of those people attending the event.

In the case of workshop one the question put forward for consideration was:

> "Is your organization environmentally sustainable?"

In the case of workshop two the question put forward for consideration was:

> "In terms of your organization what are the most significant pieces of freight handling infrastructure in the North West region of England?"

In the case of workshop three the question put forward for consideration was:

> "Which companies/organisations would you consider to be the most significant stakeholders in the freight industry of North West England?"

These questions were designed to examine the transport industry's opinion of itself and raise awareness of the issues surrounding sustainable freight transportation. Anonymity was assured to those who participated as it was considered that some of the information that they revealed could be commercially sensitive.

4.4.2 Pre-Workshop and Post-Workshop Surveys

To measure the impact of each workshop a quantitative methodology was devised. In the days preceding each workshop the attendees were asked to rate, on a scale of one (minimum) to five (maximum), their level of agreement with a number of statements. This was first performed before attending the event and then performed for a second time after attending the event. The responses to these statements were compiled and used to identify the areas where each event had its greatest impact. The nature of each set of questions was dictated by the content of each workshop.

The statements used to assess the impact of Workshop One were:

1. I understand the environmental issues that my company contributes to.
2. I am confident in the sustainability of my company's operations.
3. I believe that my company could operate more sustainably.
4. I believe that progress has been made towards delivering the Department for Transport's Local Transport White Paper's agenda.
5. I believe that it is possible to deliver both environmental and growth agendas simultaneously.

The statements used to assess the impact of Workshop Two were:

1. I understand the security issues that affect my company.
2. I am confident in my company's current security measures.
3. I believe that my company's current security measures could be improved.
4. I believe that academia has an accurate understanding of the security needs of industry.
5. I believe that current maritime security research can help improve the performance of my company.

The statements used to assess the impact of Workshop Three were:

1. I know which infrastructure my company uses for its freight movements.
2. I am confident that my company uses the most appropriate infrastructure for its freight movements.

3. I believe that my company's current choice of infrastructure use could be improved.
4. I am aware of the upcoming developments within the Port of Liverpool / Manchester Ship Canal corridor.
5. I believe that the developments within the Port of Liverpool / Manchester Ship Canal corridor have the potential to bring transformational change to the North West region of England.

4.5 Results

The activities of this chapter were performed in a bid to collect data that would be of use in the model development that is to be undertaken in the following chapters. The data collected is necessary to be able to represent the problem as thoroughly as possible and identify attributes that may contribute towards its solution.

In addition to other information revealed, the results address two of the research objectives of this work. The first being to identify regionally significant freight handling infrastructure in the North West region of England. The second to identify organisations that play a significant role in the present day freight industry of the North West region of England.

4.5.1 Workshop Questions

To focus the debate within each workshop a question was asked that could be discussed at length. Each of these was constructed to take into account the likely qualifications, experience and fields of interest of those people attending the event.

4.5.1.1 Workshop One – Environmental issues

In the case of this workshop the question put forward for consideration was:

> "Is your organization environmentally sustainable?"

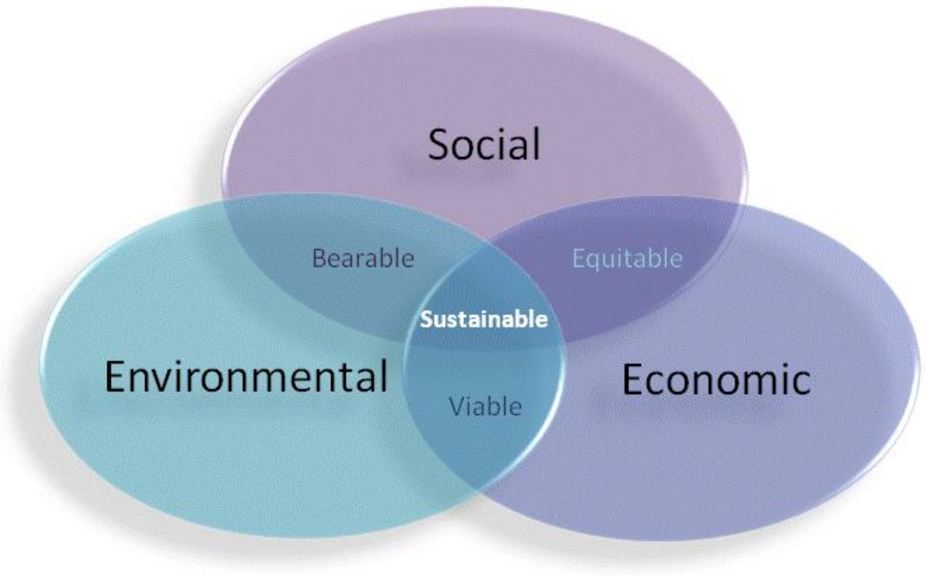
The main issue that came to light during the discussion was the need for a clear and concise definition of sustainability. Without such a definition it was considered difficult to determine whether an organization was operating in an environmentally sustainably way.

The Brundtland Report (United Nations World Commission on Environment and Development, 1987) provided what is now one of the most widely recognised definitions of sustainable development:

> "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

It is accepted that to allow future generations to meet their needs current economic, environmental, and social issues have to be addressed and balanced (Fig. 4.4).

When considering "greener" solutions to present day freight transportation issues it is important to have an appreciation of the overall scale of the problem. Pollution affects everyone on the planet and its reduction goes hand in hand with the development of more sustainable, greener logistics.



Source: International Road Transport Union (2012)

Fig. 4.4: What is sustainable? The triple bottom line: People, Planet, Profit.

4.5.1.2 Workshop Two - Freight Transport Infrastructure

In the case of Workshop Two the question put forward for consideration was:

> "In terms of your organization what are the most significant pieces of freight handling infrastructure in the North West region of England?"

To demonstrate the variety of 'soft' infrastructure **(**manufacturers, logistics providers**)** and 'hard' infrastructure **(**infrastructure providers) in operation within the North West region of England an exercise was carried out to identify a cross section of the stakeholders active in these fields.

'Soft' Infrastructure

The organisations chosen to populate the goods providers (manufacturers) and service providers (warehousing, distribution) groups are listed in Appendix One and Appendix Two respectively along with a brief description of their activities. This list should not be considered exhaustive but rather as identifying a representative cross section of stakeholders in North West England's freight transportation industry.

'Hard' Infrastructure

Hard infrastructure is divided into two sections. These sections are: the organisations responsible for the creation and maintenance of the infrastructure and the infrastructure itself. The organisations chosen to populate the infrastructure providers group are listed in Appendix Three along with a brief description of their activities.

From all of the hard infrastructure present in the North West of England the road, rail, aviation and maritime networks were those identified as being of the most significance to freight transportation. Within each of these categories the infrastructure identified as being the most importance is as follows:

Maritime Infrastructure

Since the year 2000, DfT has identified major ports as being those with cargo volumes of at least one million tonnes annually (plus a small number of strategic ports with less tonnage). Data is available annually for the preceding year. The most recent year for which data is available is 2017.

The experts consulted at the workshop, in combination with the 2017 data, identified the most significant freight handling ports in the North West of England as being:

- Port of Liverpool
- The Manchester Ship Canal
- Heysham Port

- Port of Garston
- Port of Barrow
- Port of Silloth
- Lancaster Port
- Port of Workington

More information on each of these can be found in Appendix Four.

Aviation Infrastructure

The Civil Aviation Authority (CAA) gathers data on annual freight movements through British Airports. The most recent set of available annual data is for 2017. This data indicates Heathrow as the United Kingdom's leading freight airport. In 2017, Heathrow carried 1,698,461 tonnes of freight. This amounts to more than all of the other UK airports combined. With this in mind it can be seen that in terms of freight handling the airports of the North West of England are of importance within their own region but only play a secondary role on a national level.

The CAA data for 2017 identifies the busiest freight airports of North West England. In contrast, the workshop determined the most significant airports in the region to be:

- Manchester
- Liverpool John Lennon

More information on these can be found in Appendix Five.

Road Infrastructure

The administrative classification of the English road network is based on the function performed by the road. Classification is based on the allocation of letters and numbers to roads. The Classified Road Network in England is composed of Motorways, A, B, C, D, and U roads.

Established by the Trunk Road Act of 1936, "Trunk road" is a legal term that describes any road or section of road under the control of central government. Trunk roads form a network of national importance that provides long distance routes linking centres of national importance. These centres include the major: urban areas, industrial areas, seaports, airports, and tourist regions.

Trunk roads form the recommended routes for long-distance freight traffic. The United Kingdom's network of trunk roads is commonly referred to as the Strategic Road Network. Most motorways and many of the long distance A-roads are trunk roads. In England the Highways Agency manages the Trunk Road Network on behalf of the Department for Transport. The Trunk Road Network (also known as the Strategic Road Network) accounts for nearly 7,000km of Motorway and 'A' roads. This represents 3% of the total roads in England but carries nearly a third of all road traffic and two thirds of all large goods vehicle traffic.

Overall the strategic road network in the North West region of England is of good quality, with most routes being of dual carriageway or motorway standard. For the purpose of this research elements of the Strategic Road Network (Trunk Roads) of the North West of England are being used to represent the road element of freight transportation. The parts of the Strategic Road Network considered by the workshop to be of regional significance to the transport of freight can be divided in to Motorway or 'A' roads.

Motorways

Motorways are major roads of regional and urban strategic importance, often used for long distance travel. In the United Kingdom a set of standards is common to the vast majority of the motorway network. These standards can be used to determine whether a road is a motorway. Motorways are:

- Specifically sign-posted as a motorway.
- Reserved for specific categories of road vehicles.
- Governed by motorway regulations.
- Numbered and then prefixed with "M" or suffixed with "(M)".
- Entirely dual-carriageway with separate carriageways for the two directions of traffic. Carriageways are separated from each other by a dividing strip not intended for traffic.
- Generally three or more lanes in each direction, but minor ones with lower use have two lane sections.
- Designated with a maximum speed limit of 110km/h (70mph)
- Not designed to serve all properties bordering them, they have limited access.
- Constructed with grade-separated junctions. They are not designed to cross at level with any road, railway or tramway, or footpath. This removes the requirement for traffic lights to control crossing flows of traffic.

- Equipped with hard shoulders for most of their length.
- Equipped with emergency telephones along the hard shoulder every 1.5km (1 mile)

In terms of freight transportation the most significant Motorways in North West England are:

- M6
- M53
- M55
- M56
- M57
- M58
- M60
- M61
- M62
- M65
- M66
- M67
- M602

More information on these Motorways can be found in Appendix Six.

A-roads

Unlike motorways, A-roads do not have a set of standards that are common across the entire road network. Only a small number of characteristics can be said to be universally applicable to every A-road. A-roads:

- Vary from motorway-standard to narrow local roads.
- Tend to have heavy traffic flows, though not as high as motorways.
- Have numbers prefixed with 'A' e.g. A66, A663, A5117.

In terms of freight transportation the most significant ‘A’ roads in North West England are:

- A55
- A56
- A66
- A69
- A494
- A556
- A580
- A585
- A590
- A595
- A628
- A5036

More information on these ‘A’ roads can be found in Appendix Seven.

Rail Infrastructure

The North West of England, particularly the region between Manchester and Liverpool, has an extensive rail network. Most of this infrastructure is owned by Network Rail. The purpose of this work was to determine which parts of this network representatives of the freight industry deemed the most important. The validity of the opinions offered was examined through a study of the appropriate Network Rail Regional Route Utilisation Strategy (RUS) documents. The RUS that were taken in to account include: West Coast Main Line RUS (2011), Freight RUS (2007), Merseyside RUS (2009), Lancashire and Cumbria RUS (2008), and the Northern RUS (2011).

The list of rail links produced for this work was done with a specific focus on the North West Region of England. Many of the rail links identified are substantially longer than the sections which are found within this region. Along their complete length the significance of these lines to the handling of freight will vary. With all of this in mind and having taken the RUS into account, the rail links considered by the workshop to be of most relevance to the transport of freight within the North West region of England are:

- Caldervale Line
- Crewe to Manchester Line
- Hope Valley Line
- Kirkby Branch Line.
- Liverpool to Wigan Line
- Settle-Carlisle Line
- Styal Line
- Tyne Valley Line
- West Coast Main Line
- West Coast Main Line – Liverpool Branch

More information on these lines can be found in Appendix Eight. However, the railway lines themselves only represent part of the story in the movement of containerised / unitised freight. Intermodal rail terminals are another indispensable part of the network. Within the North West region of England intermodal rail terminals of regional significance can be found at:

- Widnes – Mersey Multimodal Gateway (Halton Borough Council and the Stobart Group)
- Knowsley – Knowsley Distribution Centre (Potter Logistics)

- Garston – Garston Freightliner Terminal (Freightliner)
- Manchester – Manchester Container Terminal (Roadways Container Logistics)
- Liverpool – Royal Seaforth Docks (Freightliner)
- Trafford Park – Euroterminal (DB Schenker) and Euroterminal (Freightliner)
- Workington – Port of Workington (Cumbria County Council)

4.5.1.3 Workshop Three – Freight Transport Industry Stakeholders

In the case of Workshop Three the question put forward for consideration was:

> "Which companies/organisations would you consider to be the most significant stakeholders in the freight industry of North West England?"

The provision of suitable infrastructure is only part of the system that moves freight around the United Kingdom. Expert opinion suggests that the organisations involved in freight movement can be broken down in to three main groups (Gallop, 2012):

- Goods providers (Manufacturers)
- Service providers (Warehousing, Distribution)
- Infrastructure providers (Owners, Operators)

Based on access to independent expert opinion (representing over two hundred and fifty years of experience in the manufacturing, infrastructure ownership and operation, warehousing and distribution industries) a representative cross section of these groups was produced and found to be composed of eighty four organisations that are perceived as holding a significant stake in the freight transport industry of the North West region of England. This original list was then added to by expert:

- Knowledge of the region
- Study of the stock market e.g. FTSE 100, CAC 40, DAX, AEX, OMXC20.
- Identification of brand leaders
- Review of industry magazines and publications e.g. Nautilus Telegraph, BIFA Link, Railway Strategies, Warehouse and Logistics News, Fleet Transport.
- Identification of organisations that have received awards from learned institutes e.g. recipients of the CILT (UK) annual award for excellence.

- Review of the attendance list of relevant events e.g. North West Transport Lecture, Multimodal, Infrarail.

The final list generated was composed of one hundred and three organisations which were perceived as being of moderate to high importance in the freight industry of North West England. Some of these organisations operate across a wide range of specialisations. With this in mind the interviewees were asked to categorise such companies in accordance with the section of their organisation which made the greatest contribution to the freight industry of North West England. For example, Maersk is a service provider in that it offers a distribution service for the movement of intermodal shipping containers. It is also an infrastructure provider as it owns and operates ports across the world. However, as none of these ports are in the North West of England for the sake of this piece of research Maersk is considered a service provider and not an infrastructure provider.

4.5.2 Pre-Workshop and Post-Workshop Surveys

At their request the identities of those who participated in the surveys have been withheld. The answers provided were deemed by some to potentially reveal privileged information which may be of use to their competitors. To allow the survey results to be used in this work it was necessary to guarantee each of the participants that their individual responses would be treated as confidential. As a result, the data collected is only presented in the form of arithmetic mean figures for the group rather than as individual responses assigned to specific participants.

4.5.2.1 Workshop One – Environmental issues

The attendees of this workshop provided data through their responses to questions asked in separate pre-workshop and post-workshop surveys. The individual data sets were combined into a group data set the results of which have been compiled as shown in Table 4.1.

1. <u>I understand the environmental issues that my company contributes to.</u>

   Prior to the event attendees were not particularly confident (2.2/5.0) in their understanding of the impacts that their organizations had upon the environment. This improved after the event (3.7/5.0) and it was promising to hear attendees state that they were now more interested in understanding the impacts of their organizations on the environment.

2. I am confident in the sustainability of my company's operations.

Prior to the event attendees were quite confident (3.7/5.0) in the environmental sustainability of their companies' operations. After the event this was less so (2.6/5.0) as attendees had developed a greater understanding of what the environmental issues were. The result from the pre-workshop survey seems anomalous when it is considered in conjunction with the results from question 1.

In question 1 the pre-workshop results found that attendees were not particularly confident in their understanding of their organization's impact upon the environment. Yet the pre-workshop survey results from question two suggest that despite this lack of confidence the attendees were still quite confident that their companies are operating in an environmentally sustainable manner.

Table 4.1: The arithmetic mean value of responses in Workshop One.

Question	Before Event	After Event
1	2.2/5.0	3.7/5.0
2	3.7/5.0	2.6/5.0
3	1.6/5.0	4.2/5.0
4	1.8/5.0	3.3/5.0
5	4.2/5.0	3.8/5.0

3. I believe that my company could operate more sustainably.

Prior to the event attendees were confident of the environmental friendliness of the activities carried out by their companies. This was reflected by very few of them believing (1.6/5.0) that their companies could improve their environmental sustainability. After the event a complete reversal of opinion had occurred. Most of the attendees now believed (4.2/5.0) that there were ways that their companies could reduce their impact upon the environment.

4. I believe that progress has been made towards delivering the Department for Transport's Local Transport White Paper's agenda.

   Prior to the event most of the attendees did not believe (1.8/5.0) that the Department for Transport had made much progress. After the event this had changed (3.3/5.0) although this figure may be painting a false image. A few attendees had shifted their opinion to strongly believing that considerable progress has been made towards the Local Transport White Paper's agenda but the majority were still opposed to the idea.

5. I believe that it is possible to deliver both environmental and growth agendas simultaneously.

   Prior to the event attendees were very confident (4.2/5.0) that a growth agenda could be delivered whilst also taking into account the environment. After the event this confidence had reduced (3.8/5.0) but not by a substantial amount.

Radar Charts are a useful way of allowing comparisons to be made between the group's pattern of thought before and after its constituent members attended this event. The Radar Chart for this workshop shows two clearly defined patterns (Fig. 4.5), these are:

- The 'Before' attending pattern which shows a low level of understanding of the relevant environmental issues combined with a high level of belief that these issues were being, are being, and will continue to be effectively addressed.
- The 'After' attending pattern which shows a higher level of understanding of the relevant environmental issues combined with a lower level of belief that these issues were being, are being, and will continue to be effectively addressed.

Comparing these patterns suggests that a greater understanding of the environmental issues resulting from freight transport provides a greater appreciation for their severity and the implications that they have for future generations of people.

If the attendees of this event left with a better understanding of freight transport related environmental issues then this is a step in the correct direction for the transport industry of North West England.

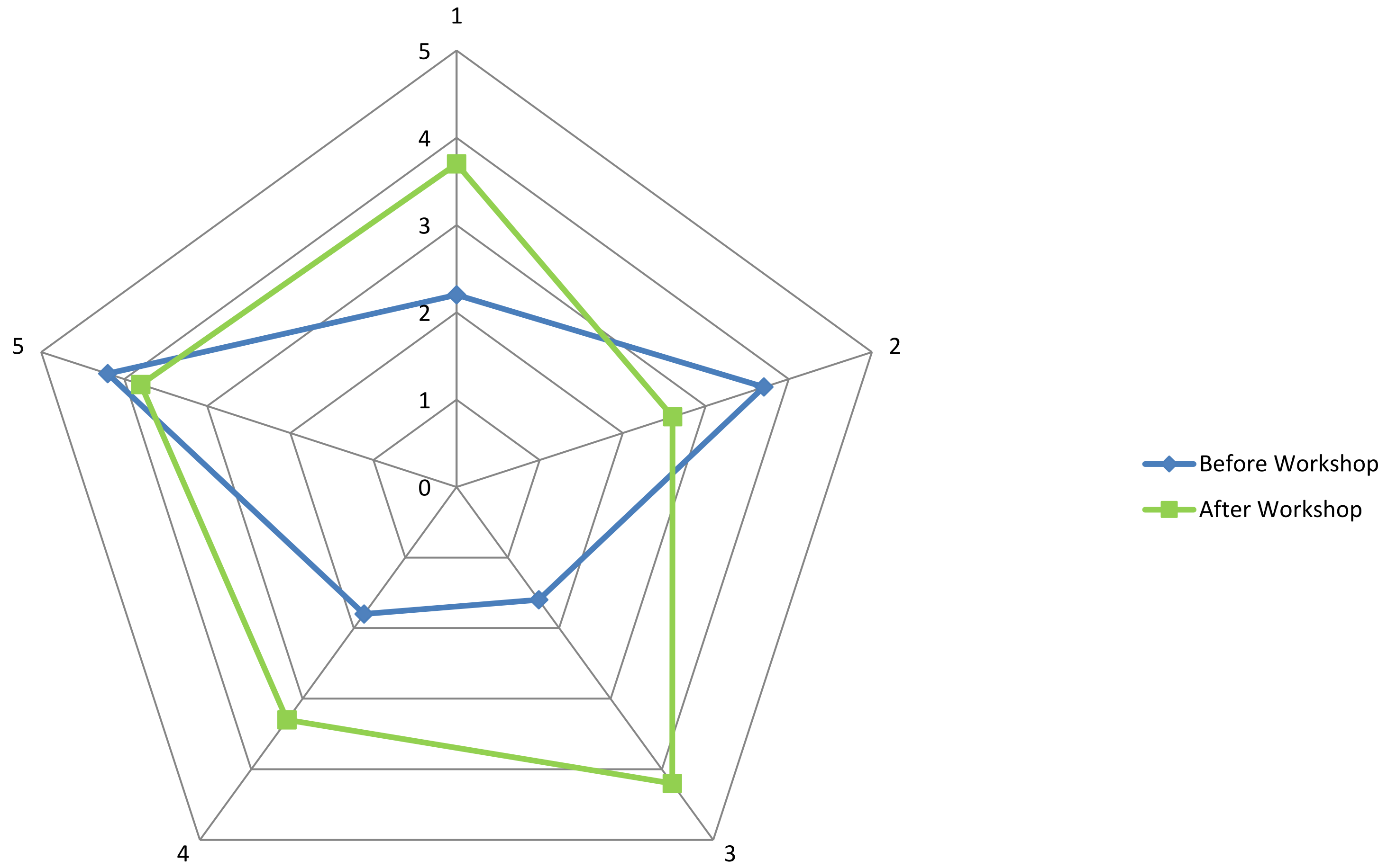


Fig. 4.5: Radar chart demonstrating the impact of the first workshop.

4.5.2.2 Workshop Two – Freight Transport Infrastructure

The attendees of this workshop provided data through their responses to questions asked in separate pre-workshop and post-workshop surveys. The individual data sets were combined into a group data set the results of which have been compiled as shown in Table 4.2.

Table 4.2: The arithmetic mean value of responses in Workshop Two.

Question	Before Event	After Event
1	3.9/5.0	4.6/5.0
2	3.0/5.0	3.9/5.0
3	2.3/5.0	3.3/5.0
4	2.1/5.0	3.5/5.0
5	1.8/5.0	2.9/5.0

1. I understand the security issues that affect my company.

   Prior to the event attendees were confident (3.9/5.0) that they understood the security issues that affected their companies and this improved after the event (4.6/5.0). The members of a company's security team would be expected to have a good grasp of the issues that they could potentially be dealing with. The event confirmed for many of the attendees that they had an accurate understanding of the relevant security issues.

2. I am confident in my company's current security measures.

   Prior to the event attendees were quite confident (3.0/5.0) in their company's current security measures. After the event this was more so (3.9/5.0) as in many cases the measures employed by the security staff were validated through the networking that occurred between attendees during the event.

3. I believe that my company's current security measures could be improved.

   Prior to the event most of the attendees believed that their company's security measures were very good and that it would be difficult to improve upon them. However, a small number of attendees felt that their organisation's security was particularly poor and this resulted in a higher than expected value in response to this statement (2.3/5.0). After the event many of the attendees tended to have a more open mind to the possibility of improving their company's security measures (3.3/5.0).

4. I believe that academia has an accurate understanding of the security needs of industry.

   Prior to the event most of the attendees had a worryingly low opinion of academia. This was due to the belief that academics exist in ivory towers with very little contact with the real world. However, a small number of the attendees who had worked with universities in the past were quite positive in their position and this kept the value in response to this statement higher than it would have been otherwise (2.1/5.0). After the event it was apparent that many attendees had begun to develop a greater understanding of how universities work and begin to build working relationships with some of the universities academics. This was a cautious step in the right direction that was then reflected by the improved response to this statement after the event (3.5/5.0).

5. I believe that current maritime security research can help improve the performance of my company.

   Prior to the event attendees felt that current maritime security research had very little to offer them (1.8/5.0) but after the event this had changed (2.9/5.0). When asked what motivated this change many of the attendees stated that it came down to them now understanding that they could play a role in influencing the nature of research that was being carried out.

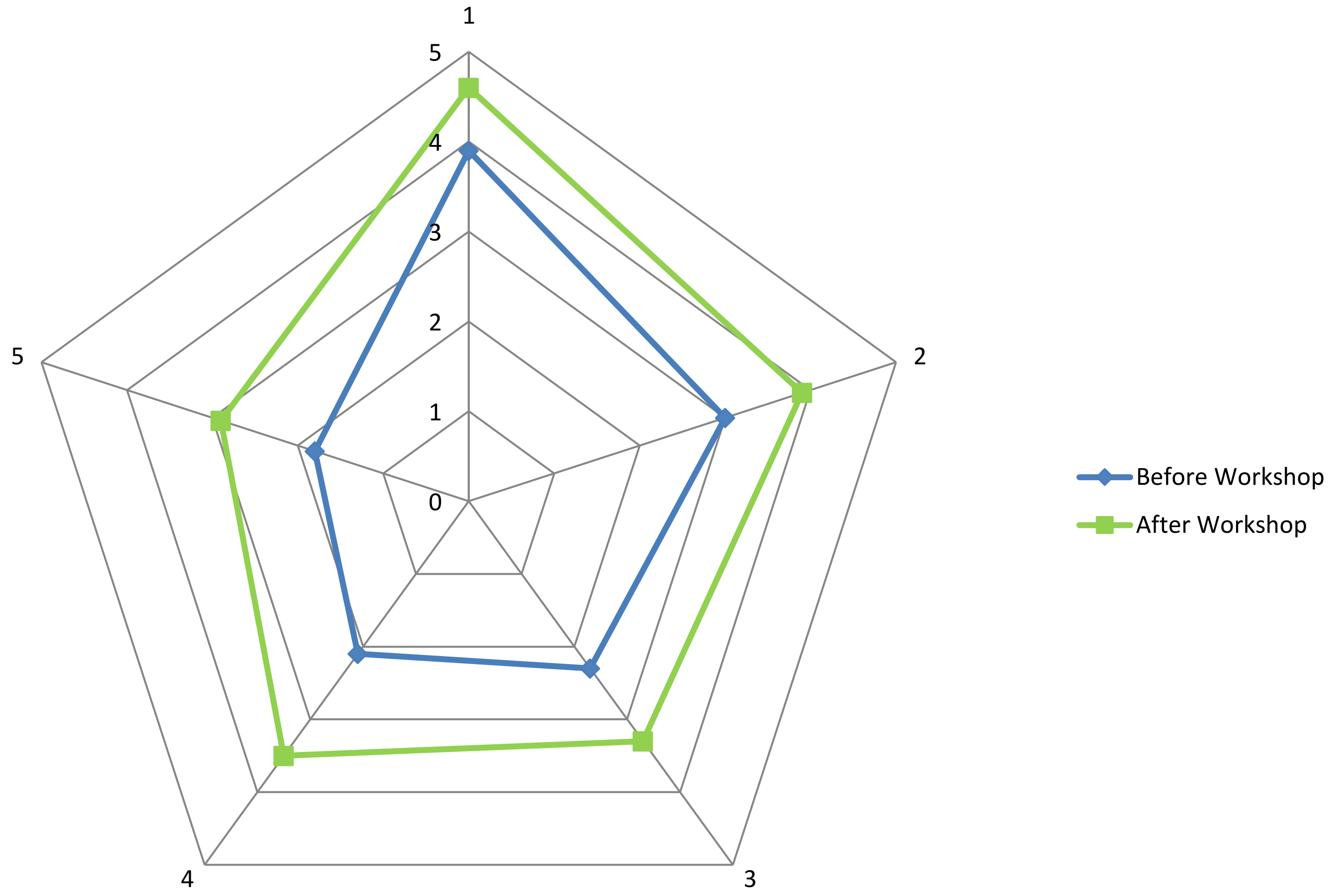


Fig. 4.6: Radar chart demonstrating the impact of the second workshop.

The Radar Chart for this workshop shows two clearly defined patterns (Fig. 4.6), these are:

- The ‘Before’ attending pattern where attendees show a high level of confidence in their own security measures combined with a low level of interest in what academia has to offer.
- The ‘After’ attending pattern where attendees show a slightly elevated level of confidence in their own security measures combined with an increased level of acceptance that academia may have something to offer the security industry.

Comparing these patterns suggests that beneficial things could be achieved if industry worked closer with academic institutions and these same academic institutions made an effort to address the issues that matter to industry.

4.5.2.3 Workshop Three – Freight Transport Industry Stakeholders

The attendees of this workshop provided data through their responses to questions asked in separate pre-workshop and post-workshop surveys. The individual data sets were combined into a group data set the results of which have been compiled as shown in Table 4 .3.

Table 4.3: The arithmetic mean value of responses in Workshop Three.

Question	Before Event	After Event
1	4.3/5.0	4.5/5.0
2	4.2/5.0	3.1/5.0
3	1.9/5.0	3.9/5.0
4	1.9/5.0	4.8/5.0
5	1.7/5.0	3.1/5.0

1. I know which infrastructure my company uses for its freight movements.

   Prior to the event attendees were confident (4.3/5.0) that they knew which infrastructure that their companies used for their freight shipments. This improved after the event (4.5/5.0) but only by a small margin. The limited nature of this increase and the very similar distribution of responses suggest that the event had a negligible impact in this regard.

2 I am confident that my company uses the most appropriate infrastructure for its freight movements.

   Prior to the event attendees were quite confident (4.2/5.0) that their companies were using the most appropriate infrastructure for their freight movements. After the event this was less so (3.1/5.0). In many cases an increasing element of doubt had begun to be introduced in to the minds of the attendees. This is a noteworthy development as they will now have a more open mind as to the sustainability of their companies transport operations.

3 I believe that my company's current choice of infrastructure use could be improved.

   Prior to the event most of the attendees believed that their company's choice of infrastructure use was quite good and that it would be difficult to improve upon it (1.9/5.0). After the event many of the attendees had a more open mind to the possibility that their companies could make more sustainable choices when it came to their freight transportation activities (3.9/5.0).

4. I am aware of the upcoming developments within the Port of Liverpool / Manchester Ship Canal corridor.

   Prior to the event many of the attendees stated that they were unaware of the upcoming developments proposed for the Port of Liverpool / Manchester Ship Canal corridor (1.9/5.0). A wide range of reasons were offered to explain this but it was also suggested that some attendees may have feigned their lack of awareness to avoid giving away anything about their businesses activities. However, after the presentation and the very thorough question and answers session provided by Peel Ports during the event all of the attendees undoubtedly left with a much greater understanding of what was planned for the Port of Liverpool / Manchester Ship Canal corridor (4.8/5.0).

5. I believe that the development within the Port of Liverpool / Manchester Ship Canal corridor have the potential to bring transformational change to the North West region of England.

   Prior to the event there was a definite lack of confidence that the proposed developments would have the potential to bring transformational change to the North West region of England (1.7/5.0). This could be explained by the attendees' lack of understanding (identified in question four) of what these developments actually entailed. After the event, although all of the attendees had a much greater understanding of what was planned and many of them could see the potential of what was being proposed some still needed further convincing (3.1/5.0).

The Radar Chart for this workshop shows two clearly defined patterns (Fig. 4.7), these are:

- The 'Before' attending pattern, where attendees show a high level of understanding of the infrastructure which their companies utilise and a high level of confidence in it being the most suitable choice. This is accompanied by a limited understanding of the upcoming developments in the Port of Liverpool / Manchester Ship Canal corridor.

- The 'After' attending pattern, where attendees show a high level of understanding of the infrastructure which their companies utilise but a lower level of confidence in it being the most suitable choice. This is accompanied by a much greater level of understanding of the proposed developments in the Port of Liverpool / Manchester Ship Canal corridor but some degree of uncertainty as to whether they will deliver what they promise.

Comparing these patterns suggests that attendees will have left the event with a more critical opinion of the transport choices made by their companies and an increased understanding of one of the largest infrastructure projects to be undertaken in the region over the next few years.

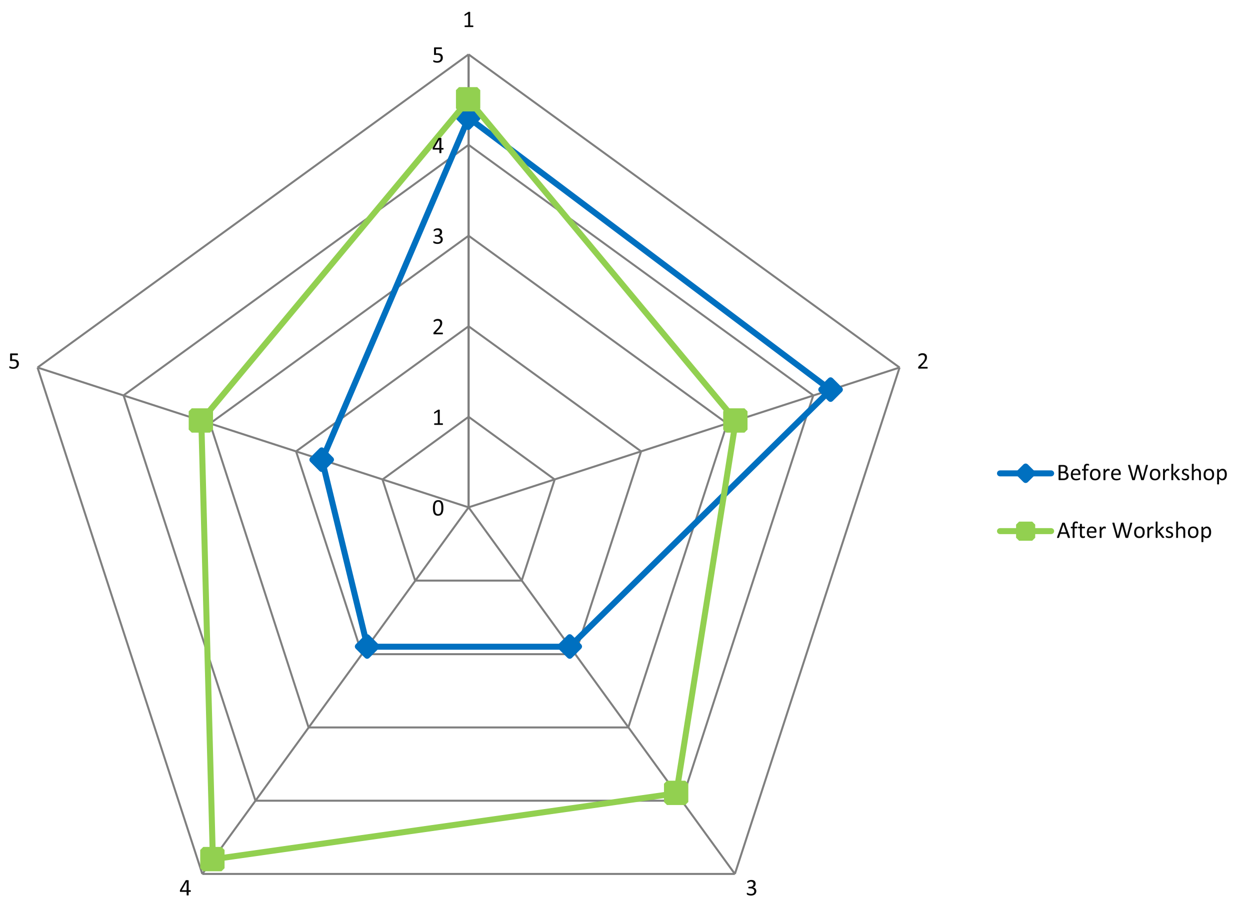


Fig. 4.7: Radar chart demonstrating the impact of the third workshop

4.6 Discussion

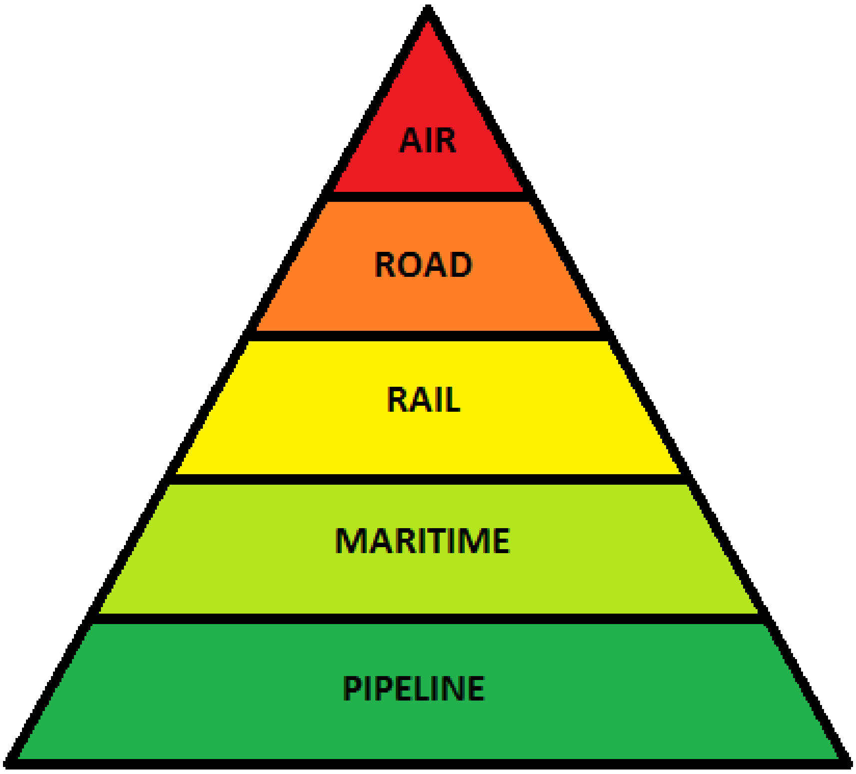
4.6.1 Workshop One – Environmental Issues

When presented with information regarding pollution, global warming, and environmental degradation most people say "That's all well and good, but what can I do?" A pyramid of sustainability is a useful method for allowing practitioners to easily grasp what needs to be done in the freight transport industry. Such pyramids have been used to address a range of transport related issues and with a slight adjustment they can be relevant here as well. Air is located at the top of the pyramid. This is the least sustainable mode of freight transportation. Pipelines are located at the base of the pyramid. This is the most sustainable mode of transport. The other modes fall somewhere in between these two extremes.

Some cargoes lend themselves to being transported by a particular mode: Intermodal containers were originally designed for transport by ships; high value, small sized, perishable cargoes are often shipped by air; bulk liquid cargoes tend to be transported by a combination of pipeline and maritime. It is not feasible to completely rule out any mode, or claim that one mode is suitable for transporting all types of cargo.

However, what is feasible in attempting to make supply chains greener, and more sustainable, is to develop a trend where shipments are moved away from transport modes located in the upper portion of the sustainability pyramid to those in the lower portion. When making the choice as to how a shipment should be transported the sustainability pyramid could be used to ensure that the mode selected is the lowest mode in the pyramid which is both suitable for the cargo in question as well as the available routes.

It has been said that the positions of some modes in the pyramid are interchangeable and that depending upon the specific circumstances of a route one may be the more sustainable than the other. With regard to this the pyramid serves as a focal point for debating the issue. If, based on the pyramid, a definitive outcome can be reached where the better management of freight transport modal choice provides a more sustainable future for the freight transport industry then the pyramid will have served its purpose.



Source: Own. Amended from the Bicycle Innovation Lab (2013) and Odum, H. T., Odum, E.C. (2001).

Fig. 4.8: Pyramid of transport sustainability by mode.

4.6.2 Workshop Two – Freight Transport Infrastructure

When conducting research that involves connecting with industry it is often the case that the question is asked "who do we talk to?" or "what data do we need?" The work carried out for this workshop serves as an example of how to build a framework of organisations that are perceived as being of relevance to the industry in question, in this case the freight industry.

The academics' role to act as an independent party in this process is key to its success. Industrial representatives are only human and depending upon which representatives are interviewed the results produced can be distinctly self-serving. This can be the case when: manufacturers omit their competitors, road distributors omit rail distributors, or misleading data is provided to avoid giving away sensitive information.

With this in mind the academic could be seen as performing the role of a referee. They are not there to simply trawl the internet and produce a list of organisations that they themselves deem to be relevant. A methodical approach must be adopted where industry is firstly asked to assess itself before the academic is allowed to make additions to the list that they feel have been omitted (by accident or intent) up to that stage.

The list produced by this research is by no means an exhaustive one but it does represent a cross section of the North West of England's freight industry. Despite this it is certain that the organisations found here will generate debate on which stakeholders should or should not have been included. This list was developed to cover the North West region of England. With that in mind it is fair to say that a different list would have been generated if a different set of experts were consulted or a different region was discussed.

4.6.3 Workshop Three – Freight Transport Industry Stakeholders

This workshop serves as an example of how engaging with members of local industry can help to produce insights into their operations without having to ask them to directly reveal information which they may consider to be sensitive. In this case the result is a list of the infrastructure that local industry perceives as being of significance to the long distance transportation of freight.

The academics' role to act as an independent party is also important in this process. Industrial representatives are only human and depending upon which representatives are interviewed the results produced can begin to have a distinctly self-serving flavour. This can be the case when road distributors omit rail infrastructure, or likewise when misleading data is provided to avoid giving away sensitive information.

With this in mind the academic could be seen as performing the role of a referee. They are not there to simply trawl the internet and produce a list of infrastructure that they themselves deem to be relevant. A methodical approach must be adopted where industry is firstly asked to assess itself before the academic is allowed to make additions to the list that they feel have been omitted (by accident or intent) up to that stage.

The list produced by this research is by no means an exhaustive one but it does identify a good cross section of the major infrastructure in the North West of England. It does not represent the entirety of the United Kingdom and it is also not concerned with the problem of the last mile.

Despite this it is certain that the infrastructure found here will generate some debate on which pieces should or should not have been included. With that in mind it is fair to say that a different list would have been generated if either a different set of experts were consulted or a different region was discussed.

4.7 Conclusion

The purpose of this chapter was to gain a deeper understanding of the freight transportation industry. This deeper understanding was achieved by identifying the key stakeholders in North West England's freight industry, determining which freight handling infrastructure they believe to be the most important and then assessing their ability to deliver more sustainable freight transportation solutions.

This process was important as it generated a list of the organisations that need to be engaged with if the possibility of achieving a modal shift in the North West of England is to be realised. It also identifies the alternative options for moving freight that industry already knows exists, accepts as relevant and has confidence in but does not necessarily utilise to its full potential. By taking the infrastructure that was identified for the North West as a marker it would be possible to extend this in to surrounding regions to establish a network of what industry believes to be the most significant freight handling infrastructure for the rest of the United Kingdom and beyond.

A number of other important points were also identified in this chapter. Primarily, the freight industry appears to have a low level of understanding of its impact upon the environment. This is not surprising as the people involved are business people rather than environmentalists. However, those people that attended the first workshop left with a greater appreciation of the environmental implications of their industry as well as being more open to the possibility of attempting to reduce their environmental impact.

Secondarily, it was found that representatives of the freight industry have, not surprisingly, a good understanding of the transport modes which they utilise on a day to day basis through their business. Unfortunately, it was also found that this does not extend to a broader understanding of other transport modes which their business may not use as frequently.

Subsequently, it was found that those representatives of the freight industry that attended workshop two had a low expectation of what academia could offer their business. However, after being engaged by the university, and given the opportunity to address their concerns, members of the business community began to see that they could benefit from working with academia.

These findings help to justify the research that is to be carried out in the subsequent chapters of this work. The findings demonstrate that the freight industry has a lack of understanding of its impact upon the environment and also a lack of appreciation for alternative modes of transport. However, if the benefits are made clear to them from the start then they are open to co-operating with academia and adopting ideas that are jointly produced. This applies with a view to addressing industrial issues in general but in this case it applies to identifying more sustainable freight solutions.

By determining the industry's perceptions of itself, the insights gained will be invaluable when they are used in the development of a modal choice framework and the subsequent promotion of more sustainable freight transportation. In particular, this chapter has produced a strong foundation to build on when going on to identify the key criteria in the modal choice decision making process in the next chapter of this work.

Chapter Five

A subjective evaluation of selected modal choice decision making criteria using the Analytic Hierarchy Process (AHP)

5.1 Introduction

The identification and subsequent analysis of modal choice decision making criteria is limited by inadequate data. As a result there is the need to develop a decision making methodology to address this problem. With this in mind the first step is taken in this chapter by utilising a suitable multi-criteria decision making analysis (MCDA) tool to produce a generic model of the modal choice decision making process.

The MCDA tool used in this chapter is the Analytic Hierarchy Process (AHP). It is used to determine the weights that are attached to each of the criteria that make up the component parts of the model. A greater understanding of what influences the modal choice decision making process will allow informed decisions to be made on how to more efficiently utilise the United Kingdom's most commonly used modes of freight transport (road, rail, water).

The data gathered through the application of AHP provides a foundation that can be built upon by either industry, central government or regional government to determine how best to promote modal shift.

The AHP approach has been adopted specifically to address the limited data made available by the freight transportation industry in support of this research and the inadequacy of the data which is publicly available through mainstream sources. This made it necessary to pursue a qualitative approach to this work rather than a quantitative one. Before proceeding any further a brief introduction to AHP is necessary.

5.2 Methodology

AHP follows a clearly established procedure to allocate weights to criteria (Saaty, 1980). This procedure was integrated into this work to allow AHP to assess the modal choice decision making process. The steps utilised to apply AHP to this problem are as follows:

5.2.1 Identify the criteria that are stated as influencing the modal choice decision making process (*Step 1*)

To understand the process involved in making a modal choice the first major step is to determine the factors that influence the decision making process. The qualitative and quantitative criteria that influence freight transportation modal choice decision making have been widely examined in recent years (Branch, 1986; Bird, 1988; D'Este and Meyrick, 1992; Matear and Gray, 1993; Murphy *et al.*, 1997; Cullinane and Toy, 2000; Mangan *et al.*, 2002; Vellay and Jong, 2003; Punakivi and Hinkka, 2006; Beuthe and Bouffioux, 2008; Garcia-Menendez and Feo-Valero, 2009; Feo-Valero *et al.*, 2011). These and others have identified an extensive list of potential criteria.

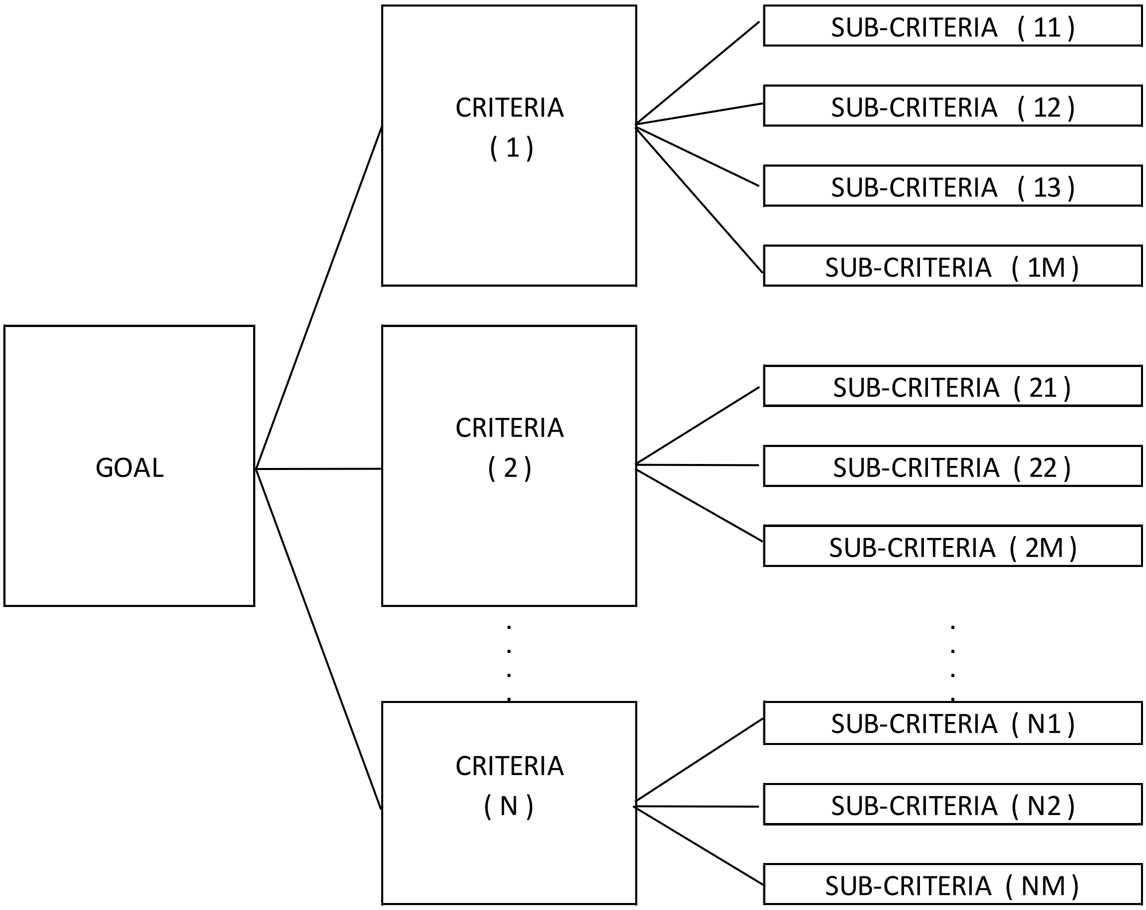
Identifying the criteria that are of interest to this particular decision making exercise will allow a general hierarchical model to be constructed. This model will be used to represent the decision making process for the transportation mode carriage selection of freight cargo in the United Kingdom.

5.2.2 Group similar criteria together under individual headings (*Step 2*)

Previous research (D'Este and Meyrick, 1992) has demonstrated that the grouping of criteria which influence modal choice into broad categories is feasible. However, each of the individual headings (criteria) under which the similar criteria (sub-criteria) are to be grouped will need to be given a relevant title.

5.2.3 Construct a modal choice decision making framework (*Step 3*)

The hierarchical structure will initially be divided into three levels. These are: Goal, Criteria, and Sub-Criteria (Fig. 5.1). The Goal in this work is to study the modal choice decision making process between road, rail and water. The criteria are the titles that are allocated to describe the similar sub-criteria grouped beneath them. The sub-criteria are the factors that were identified through a review of literature as having a role to play in the decision making process.



Source: Own

Fig. 5.1: Example of a general hierarchical model

5.2.4 Construct a pairwise comparison questionnaire for gathering data (*Step 4*)

The key to understanding how a modal choice decision is made is determining the relative importance of the factors that are associated with the decision making process (D'Este and Meyrick, 1992). This can be done theoretically (Dial, 1979; Gursoy, 2010) or based on empirical evidence (Garcia-Menendez and Feo-Valero, 2009). The pairwise comparison process serves to generate empirical data where there is currently a lack.

5.2.5 Conduct pairwise comparisons (*Step 5*)

Pairwise comparison data is gathered through the completion of pairwise comparison questionnaires by industry experts. An example of how these values are found by using the pairwise comparison scale of measurement is demonstrated through a piece of work whose goal is to select the most important part of a computer.

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
Vs MOUSE															X		
Vs KEYBOARD											X						
Vs CPU	X																

Source: Own

Fig. 5.2: Pairwise comparisons of a monitor versus other computer parts

This excerpt (Fig. 5.2) looks at the importance of the monitor in comparison to other parts of the computer. In this case the identified criteria are: Monitor, Mouse, Keyboard, Central Processing Unit (CPU). As a result, the pairwise comparisons are: Monitor vs. Mouse, Monitor vs. Keyboard, and Monitor vs. CPU.

The expert opinion of a computer technician with over ten years' experience in the field and a Computer Science BSc determined that:

- The monitor is seven times "more important" than the mouse. We can still use a computer without the mouse. If the mouse is broken then the short cut system (Ctrl+P to print, Ctrl+S to save) can be used to access a file or document in the computer by using the keyboard.
- The monitor is three times "more important" than the keyboard. We can still use a computer without a keyboard. If the keyboard is broken then the mouse can be used to access files through My Document. The only thing that cannot be done is typing.
- The monitor is nine times "less important" than the CPU. We cannot use a computer without the CPU. If the CPU is broken then the monitor is of no use at all.

5.2.6 Utilise the collected data to establish criteria weights (*Step 6*)

The established process to follow to achieve this is:

a) Develop pair-wise comparison matrices for both the criteria and sub-criteria within each criteria group.

b) Multiply the value of each row and calculate the n^{th} root of each criterion.

c) Normalise the n^{th} roots of the weights obtained for each criterion.

d) Calculate and validate the Consistency Ratio (CR).

5.3 Case Study - Determining the weight of each criterion using AHP

The generic model developed in this case study utilises the subjective knowledge and judgement of experts in the field to provide data for analysis through AHP. To apply AHP to the modal choice decision making process steps (1 to 6) were performed.

5.3.1 Identify the criteria that are stated as influencing the modal choice decision making process (*Step 1*)

Over the last few decades, qualitative factors associated with the transportation of freight have been widely examined by researchers. Having a firm grasp of the factors that influence modal choice is a fundamental part of this research. A review of the literature that covers the field of modal choice was performed and identified one hundred and two journal papers from the last forty years that were considered to be representative of the field.

A group of ten managers from within North West England's freight industry were then invited to consider these papers. By way of a Delphi approach, consensus was ultimately achieved between them and the list was reduced to forty papers that were deemed to have the most relevance to modern day freight transportation within the geographical are in question (Appendix Nine).

From these papers an extensive list of potential criteria were identified. Some of these criteria, such as transit time and cost, have always been found to be relevant. Others, such as external impacts and security, have been found to come in and out of fashion over time. Yet others have been found to have been omitted entirely, such as certification and mode image. All of the terms found in these papers, along with those offered by industry representatives, are compiled in Appendix Ten.

With a view to moving the research in this field forward it was deemed appropriate to include those criteria e.g. certification and security that have previously been omitted from other models. Electing to include these previously unrepresented criteria in this work will allow it to be established whether they are irrelevant or have not been considered before as a result of an oversight. The justification behind selecting these 'new' criteria is outlined alongside their entry in the following pages.

5.3.2 Group similar criteria together under individual headings (*Step 2*)

Consultation with industry, in conjunction with the forty selected papers, was used to construct a list of all the terms typically identified as influencing the modal choice decision making process. To produce a more easily manageable model it was necessary to group these terms under relevant headings. Each term was gathered together with other similar terms and then these collections were issued with a heading that reflected the nature of the group. The headings, under which previous terms have been grouped, as well as the previous terms themselves, can be found in Appendix Ten.

A wide variety of terms to identify individual criteria have been used in previous modal choice decision making studies. The terms used in this work are those which are most commonly encountered in the research literature as well as those which are currently in use in the freight industry.

5.3.3 Construct a modal choice decision making model (*Step 3*)

Utilising the established criteria headings (Appendix Ten) a concise framework was generated (Fig. 5.3) for modelling the modal choice decision making process. In this study the main criteria serve as umbrella categories whose purpose it is to allow various sub-criteria to be united under a single heading. The four criteria selected for use in this study are:

- Service - This refers to the range of factors that affect the perceived quality of the transport provided. McGinnis (1980), D'Este and Meyrick (1989), Matear and Gray (1993), the Department for Transport (2010), and Grosso (2011) have identified elements of service as a broad category which influences modal choice.

- Route - Route related factors are those that identify the characteristics of a chosen route. Bardi *et al.* (1989), Premaux (2007), Fremont and Franc (2010), and Feo *et al.* (2011) have identified the importance of route characteristics in modal choice.

- Carrier - Carrier related factors are those that refer to the procedural effectiveness of the company providing the transport service. Various aspects of carrier criteria have been identified in Abshire and Premaux (1991), Kent and Parker (1999), Dobie (2005), and Gursoy (2010).

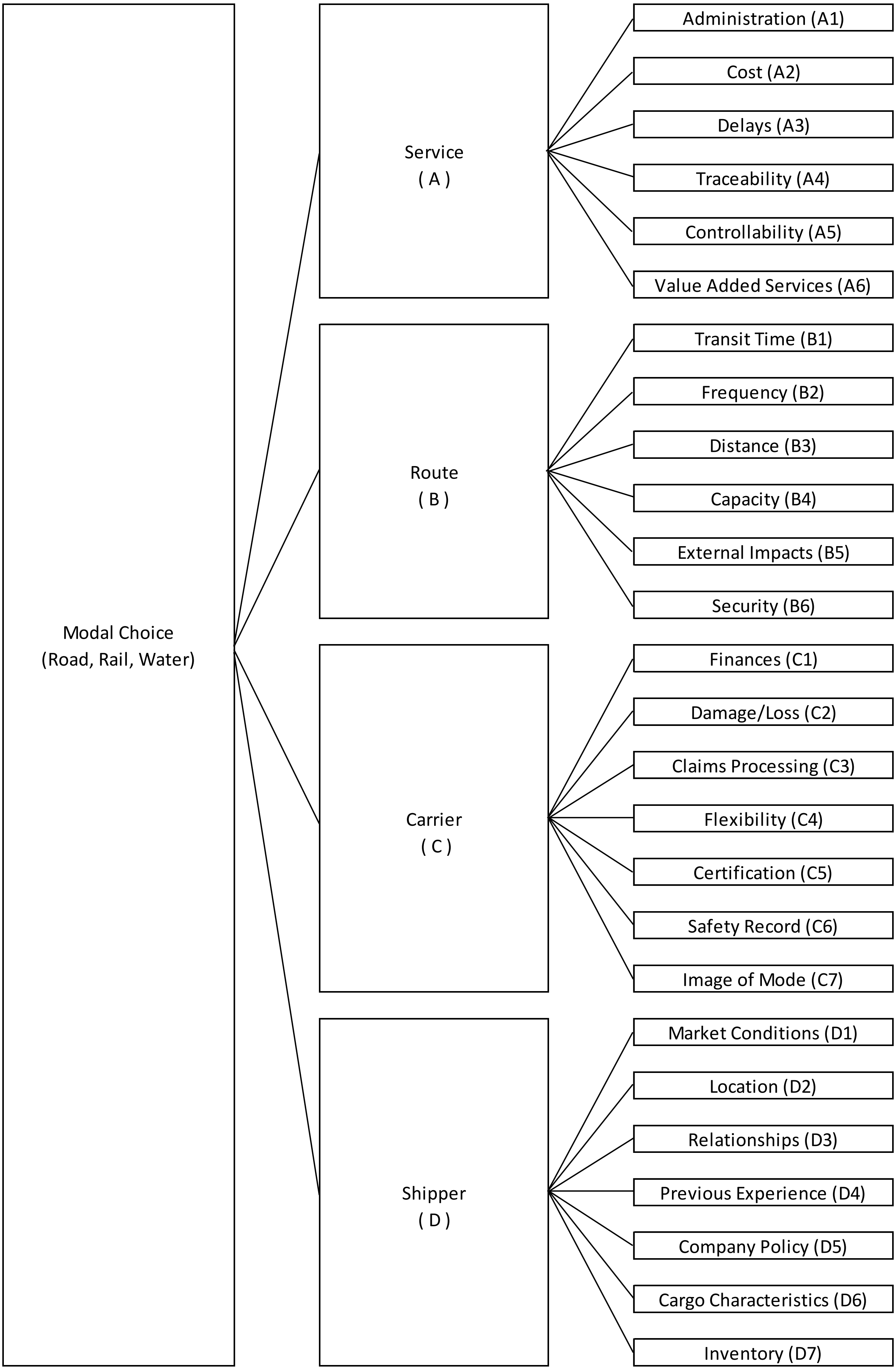


Fig. 5.3: Framework for modelling the modal choice decision making process

- Shipper - Shipper related factors are those that influence the person making the freight transport decision as they operate within their own organisation. Previous research by Gray (1985), McGinnis (1989), and Wong (2008) has found that shipper related criteria can have a significant effect on decision making.

The next part of this process was to attach a definition to each sub-criterion to ensure the transparency of the model and avoid causing confusion amongst the experts that completed the questionnaire. These definitions are as follows:

5.3.3.1 Service Criteria (A)

The sub criteria selected to make up the Service criterion, a brief definition and some of the reasoning behind the selection of each of these criteria are as follows:

A1. Administration – The timeliness, efficiency, and accuracy of the administrative processes involved with moving a shipment from its origin to its destination.

A2. Cost – The total cost of moving a shipment from its origin to its destination.

A3. Delays – The punctual arrival of shipments at their destination.

A4. Traceability – The real time tracking of cargo after it has been dispatched.

A5. Controllability – The ability to control a shipment after it has been dispatched.

A6. Value Added Services – The ancillary service options offered to compliment the core service. These are something extra that is typically provided at no additional charge.

The lightning speed of development over recent decades has brought computers firmly into the day to day processes of the business world. Studies of many industries have demonstrated the indispensable role that computers now play. Freight transportation has not escaped this trend. A range of studies (Evers and Johnson, 2000; Dobie, 2005; Department for Transport, 2010) have identified “Information and Communications Technology” as a criterion that now influences modal choice. This factor is represented in this work by the Administration sub-criterion.

The criterion that cuts straight to the heart of the modal choice issue is cost. Research on route-mode choice (Dial, 1979) has defined cost as the "total user cost". This can be taken to mean the total amount of money expended to take the cargo from door to door. This includes transport, handling, storage, and any other financial outgoings resulting from the movement of the freight. Cost is ultimately the figure presented to the shipper by the carrier for supplying the requested service.

Transit time reliability, more commonly known as delays or punctuality, is another issue often found to heavily influence modal choice decision making (Danielis *et al.*, 2005; Grosso, 2011). It refers to the degree of certainty and predictability in travel times on a given transportation system. The more reliable modes of transport provide the shipper with a greater level of assurance that their shipment will arrive at its destination within a reasonable range of its expected time. Within this work the Delays sub-criterion represents the level of confidence that can be placed on the carriers anticipated journey time from door to door.

In Cullinane and Toy (2000) the number of article appearances of specified modal choice criteria were assessed and it was found that Controllability/Traceability was amongst the top fifteen criteria used in modal choice studies. The high number of mentions that this criterion received makes it essential to include in this work. However, Controllability (the ability to influence a shipment) and Traceability (the ability to see where a shipment is) are clearly two separate things. As a result, they have been included in this work as separate criteria named 'Controllability' and 'Traceability'.

The term 'Value Added Service' is one that is commonly used to refer to an add-on that is outside of the standard service offered. Such add-ons are typically made available at little or no extra cost to enhance a company's standard service. It is a phrase that is often heard in regards to the telecommunications industry but it can be applied to a multitude of other industries. In Wong *et al.* (2008) the existence of a pickup service is taken as a criterion of significance to modal choice. However, the model being used in this work takes a step back and uses the broader criterion of Value Added Services to cover a wider range of potential additional services.

5.3.3.2 Route Criteria (B)

The sub criteria selected to make up the Route criterion, a brief definition and some of the reasoning behind the selection of each of these criteria are as follows:

B1. Transit Time – The time taken to move a shipment from its origin to its destination.

B2. Frequency – The number of journeys carried out by a transport mode between a shipment's origin and destination over a given period of time.

B3. Distance – The distance travelled by a shipment from its origin to its destination.

B4. Capability – The physical facilities and processes available to meet the needs of the shipper.

B5. External Impacts – The pollution and other externalities resulting from the movement of a shipment from its origin to its destination.

B6. Security – The security of the supply chain between the shipments origin and destination.

The review of literature revealed that transit time has previously (Bardi *et al.*, 1989) been identified as an important indicator for freight shippers. Transit time has been defined as the "door-to-door transport time, including loading and unloading". However, it is also referred to as timescale, shipping speed, and wait time. Transit time reflects the length of time that the receiver has to wait to take receipt of the cargo after the time of ordering.

A literature review also revealed that service frequency (Grosso, 2011) has been identified as an important indicator for freight shippers. Beuthe and Bouffioux (2008) define service frequency as the "service per week actually supplied by the carrier or the forwarder". Service frequency is also among the criteria used to characterise the future European Motorways of the Sea (European Commission, 2012).

The distance that a given route covers is another significant factor that often occurs in modal choice literature (Spencer *et al.*, 1992; Cullinane and Toy, 2000; Feo *et al.*, 2011). It has been argued (Jiang *et al.*, 1999; Paixao and Marlow, 2002) that modal choice is a direct function of distance. In Hjelle (2010) distance was used to argue that the most energy efficient freight routes are those which are based upon cargo movements by road. This conclusion resulted from the low load factor of seaborne transport compared with that of road.

The capability of a mode to deliver freight from its origin to its destination is critical in modal choice decision making (Fremont and Franc, 2010). In recognition of this, Vellay and Jong (2003) included access to the transport network, with reference to rail transport, as a criterion in their model. This criterion can however have a broader application, regardless of the transport mode examined, if the shipper cannot access the network then they cannot use it (Premaux, 2007).

Whilst energy efficiency is of importance when considering the distance that a given route covers it is also of importance with regard to the external impacts (pollution) resulting from freight transportation. The more energy required to move a cargo from its origin to its destination the more pollution that will be produced (Hjelle, 2010). In the past, work has been done to identify the gaps in modal choice and carrier selection research (Meixell and Norbis, 2008). Environmental concerns were found to be a theme that was entirely missing in their body of research. None of the forty eight articles reviewed by Meixell and Norbis had any mention of these issues in them. However, in more recent years a number of papers have begun to include external impacts (Meers *et al.*, 2013, Minal and Sekhar, 2014, Nugroho *et al.*, 2016, Huber, 2017) in their models. As a result of the more recent papers including this criterion it is also included in this model.

In a similar way to how pollution has been overlooked in previous studies of the modal choice decision making process, security is also under represented. Only one paper from all of those selected by Meixell and Norbis considered security. In that paper (Voss *et al.*, 2006) security was identified as a potential new criterion for inclusion in future modal choice studies. A definition of security in a containerised supply chain is offered in Riahi (2010) as “the physical and procedural security standards of the various commercial perimeters e.g. warehouse, container consolidation facilities”. To address the absence of this criterion in previous modal choice work and in accordance with Voss *et al.* security is to be included in this model.

5.3.3.3 Carrier Criteria (C)

The sub criteria selected to make up the Carrier criterion, a brief definition and some of the reasoning behind the selection of each of these criteria are as follows:

C1. Finances – The size of the carrier company and its financial stability as perceived by its users.

C2. Damage/Loss – The carrier's history of shipment loss and damage.

C3. Claims Processing – The ease by which the carrier finalises settlements to cover loss, damage, over charge, or other complaints.

C4. Flexibility – The ability of the carrier to accommodate the varying requirements imposed upon them by customers.

C5. Certification – The management systems that are in place within the carrier organisation and which are recognised by ISO (or equivalent) awards.

C6. Safety Record – The carrier's history of injuries, fires, fatalities, collisions, groundings, and any other accidents resulting from the transportation of shipments between their origin and destination.

C7. Image of Mode – The public image of the transport mode most commonly associated with the carrier.

The finances of a company can be a difficult criterion to collect data for. It is for this reason that many studies of the modal choice decision making process choose not to include it. However, The United Kingdom's Department for Transport issued a report in 2010 that identified financial conditions as playing a role in modal choice. With this in mind the size and financial stability of the carrier company was included in this model.

The idea of claims processing as a criterion influencing modal choice is suggested in Wong *et al.* (2008). This paper is aimed at modal choice in China where the legal structure surrounding claims awards compensation to both the plaintiff and the defence in a case. Under these circumstances the efficiency with which claims can be processed is of concern to everyone involved. The legal system in the United Kingdom is different but with claims processing being omitted from many of the existing modal choice studies it was felt that it should be included in this model.

In Garcia-Menendez *et al.* (2004) the Damage criterion is identified. It is defined as the "average percentage of cargo losses and damages of a specific product" when it is being shipped "to a determined point of destination". This is quite a rigid definition as it suggests that the value attached to this criterion will vary depending upon the product being shipped and the destination to which it is being transported.

In terms of the research being carried out here this definition may be too narrow and unnecessarily rigid. The alternative and much simpler definition provided by Tuna and Silan in their 2002 paper states that this criterion can be described as a company's ability to "deliver the cargo without damage". If it is accepted that damage can also include the complete loss of a shipment then the Tuna and Silan definition is much more appropriate for the model to be constructed and it is included with that definition in mind.

Flexibility is referred to in Beuthe and Bouffioux (2008). When defining flexibility in a supply chain it has been said that this trait is best reflected by the ability to make an amendment to a shipment after it has been dispatched. In Kannan and Bose *et al.* (2011) flexibility is identified as rescheduling at short notice. They define this as the ability to "accept requests for diversion or re-consignment of cargo" after a shipment has been dispatched.

The acknowledgment of good practice within companies is a recognised part of modern business. With the International Organization for Standardization (ISO) promoting worldwide proprietary, industrial and commercial standards they have generated a number of world-class specifications for products, services and systems, to ensure quality, safety and efficiency. These standards are instrumental in facilitating international trade.

An example of these standards is ISO 9001. This is a certified quality management system (QMS) for organisations that want to prove their ability to consistently provide products and services that meet the needs of their customers and other relevant stakeholders. In addition, ISO 27000 represents a family of standards that are there to help organisations keep their information assets (such as financial information, intellectual property, employee details or information entrusted to them by third parties) secure.

When reviewing the existing literature it was found that there was no criterion to be found, amongst the papers looking at modal choice, which represented the ISO certifications held by a carrier company. The absence of a criterion covering this represents a gap in the study of modal choice. With this in mind certification is included in this model.

The model produced by Gursoy in his 2010 paper includes "shipping safety" as a criterion that is "assumed to be effective in the shipping mode choices of shippers". However this criterion is not commonly found amongst the multitudes of other papers covering modal choice. This lack of mention of a mode or company's safety record in many models represents a gap in the study of modal choice. With this in mind safety record is included in this model.

Having had discussions with a number of operators in the freight industry this research has found that shippers have a biased image in their mind of what a given mode has to offer. It is hoped that this has been addressed by the work done by the University of Westminster to analyse the strengths and weaknesses of the road, rail and water modes of transportation (Department for Transport, 2010). Their results led to the production of a modal strengths and weaknesses table that is found in Table 2.1 of this work.

The concerns of the freight operators that were spoken to, in combination with the efforts of the University of Westminster, have identified the image of a mode as being relevant to the modal choice decision making process. Because of this established link a criterion has been included in this model to reflect the individual image of each mode.

5.3.3.4 Shipper Criteria (D)

The sub criteria selected to make up the Shipper criterion, a brief definition and some of the reasoning behind the selection of each of these criteria are as follows:

- D1. Market Considerations – What is going on in the shippers chosen market? The market factors that influence the decision maker from outside the shipper's organisation.

- D2. Location – The position of the shipper with regards to freight transport infrastructure and the level of access that this offers to each mode.

D3. Relationships – The condition of existing relationships that the shipper has with its existing (but also potential) suppliers, carrier companies, and customers.

D4. Previous Experience – The shipper's level of satisfaction with the outcome of previous cargo shipments.

D5. Company Policy – The company policies that influence the decision maker internally within the shipper's organisation.

D6. Cargo Characteristics – The nature of the cargo being transported. Is it hazardous, perishable, out of gauge, or likely to contaminate other cargoes?

D7. Inventory – The inventory levels held by the shipper. Is the shippers supply chain push or pull focused?

In the past, there have been a number of factors that have been considered in modal choice studies that could be grouped under the heading of market factors. These are those that influence people within an organisation from outside without them necessarily knowing. Those that have been studied, include: financial stability (Menon *et al.*, 1998), global container rates (Bird, 1988), market attributes (Gray, 1982), lack of investment (Department for Transport, 2010) and market considerations (Mangan *et al.*, 2001). To capture the variety of issues that exist in this area this model includes a criterion entitled 'Market Considerations'.

It is all well and good to suggest that more sustainable transport modes should be used more frequently but the issue that often prevents this is the availability of the necessary infrastructure. This could include: seaports, airports, railways, railway freight yards and in some cases even roads. If the necessary transport infrastructure is unavailable then access to that transport mode is blocked. Cullinane and Toy (2000) found that "infrastructure availability" was increasingly playing a more significant role in modal choice. This idea was reinforced in by Garcia-Menendez and Feo-Valero (2009) when they found that "the degree of accessibility to port infrastructure is also a modal choice determinant". The approach used in this model is to consider the position of the shipper with regards to freight transport infrastructure and the subsequent level of access that this offers to each mode. This criterion was then referred to as 'Location'

The existence of a good working relationship between the shipper and the carrier is an obvious dimension to take in to account when considering modal choice. Previous work (Matear and Gray, 1993) has suggested that a good relationship may come as a result of the carrier operating a schedule that is currently convenient to the shipper or as a result of the shipper having a sense of loyalty to the carrier due to previous shipments that the carrier has successfully handled.

In this work the approach is taken that the existing relationship and the previous experiences that the shipper and carrier have shared from previous shipments should be considered separately. This will allow it to be determined which plays a more significant role. As a result, in this model there is a 'Relationships' criterion as well as a 'Previous Experience' criterion.

Previous research into modal choice (McGinnis, 1979) found that Company Policy has a limited impact upon the decision making process. However, when considering the issue with a rational mind it is difficult to accept the idea that modern companies are selecting transport modes in a completely unrestricted manner. The transport policy of a company will unavoidably influence how that company moves its freight. Having accepted this, Company Policy has been included as a criterion in this model.

The characteristics of the goods that make up a shipment will in some regards play a role in determining the most likely mode of transport for the shipment. This was the position held by Cullinane and Toy (2000). It is intuitive that if a cargo is composed of a valuable commodity, a perishable product, a large sized object or if it is particularly dense or even if it is a liquid then these characteristics will play to the established strengths and weaknesses of the established modes of transport. With this in mind, Cargo Characteristics is a criterion that will be used in this work.

Historically, inventory levels have received a significant amount of consideration with regards to their influence upon transport selection (Meyer *et al.*, 1959; Ballou and DeHayes, 1967). The levels of freight transportation are widely recognised as being determined by demand (McGinnis, 1979). Greater levels of demand will require the existence of a more frequent transport service and this will influence a company's decision making. The long established acceptance of Inventory as a criterion that plays a role in modal choice has led to it being included in this model.

5.3.4 Construct a pairwise comparison questionnaire for gathering data (*Step 4*)

Due to the lack of publicly available data it was necessary to ascertain the weights of each criterion through expert opinion gathered from industry. The framework previously devised (Fig. 5.3) was the starting point for this work. A pairwise comparison questionnaire was constructed to populate this framework with weights (Appendix Eleven).

5.3.5 Gather completed pairwise comparison questionnaires (*Step 5*)

Experts with sufficient experience and qualifications were selected from the fields of logistics, manufacturing, and infrastructure management and they agreed to co-operate based upon the work not revealing their identities. This work adopts an approach of quality over quantity whereby the knowledge of a select few experts is considered to out weight that of a wider pool of non-experts. A brief profile of each of these expert is as follows:

A – An executive consultant with over thirty seven years' experience in the manufacturing industry. The last 10 years of this were spent as the Technical Director of an SME. Although they have a range of industrial qualifications this expert does not hold a degree.

B – The owner operator of a European road freight transportation SME with over twenty six years' experience in the road freight transportation industry. Although they have a range of industrial qualifications this expert does not hold a degree.

C – A site manager with a BSc degree and over fourteen years' experience in overseeing operations on a two hundred acre retail, leisure and business complex along with its supporting transport infrastructure.

D – A mid-level manager with a BSc degree and over twelve years' experience in the maritime industry. This experience is predominantly within the international container trade and includes time served as a ship's officer.

E – A consultant with a BSc degree and over eleven years' experience in the development of both national and international freight transportation strategies with a focus on the integration of airports in to the surrounding regional transport infrastructure.

For the purpose of this work the opinions of each of the experts are being considered to carry the same weight. In effect this means that none of them are considered to be of more importance or have more deep a level of insight in to the issue in question than any of the others.

The opinions of these experts were fed through the pairwise comparison methodology. Pairwise comparison is particularly useful due to its simplicity, intuitive nature and the ease with which it can be understood by experts.

5.3.6 Utilise the collected data to establish criteria weights (*Step 6*)

Once the data had been collected it was used to determine the weights of the identified criteria and sub-criteria in the framework (Fig. 5.3) to model the modal choice process. This was done by utilising the AHP methodology.

Pairwise comparison involves one-on-one comparisons being performed between each of the criteria in the model and each of the sub-criteria within a criteria group. This analysis employs the subjective judgements of experts in the field on the relative importance of each pair.

The results provided by the pair-wise comparison method are then analysed to reveal the consistency or the reliability of the responses obtained from experts. The scores generated indicate when there is an unacceptable level of inconsistency within the responses and also highlights where the inconsistency may originate from. This ensures that the indicators are transparent and allows decision makers to have a sound understanding of them. Such an analysis will aid policy makers in targeting their efforts towards areas that will have a greater impact upon the end result.

The Analytic Hierarchy Process (AHP) procedure used for calculating the weights of the criteria and sub-criteria can be realized as outlined in Kunz, 2010. To follow this approach Step 6 contains four stages (a to d). In more detail this four stage process consists of:

a) Developing pair-wise comparison matrices for both the criteria and sub-criteria within each criteria group.
b) Multiplying the values of the indicators' pairs in each row of the matrix in order to estimate the n^{th} root.

c) Normalizing the n^{th} root of the pairwise comparison outputs to obtain the weights of the indicators.
d) Calculating and validating the consistency ratio (CR).

These four stages were performed as follows using the pairwise comparison data provided through the completed questionnaires recording the expert opinion of representatives of the freight transport industry:

5.3.6.1 Developing pair-wise comparison matrices for both the criteria and sub-criteria within each criteria group (Stage a)

The computation process relies on the responses given in the "Pairwise Comparison of Criteria" section of the survey questionnaire (Appendix Eleven). Within this context the eigenvalue-method of AHP was employed and is shown in the 4x4 matrix of Table 5.1. The initials A, B, C and D were used to represent the criteria. These are the Service, Route, Carrier, and Shipper criteria respectively.

Table 5.1: 4x4 matrix showing the pairwise comparison results of the main criteria.

	A	B	C	D
A	1.000	5.750	4.500	4.000
B	0.174	1.000	0.458	0.396
C	0.222	2.183	1.000	1.125
D	0.250	2.525	0.889	1.000

5.3.6.2 *Multiply the value of each row and calculate the N^{th} root of each criterion (Stage b)*

To calculate the N^{th} root in this 4x4 matrix it is necessary to compute the 4^{th} root of the pair-wise comparison output in each row of the matrix.

An example is given below:

$$A = \left((1.000 \times 5.750 \times 4.500 \times 4.000)^{\frac{1}{4}}\right) = 3.190$$

The 4^{th} roots of every criterion must be individually calculated in a similar manner. The results for these are shown in Table 5.2 along with the total aggregated result of the 4^{th} roots, which was 5.336.

Table 5.2: The N^{th} root of each criterion and the aggregated result of the 4^{th} roots

	A	B	C	D	N^{th} Root of Criteria
A	1.000	5.750	4.500	4.000	3.190
B	0.174	1.000	0.458	0.396	0.421
C	0.222	2.183	1.000	1.125	0.859
D	0.250	2.525	0.889	1.000	0.865
SUM					5.336

5.3.6.3 *Normalise the N^{th} roots of the weights obtained for each criterion (Stage c)*

To normalise the weight of each criterion their N^{th} root should be divided by the aggregated total of N^{th} roots. In the case of criterion A this is calculated as follows:

$$\frac{3.190}{5.336} = 0.598$$

The normalised weight for criterion A is 0.598. This same process is followed for each of the other criteria. The results of this have been presented in Table 5.3.

Table 5.3: Priority Weight (PW) of each criterion and aggregated result of the 4^{th} roots

	A	B	C	D	N^{th} Root of Criteria	Priority Weight (PW)
A	1.000	5.750	4.500	4.000	3.190	0.598
B	0.174	1.000	0.458	0.396	0.421	0.079
C	0.222	2.183	1.000	1.125	0.859	0.161
D	0.250	2.525	0.889	1.000	0.865	0.162
SUM					5.336	

5.3.6.4 Calculate and validate the Consistency Ratio (Stage d)

The Consistency Ratio (CR) demonstrates how consistent the responses have been throughout the process of making pair-wise comparisons.

To determine the CR for this data set the first step is to find the total for each column in the 4x4 matrix. For criterion A this is done as follows:

$$\text{SUM} = (\ 1.000 + 0.174 + 0.222 + 0.250\ ) = 1.646$$

This SUM value is then multiplied by the respective Priority Weight (PW) value for that criterion to give the SUM x PW. For criterion A this is done as follows:

$$\text{SUM x PW} = 1.646 \text{ x } 0.598 = 0.961$$

This process is repeated for each of the criteria and the result is shown in Table 5.4.

Table 5.4: The SUM x PW value for each criterion

	A	B	C	D	N^{th} Root of Criteria	Priority Weight (PW)
A	1.000	5.750	4.500	4.000	3.190	0.598
B	0.174	1.000	0.458	0.396	0.421	0.079
C	0.222	2.183	1.000	1.125	0.859	0.161
D	0.250	2.525	0.889	1.000	0.865	0.162
SUM	1.646	11.458	6.847	6.521	5.336	
SUM x PW	0.984	0.905	1.103	1.058		

Having established the SUM x PW values the next step is to determine the λ_{max} value. λ_{max} is the sum of the overall (SUM × PW) as is demonstrated below:

$$\lambda_{max} = 0.984 + 0.905 + 1.103 + 1.058$$

$$\lambda_{max} = 4.050$$

Having found the λ_{max} value it is now necessary to calculate the Consistency Index (CI). This is done by using the following equation:

$$\text{CI} = \frac{(\lambda_{max} - n)}{(n - 1)}$$

In this case *n* is the number of criteria being compared. This equation can be used to find the CI for the current data set as follows:

$$\text{CI} = \frac{(\,4.050\ -\ 4\,)}{(\,4-1\,)}$$

$$\text{CI} = 0.017$$

Having found the CI the next step is to calculate the Consistency Ratio (CR). The Consistency Ratio (CR) is found by dividing the Consistency Index (CI) by the Random Index (RI):

$$\text{CR} = \frac{\text{CI}}{\text{RI}}$$

The random index (RI) is determined from a lookup table (Table 5.5) and is a direct function of the number of criteria being considered.

Table 5.5: Value of RI versus Matrix Order (Saaty, 1990)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

With the current matrix being composed of four criteria the RI value of interest is 0.9. Using this, the CR is calculated as follows:

$$\text{CR} = \frac{0.017}{0.9}$$

$$\text{CR} = 0.019$$

The CR value of 0.019 is well within the usually acceptable level of between 0 and 0.1 (Kauko, 2002). This means that the pair-wise comparisons performed by the experts provided a valid set of consistent responses. Having carried out AHP methodology for the Criteria portion of the model the same procedure was followed for each of the sub-criteria groups.

5.3.6.5 Converting local weights to global weights

When finding the weights of each of the sub-criteria within the model it is first necessary to calculate the local weight of each of the sub-criteria within its own criteria group. Once this has been established it is then possible to calculate the global weight of each of the sub-criteria within the overall model. This is done by multiplying the local weight of the sub criteria by the weight of its parent criteria group.

An example of this can be found in the calculation of the global weight of the Administration sub-criteria. With a local weight within its criteria group (the Service criteria) of 0.032 and a weight for the Service criteria of 0.598 the weight for Administration can be found as follows:

$$0.032 \text{ x } 0.598 = 0.019$$

5.4 Results

Through the collection of qualitative data from logistics industry experts and the subsequent processing of this data through the Analytic Hierarchy Process the results of the case study are represented in Table 5.6, Table 5.7, Table 5.8 and Fig. 5.4.

Table. 5.6: Consistency Ratio (CR) values of pairwise comparisons of sub-criteria

SUB-CRITERIA	CONSISTENCY RATIO (CR) VALUE
SERVICE (A1, A2, A3, A4, A5, A6)	0.102
ROUTE (B1, B2, B3, B4, B5, B6)	0.085
CARRIER (C1 C2, C3, C4, C5, C6, C7)	0.103
SHIPPER (D1, D2, D3, D4, D5, D6, D7)	0.091

Table 5.7: Consistency Ratio (CR) value of pairwise comparisons of criteria

CRITERIA	CONSISTENCY RATIO (CR) VALUE
SERVICE, ROUTE, CARRIER, SHIPPER (A, B, C, D)	0.019

Table 5.8: Sub-criteria weights in the decision making process

RANK	SUB-CRITERIA	GLOBAL WEIGHT	GLOBAL WEIGHT (%)
1	DELAYS	0.215	21.5%
2	COST	0.200	20.0%
3	TRACEABILITY	0.071	7.1%
4	DAMAGE/LOSS	0.070	7.0%
5	CONTROLLABILITY	0.053	5.3%
6	LOCATION	0.041	4.1%
7	FLEXIBILITY	0.040	4.0%
8	FREQUENCY	0.032	3.2%
9	TRANSIT TIME	0.031	3.1%
10	CARGO CHARACTERISTICS	0.030	3.0%
11	PREVIOUS EXPERIENCE	0.026	2.6%
12	VALUE ADDED SERVICES	0.025	2.5%
13	COMPANY POLICY	0.024	2.4%
14	SAFETY RECORD	0.022	2.2%
15	CERTIFICATION	0.019	1.9%
16	ADMINISTRATION	0.019	1.9%
17	INVENTORY	0.014	1.4%
18	MARKET CONSIDERATIONS	0.013	1.3%
19	RELATIONSHIPS	0.012	1.2%
20	CLAIMS PROCESSING	0.011	1.1%
21	CAPABILITY	0.008	0.8%
22	FINANCES	0.008	0.8%
23	SECURITY	0.005	0.5%
24	IMAGE OF MODE	0.004	0.4%
25	EXTERNAL IMPACTS	0.003	0.3%
26	DISTANCE	0.002	0.2%

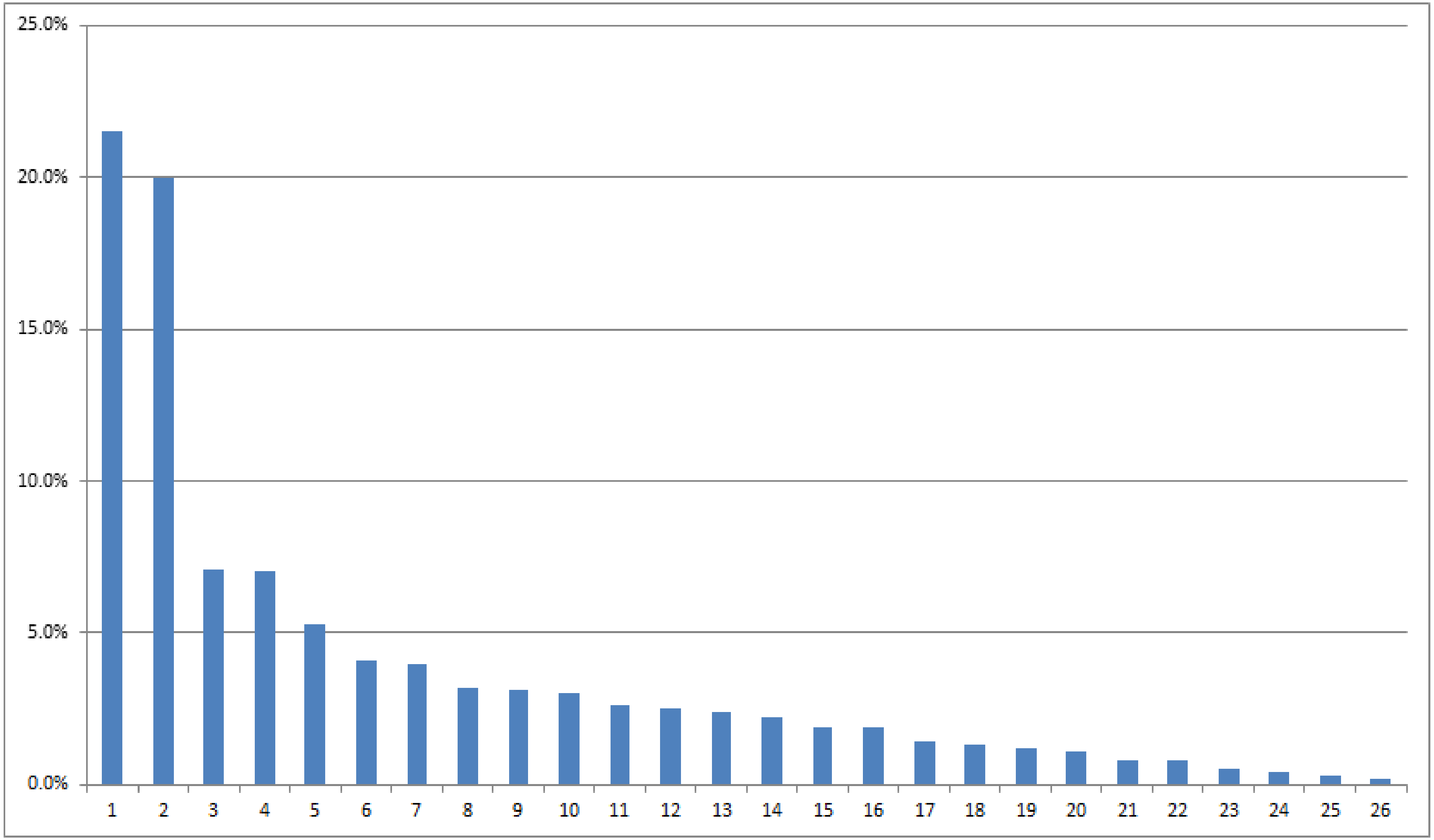


Fig. 5.4: Sub-criteria weights in the decision making process

5.5 Discussion

It has been stated (Kauko, 2002) that a CR value of up to and including 0.1 is a usually acceptable level. As can be seen in Tables 5.6 and 5.7 the results generated by this work have produced some CR values (Service, 0.102; Carrier, 0.103) that slightly exceed this value. However, given the varying backgrounds of the experts, the large number of criterion under consideration and the small margin by which the acceptable level has been exceeded these results can still be considered to be acceptable. This means that the pair-wise comparisons performed by the experts provided a valid set of consistent responses. With this confirmed it can be considered that the experts involved in this work have produced a reliable data set that can be used to discuss the modal choice decision making process.

The finding in this chapter that the top two criteria (Delays and Cost) dominate the others suggests that it would be prudent for any future modal share policies devised by the EU to have as a centre piece elements aimed at utilising these two criteria to influence the decision maker. However, to get a broader picture it is worth considering in turn the top nine criteria by weight and then the top four criteria by weight.

5.5.1 The top nine criteria by weight

The following criteria represent the top nine in terms of weight in the decision making process:

1) Delays - The punctual arrival of shipments at their destination.
2) Cost - The total cost of moving a shipment from its origin to its destination.
3) Traceability - The real time tracking of cargo after it has been dispatched.
4) Damage/Loss - The carrier's history of shipment loss and damage.
5) Controllability - The ability to control a shipment after it has been dispatched
6) Location - The position of the shipper with regards to freight transport infrastructure and the level of access that this offers to each mode.
7) Flexibility - The ability of the carrier to accommodate the varying requirements imposed upon them by customers.
8) Frequency - The number of journeys carried out by a transport mode between a shipment's origin and destination over a given period of time (hour, day, week, month)
9) Transit time - The time taken to move a shipment from its origin to its destination.

These top nine criteria most heavily weighted criteria were found to constitute 75.3% of the total weight in the decision making process. A broader range of approaches to addressing the issue of modal share could be spread across these criteria as a whole. A combination of these factors could be utilised to try and make the less popular modes more acceptable alternatives within the logistics industry.

5.5.2 The top four criteria by weight

Perhaps the most efficient way of influencing the modal choice decision making process would be to take the top four criteria (Delays, Cost, Traceability, Damage/Loss). These provide 55.6% of the weight within the decision making process. With this representing over half of the weight in the decision, any mode that performs well when measured against these criteria would most likely be selected over other less favourable modes.

5.5.3 Implications of the top four criteria by weight

The top four criteria by weight demonstrate that the key questions being asked when a freight shipment based modal choice decision is being made are:

- Will the shipment arrive punctually at its destination?
- How much will it cost (in total) to move the shipment from its origin to its destination?
- Can the shipment's progress towards its destination be accurately monitored?
- Will the shipment arrive at its destination in good condition?

This information could be used to help improve a particular mode's share of the market. If key players within a mode of transport (road, rail or water) came together they could put agreements in place that could benefit their entire market sector. By focusing their efforts on building a reputation based on their mode's ability to deliver shipments on time, undamaged and at a cheap cost then they would no doubt improve their overall modal share.

However, the current economic conditions and the short timeframe that has been allocated to bring about a change in modal share may prevent alternative modes from being able to develop such a reputation in a timely fashion. If this is the case then a possible alternative could be for government policies to be put in place which make a given mode better able to deliver a service which is more punctual, less subject to losses and at the same time more competitively priced.

5.5.4 Shortcomings of the model

A criticism of this research could be that if different experts were selected to participate in the pairwise comparison process then there may be a significant difference in the results that were finally established. An indication that this may not be the case is provided by the top two criteria by weight. Delays and Cost were found to be the top two criteria by weight representing 41.5% of the total weight within the decision making process. Feedback on this result was sought from alternative experts in the logistics industry to see whether the suggested dominance of these criteria was unrealistic. Through discussions of the data they suggested that the dominance of a small number of criteria was representative of the real world. Industry representatives felt that although there could be significant variation amongst the less important criteria, the top nine should be less affected. Further discussion identified that this would have no impact upon the development of a reduced model in the next stage of this work.

5.6 Conclusion

This chapter shows that the top two criteria (Delays and Cost) dominate the modal choice decision making process. However, it is unwise to oversimplify what amounts to a complex real world problem. It is important to identify the criteria that are critical to the decision making process but joined up thinking is required to find a solution which will avoid the necessity to revisit the issues of transport infrastructure congestion and transport related pollution time and again in the future.

Within the model developed in this chapter the top nine criteria by weight represent a strong majority within the twenty-six identified criteria. This majority is where effort is to be applied to bring change in the way that the modern transport network is used. By identifying the criteria of most importance to the modal choice decision making process this chapter has prepared the foundation for the subsequent chapter to build upon.

The primary aim of the next chapter is to develop a model of the modal choice decision making process that is more accessible to industry. This model will be built upon a reduced selection of the criteria used in this chapter. This simplification of the model is necessary to ensure that it is accessible and easy to understand. In Chapter Six particular attention will be given to the top nine criteria by developing a reduced framework to model the modal choice decision making process.

Chapter Six

A subjective two step AHP and TOPSIS methodology for assessing the modal choice decision making process

6.1 Introduction

As has been established in the previous chapters of this work the analysis of the modal choice decision making process is limited by inadequate data. As a result there is the need to develop a decision making methodolgy to address this problem. The first step of this process was taken in Chapter Five where data was gathered through experts in the field of logistics to allocate weights to criteria in a model of the decision making process.

The next step in the process is taken in this chapter where a combination of AHP and TOPSIS is to be used. AHP was covered in some detail in both Chapter Three and Five. Within Chapter Six, AHP is once again utilised to ascertain the weights that are attached to a range of criteria within a model. However, to keep this work accessible to key stakeholders in the freight industry the model used in this chapter is a simplified version of the one that was developed in Chapter Five.

Having established a simplified model for further analysis to focus on, TOPSIS is then applied to allow the available transport alternatives to be ranked. The results gathered through the combined application of AHP and TOPSIS will paint a clear picture of the transport priorities of industry. This information can then be used to point the direction for the relevant authorities and key stakeholders in the freight industry to better promote modal shift.

6.2 Methodology

Both AHP and TOPSIS follow clearly established procedures (Saaty, 1980; Hwang and Yoon, 1981). These procedures were integrated into this work to allow AHP to allocate weights to each of the criteria and sub-criteria before TOPSIS goes on to utilise these weights to rank the alternative modes of transportation of relevance to the modern day movement of unitised freight. The steps followed to apply the combination of AHP and TOPSIS to this problem are as follows:

6.2.1 Part A - Applying AHP to the modal choice decision making process

As was seen in Chapter Five, AHP follows a clearly established procedure to allocate weights to criteria that are placed within a hierarchical model. The steps that were used to apply AHP to the reduced model of the modal choice deicsion making process that is found in the chapter were as follows:

6.2.1.1 Identify a short list of criteria that influence the modal choice decision making process (Step 1)

The work that is carried out in this chapter leads on from the results provided from the work that was undertaken in the previous chapter. Chapter Five concluded that, within the model that it developed, the top nine criteria by weight represented the majority of the weight (75%) in the modal choice decision making process.

It was decided that these nine criteria were where more effort should be applied to bring change in the way that the modern transport network is used. With this in mind these nine criteria are used in this first step as the shortlist of criteria that influence the modal choice decision making process within the geographical area of the United Kingdom.

6.2.1.2 Construct a reduced modal choice decision making framework (Step 2)

Identifying the criteria that are of interest to this particular decision making exercise will allow a general hierarchical model to be constructed. This model will be used to represent the decision making process for the transportation mode carriage selection of freight cargo in the geographical area of the United Kingdom.

As was the case in Fig. 5.3 the hierarchical structure is again to be divided into three levels. These are: Goal, Criteria, and Sub-Criteria. The Goal in this work is to study the modal choice decision making process between road, rail and water. The criteria are the titles that are allocated to describe the similar sub-criteria grouped beneath them. The sub-criteria are the nine criteria that were identified in Chapter Five as representing 75% of the weight in the modal choice decision making process.

6.2.1.3 Construct a pairwise comparison questionnaire for gathering data (Step 3)

As was stated in Chapter Five the key to understanding how a modal choice decision is made is determining the relative importance of the factors that are associated with the decision making process (D'Este and Meyrick, 1992). This can be done theoretically (Dial, 1979; Gursoy, 2010) or based on empirical evidence (Garcia-Menendez and Feo-Valero, 2009). The pairwise comparison process serves to generate empirical data where there is currently a lack.

6.2.1.4 Conduct pairwise comparisons (Step 4)

Pairwise comparison data is gathered through the completion of pairwise comparison questionnaires by experts from relevant sectors of industry. An example of how pairwise comparison values are found was provided in section 5.2.5 of this work.

6.2.1.5 Utilise the collected data to establish criteria weights (Step 5)

As was established in Chapter Five the process to follow to achieve this is:

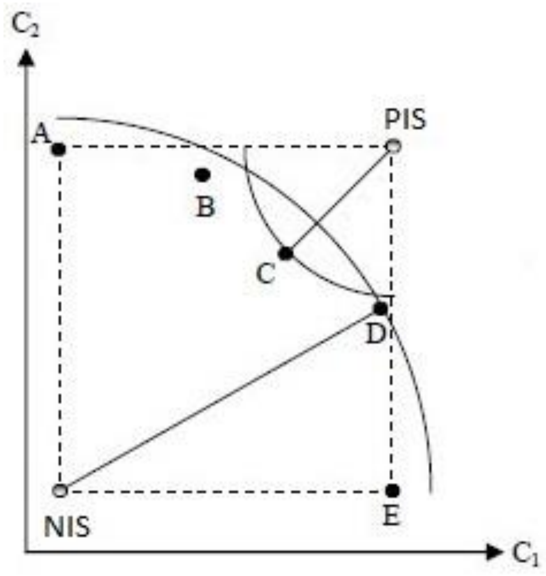
a) Develop pair-wise comparison matrices for both the criteria and sub-criteria within each criteria group.
b) Multiply the value of each row and calculate the n^{th} root of each criterion.
c) Normalise the n^{th} roots of the weights obtained for each criterion.
d) Calculate and validate the Consistency Ratio (CR).

6.2.2 Part B - Utilizing TOPSIS to obtain performance ratings for decision alternatives

The Technique for Order Preference by Similarity to Ideal Solutions (TOPSIS) is known as an ideal point Multi-Criteria Decision Analysis method. The basic concept behind TOPSIS is that the optimal alternative should, in a geometrical sense, have the shortest distance from the positive ideal solution (PIS) and the furthest distance from the negative ideal solution (NIS).

The PIS and NIS are artificial constructs. They are alternatives based on the best possible solution (PIS) and worst possible solution (NIS) to the question being considered. These solutions represent the combination of the 'best' results across all criteria (PIS) and the combination of the 'worst' results across all criteria (NIS). The PIS is composed of the most superior decision variables whereas the NIS is composed of the most inferior decision variables.

TOPSIS assumes that every criterion has the tendency to either a monotonically increasing or monotonically decreasing scale. This assumption makes it easier to define the PIS and the NIS. TOPSIS ranks alternatives by calculating and then comparing the Euclidean distance of each alternative to the PIS and NIS. This process is represented in Fig. 6.1 (Hodgett, 2014) where there are two criteria (C1 and C2) and five alternatives (A, B, C, D and E). In this case alternative C is the closest to the positive ideal solution whereas alternative D is the furthest from the negative ideal solution:



Source: Redrawn from Hodgett, R. (2014)

Fig. 6.1: Ranking alternatives through their Euclidean distance to the PIS and NIS

6.2.2.1 Identify the decision making alternatives (Step 1)

The main modes of transport that are used to carry freight in the modern logistics industry are road, rail, water and air. The maritime transportation of intermodal containers makes up a major part of the network. However, the carriage of containers by road and rail also plays a significant role.

Air transport is a different matter. Some of today's larger aircraft, such as the Antonov AN124 and the Boeing C-17 Globemaster III, could accommodate standard intermodal containers but this trade is currently very small. In addition, airborne cargo carriage systems tend to be specialist in nature, making use of the most lightweight materials acceptable. This makes the carriage of standard intermodal containers by air the exception rather than the rule.

This case study is focused on the transportation of standard intermodal shipping containers within the geographical area of North West England's Atlantic Gateway . As a result, only the modes of most significance to this particular portion of the logistics industry are to be considered. With this being the case road, rail and water have been included as decision making alternatives whereas air has not been included.

6.2.2.2 Identify the criteria that will be used to assess the alternatives (Step 2)

The work that is carried out in this section leads on from the results that came from both the work undertaken in Chapter Five and also the earlier part of this chapter. It is necessary to maintain a coherent approach to the analysis of the modal choice decision making process. With this in mind, the same criteria that are to be used in Part A to apply AHP to a reduced model of the modal choice decision making process are also to be used to determine the performance ratings of the selecetd decision alternatives.

6.2.2.3 Construct a TOPSIS questionnaire for gathering data (Step 3)

Due to the lack of publicly available data it is necessary to determine the ranks of the selected alternatives through the collection of qualitative data from expert opinion. These expert opinions are to be sought from members of industry with relevant experience and qualifications. To capture this data a questionnaire is to be produced.

6.2.2.4 Conduct TOPSIS questionnaire (Step 4)

It is necessary for suitable data to be gathered for TOPSIS to analyse. This data is to be collected through the completion of the questionnaire that was constructed in *Step 3* to capture the opinions of experts from the transport related sectors of industry. To contact suitable experts similar avenues will be taken to those that were used in Chapter Five and section 6.2.1.4 of this chapter.

6.2.2.5 Utilise the collected data to establish the ranking of alternatives (Step 5)

The established process to follow to achieve this is:

a) Establish a decision matrix
b) Calculate the normalized decision matrix
c) Calculate the weighted normalized decision matrix
d) Determine the Positive Ideal Solution (PIS) and the Negative Ideal Solution (NIS)

e) Calculate the separation distance of each alternative to the PIS and NIS
f) Calculate the relative closeness to the ideal solution
g) Rank the priority order of the available alternatives

6.3 Case Study - Determining the ranking order of alternative transport modes for freight

The generic model developed in this case study utilises the subjective knowledge and judgement of experts in the field to provide data for analysis through a combination of AHP and TOPSIS. The method that was adopted to deliver this combined approach is broken down into two parts. These are:

- Part A - Applying AHP to the modal choice decision making process

- Part B - Utilizing TOPSIS to obtain performance ratings for decision alternatives

Part A is composed of five steps that result in weights being allocated to each of the criteria and sub-criteria that make up the framework that was developed to represent the modal choice decision making process. In comparison, Part B is composed of five steps that utilise the weights calculated in Part A to determine the rankings of three modes of transport. These modes were selected to represent those most commonly used to carry unitised freight in the vicinity of the United Kingdom.

6.3.1 Part A - Applying AHP to the modal choice decision making process

AHP was applied to the reduced model of the modal choice decision making process that is found in this chapter through the following steps:

6.3.1.1 Identify a shortlist of criteria that influence the modal choice decision making process (Step 1)

By identifying the criteria of most importance to the modal choice decision making process Chapter Five provided the shortlist of criteria that would be used to construct a model of the modal choice decision making process in this chapter. The criteria that will be used, in this chapter are those which were identified in Chapter Five as representing the top nine criteria by weight. These criteria represent 75% of the total weight in the decision making process.

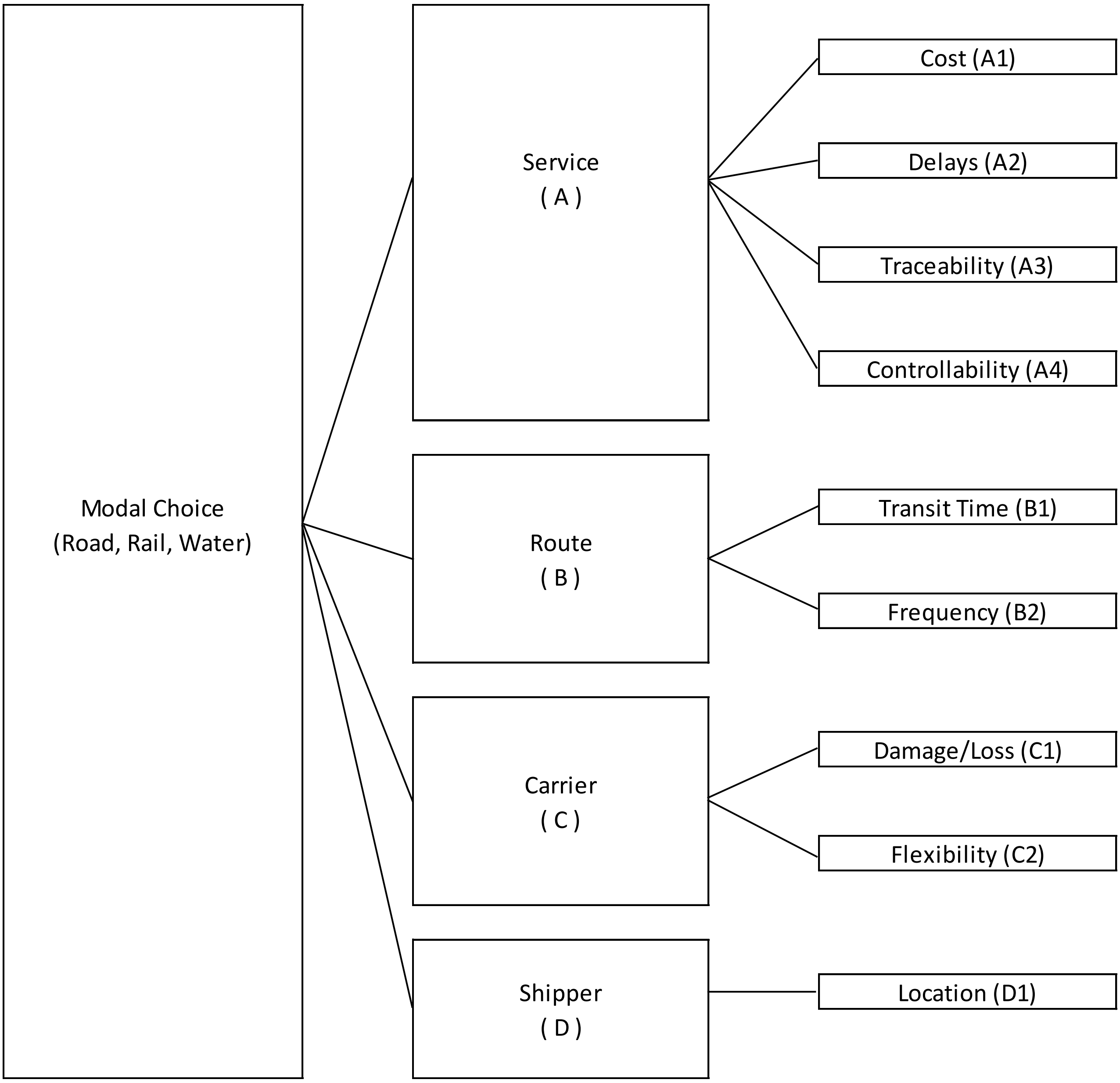


Fig. 6.2: Reduced framework for modelling the modal choice decision making process

6.3.1.2 Construct a reduced modal choice decision making framework (Step 2)

The reduced framework of the modal choice decision making process that was constructed for this chapter (Fig. 6.2) is based on the same model that was utilised in Chapter Five. There are many similarities between the two, for example the goal is the same and the criteria are the same. However, the key difference is that rather than having the original selection of twenty-six sub-criteria there are only nine sub-criteria. This reduction in the number of sub-criteria is significant but those that remain still carry the same definitions that they did in the previous framework.

6.3.1.3 Construct a pairwise comparison questionnaire for gathering data (Step 3)

The lack of publicly available data that was identified in Chapter Five is also an issue here. As a result it was once again necessary to pursue a qualitative approach rather than a quantitative one. The weights of each of the criteria and sub-criteria would have to be found through expert opinion gathered from industry. The framework devised in *Step 2* was the starting point for this and a pairwise comparison questionnaire was constructed to populate this framework with weights. The detailed pair-wise comparison questionnaire that was used in this work can be found in Appendix Twelve.

6.3.1.4 Conduct pairwise comparisons (Step 4)

The same experts that were used in Chapter Five were used again in this chapter. These experts were selected based upon the extensive experience and qualifications that they possess in the fields of logistics, manufacturing, and infrastructure management. Once again they agreed to co-operate based upon this work not revealing their identities. To recap, the profiles of each of these experts are as follows:

A – An executive consultant with over thirty seven years' experience in the manufacturing industry. The last 10 years of this were spent as the Technical Director of an SME. Although they have a range of industrial qualifications this expert does not hold a degree.

B – The owner operator of a European road freight transportation SME with over twenty six years' experience in the road freight transportation industry. Although they have a range of industrial qualifications this expert does not hold a degree.

C – A site manager with a BSc degree and over fourteen years' experience in overseeing operations on a two hundred acre retail, leisure and business complex along with its supporting transport infrastructure.

D – A mid-level manager with a BSc degree and over twelve years' experience in the maritime industry. This experience is predominantly within the international container trade and includes time served as a ship's officer.

E – A consultant with a BSc degree and over eleven years' experience in the development of both national and international freight transportation strategies with a focus on UAV applications.

In the same way that was done in Chapter Five the opinions of each of these experts were considered to carry the same weight. The responses received from the experts were fed through the pairwise comparison methodology.

Over a year had passed between the experts completing the questionnaire for Chapter Five and this questionnaire. This elapsed period of time was used to check the consistency of the responses offered by the experts. With so much time having passed since the last questionnaire it was unlikely that the experts would still remember the answers that they had given previously. Therefore, if their responses are consistent with those received in Chapter Five it will add to their validity. However, any substantial differences between the criteria weights calculated in Chapter Five and those calculated here will need to be identified and addressed.

6.3.1.5 Utilise the collected data to establish criteria weights (Step 5)

As was established in Chapter Five the process to follow to achieve this is:

a) Develop pair-wise comparison matrices for both the criteria and sub-criteria within each criteria group.
b) Multiply the value of each row and calculate the n^{th} root of each criterion.
c) Normalise the n^{th} roots of the weights obtained for each criterion.
d) Calculate and validate the Consistency Ratio (CR).

A detailed break down of the calculations that are carried out at each of these stages to find the weights of each of the criteria and sub-criteria is offered in section 5.3.6 of Chapter Five. The same procedure was followed in this chapter and the results of these calculations can be found in section 6.4 of this work.

6.3.2 Part B - Utilizing TOPSIS to obtain performance ratings for decision alternatives

TOPSIS was applied to the reduced model of the modal choice deicsion making process that is found in this chapter through the following steps:

6.3.2.1 Identify the decision making alternatives (Step 1)

The modes of freight transportation that have been selected as alternatives to be included in this model are:

- Road
- Rail

- Water

These modes have been chosen as they are reflective of the outputs of Chapter Four and they carry the most freight by volume in this geographical area. In particular they were chosen because they also play a significant role in the transportation of intermodal shipping containers.

Air transport was not included as an alternative in this model. This was due to the amount of freight carried by this mode being very small when compared to that carried by road, rail and water. In addition, air has a relatively insignificant role to play in the transportation of intermodal shipping containers as it prefers to use its own range of light weight unitised cargo handling equipment that is more suitable to the nature of that kind of transport.

6.3.2.2 Identify the criteria that will be used to assess the alternatives (Step 2)

Chapter Five found that the top nine criteria by weight in the model that it developed represented the majority of the weight (75%) in the modal choice decision making process. With this in mind these same nine criteria were used to build the reduced model that was utilised in section 6.3.1.4. In that section the AHP methodology was applied to determine the weights of each of the criteria in the reduced model. These nine criteria are to be used again in this section to assess, through the application of the TOPSIS methodology, the decision making alternatives that were selected in 6.2.2.1. For the sake of clarity these criteria will be identified again here.

The criteria that will be used in this section to assess the selected alternatives are:

- Delays - The punctual arrival of shipments at their destination.
- Cost - The total cost of moving a shipment from its origin to its destination.
- Traceability - The real time tracking of cargo after it has been dispatched.
- Damage/Loss - The carrier's history of shipment loss and damage.
- Controllability - The ability to control a shipment after it has been dispatched
- Location - The position of the shipper with regards to freight transport infrastructure and the level of access that this offers to each mode.
- Flexibility - The ability of the carrier to accommodate the varying requirements imposed upon them by customers.

- Frequency - The number of journeys carried out by a transport mode between a shipment's origin and destination over a given period of time (hour, day, week, month)
- Transit time - The time taken to move a shipment from its origin to its destination.

6.3.2.3 Construct a TOPSIS questionnaire for gathering data (Step 3)

The lack of publicly available data that was identified as being a concern for earlier parts of this work is also an issue here. As a result it was once again necessary to pursue a qualitative approach rather than a quantitative one. The reduced framework that was constructed in section 6.3.1.1 of this chapter was the starting point for this and a TOPSIS questionnaire was produced to gather data that could be used to establish the ranks of the selected alternatives. The detailed TOPSIS questionnaire that was used in this work can be found in Appendix Thirteen.

6.3.2.4 Conduct the TOPSIS questionnaire (Step 4)

The same experts that were used to gather data for the AHP portion of this chapter and Chapter Five were used again to provide qualitative data for this section. These experts were selected based on their extensive experience and qualifications in the fields of logistics, manufacturing, and infrastructure management.

As was the case on the two previous occasion's in this work where the experts were contacted, they agreed to co-operate based upon their identities not being revealed. The profiles of each of these experts can be found in section 6.3.1.4. The responses received from the experts were fed through the TOPSIS methodology to rank the selected alternatives. Based on the high levels of expertise demonstrated by these experts in their chosen fields the opinions of each of them were considered to carry the same weight.

6.3.2.5 Utilise the collected data to establish the ranking of alternatives (Step 5)

Once the data had been collected it was used to rank the priority order of the selected alternatives. This was done by utilising the TOPSIS methodolgy.

The Technique for Order Preference by Similarity to Ideal Solutions (TOPSIS) is used for ranking the priority order of a number of alternatives. It can be realized as outlined in Chen

(2011). To follow this approach Step 5 contains seven stages (a to g). In more detail this seven stage process consists of:

a) Establish a decision matrix (*Stage a*)
b) Calculate the normalized decision matrix (*Stage b*)
c) Calculate the weighted normalized decision matrix (*Stage c*)
d) Determine the Positive Ideal Solution (PIS) and the Negative Ideal Solution (NIS) (*Stage d*)
e) Calculate the separation distance of each alternative to the PIS and NIS (*Stage e*)
f) Calculate the relative closeness to the ideal solution (*Stage f*)
g) Rank the priority order of the available alternatives (*Stage g*)

These seven stages were performed as follows using the data that was provided through the completed questionnaires recording the expert opinion of representatives of the logistics, manufacturing and infrastructure management sectors.

a) Establish a decision matrix (*Stage a*)

The TOPSIS method utilised in this case study requires a decision matrix to be established to capture the data that was collected through the TOPSIS questionnaire. The formula that demonstrates how this matrix is formed is as follows:

$$D = \begin{bmatrix} x_{11} & x_{12} & x_{13} & \cdots & \cdots & x_{1n} \\ x_{21} & x_{22} & x_{23} & \cdots & \cdots & x_{2n} \\ x_{31} & x_{32} & x_{33} & \cdots & \cdots & x_{3n} \\ \vdots & \vdots & \vdots & \cdots & \cdots & \vdots \\ \vdots & \vdots & \vdots & \cdots & \cdots & \vdots \\ x_{m1} & x_{m2} & x_{m3} & \cdots & \cdots & x_{mn} \end{bmatrix}$$

Within this formula the decision matrix contains *n* alternatives and *m* evaluation criteria. Meanwhile, x_{ij} denotes the performance of the *i*-th alternative in terms of the *j*-th criteria (Triantaphyllou, 2000).

The decision matrix that was constructed to contain the qualitative data that was gathered for the purpose of this case study can be found in Table 6.1.

b) Calculate the normalized decision matrix (*Stage b*)

Normalizing the decision matrix is a key step in TOPSIS. Normalizing means transforming the dimensions of the various criteria into non-dimensional attributes. These non-dimensional attributes allow direct comparisons to be made across the attributes. The formula for normalizing the decision matrix is as follows (Onder and Dag, 2013):

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \; ; \; i = 1, 2, 3, \dots, n. \quad j = 1, 2, 3, \dots, m.$$

The formula was applied to the decision matrix and produced a normalized decision matrix which can be seen in Table 6.2.

c) Calculate the weighted normalized decision matrix (*Stage c*)

The weighted normalized decision matrix is calculated by mulitplying the values found in the normalized decision matrix by the weights generated for each criterion through AHP. This is shown in the following equation (Kumar, 2008):

$$V_{ij} = r_{ij} \times W_j \; ; \; i = 1, 2, 3, \dots, n. \quad j = 1, 2, 3, \dots, m.$$

In this formula V_{ij} is the weighted normalized matrix, r_{ij} is the normalized matrix and W_j is the weight ascertained through AHP for the j^{th} criteria. The formula was applied to normalized decision matrix and the outcome can be seen in Table 6.3.

d) Determine the Positive Ideal Solution (PIS) and the Negative Ideal Solution (NIS) (*Stage d*)

The Positive Ideal Solution, represented by V_{j+}, and the Negative Ideal Solution, represented by V_{j-} , are determined by finding the maximum and the minimum values in each column of the weighted normalized decision matrix (Kumar, 2008). The positive ideal solution (PIS) and the negative ideal solution (NIS) for each criterion can be found in Table 6.4.

Table 6.1: Decision matrix

	-	-	+	-	+	-	+	+	-
	Cost	Delays	Frequency	Transit Time	Traceability	Damage / Loss	Controllabilty	Flexibility	Location
Road	2.930	1.888	4.573	2.551	3.437	1.644	4.317	4.573	1.000
Rail	3.565	1.783	1.644	2.352	2.048	2.766	2.352	2.930	3.104
Water	4.129	2.862	2.702	3.245	2.352	3.520	2.169	3.104	4.573

Table 6.2: Normalised decision matrix

	-	-	+	-	+	-	+	+	-
	Cost	Delays	Frequency	Transit Time	Traceability	Damage / Loss	Controllabilty	Flexibility	Location
Road	0.473	0.489	0.941	0.537	0.741	0.345	0.803	0.731	0.178
Rail	0.576	0.461	0.338	0.495	0.441	0.580	0.438	0.468	0.553
Water	0.667	0.741	0.556	0.683	0.507	0.738	0.404	0.496	0.814

Table 6.3: Weighted normalised decision matrix

	-	-	+	-	+	-	+	+	-
	Cost	Delays	Frequency	Transit Time	Traceability	Damage / Loss	Controllabilty	Flexibility	Location
Road	0.127	0.121	0.031	0.008	0.037	0.057	0.028	0.025	0.027
Rail	0.154	0.114	0.011	0.007	0.022	0.096	0.015	0.016	0.083
Water	0.179	0.183	0.018	0.010	0.025	0.123	0.014	0.017	0.123

e) Calculate the separation distance of each alternative to the PIS and NIS (*Stage e*)

The separation distance of each alternative from the PIS and NIS is found by calculating the Euclidean distance of the alternatives from the ideal solutions. This is done through the following formulae (Triantaphyllou, 2000):

$$S_{i+} = \sqrt{\sum_{j=1}^{n} \left(V_{ij} - V_{j+}\right)^2} \; ; \; i = 1, 2, 3, \dots, m \; ; \; j = 1, 2, 3, \dots, n$$

In this formula S_{i+} represents the Euclidean distance of a solution to the Positive Ideal Solution. In turn, the following formula is applied to find the Euclidean distance of a solution to the Negative Ideal Solution which is represented by S_{i-} (Triantaphyllou, 2000):

$$S_{i-} = \sqrt{\sum_{j=1}^{n} \left(V_{ij} - V_{j-}\right)^2} \; ; \; i = 1, 2, 3, \dots, m \; ; \; j = 1, 2, 3, \dots, n$$

Both of these formulae were applied to the existing data. This process utilised the results from *Stage c*, where the weighted normalized decision matrix was calculated, and *Stage d*, where the Positive Ideal Solution (PIS) and the Negative Ideal Solution (NIS) were determimed. The result of this can be found in Table 6.5 where the separation measure between each criterion and the positive ideal solution (PIS) is shown and in Table 6.6 where the separation measure between each criterion and the negative ideal solution (NIS) is shown.

f) Calculate the relative closeness to the ideal solution (*Stage f*)

The relative closeness to the ideal solution is calculated using the following equation (Chen, 2011):

$$C_{i+} = \frac{S_{i-}}{S_{i+} + S_{i-}} \; ; \; i = 1, 2, 3, \dots, m \; ; \; 0 \le C_{i+} \le 1$$

Table 6.4: Positive ideal solution (PIS) and negative ideal solution (NIS) for criterion

	-	-	+	-	+	-	+	+	-
	Cost	Delays	Frequency	Transit Time	Traceability	Damage / Loss	Controllabilty	Flexibility	Location
PIS	0.127	0.114	0.031	0.007	0.037	0.057	0.028	0.025	0.027
NIS	0.179	0.183	0.011	0.010	0.022	0.123	0.014	0.016	0.123

Table 6.5: The separation measure between criterion and the positive ideal solution (PIS)

	Cost	Delays	Frequency	Transit Time	Traceability	Damage / Loss	Controllabilty	Flexibility	Location
Road	0	4.50377E-05	0	3.9479E-07	0	0	0	0	0
Rail	0.000755325	0	0.000395619	0	0.000223932	0.001525236	0.000163821	7.97444E-05	0.003199523
Water	0.002692927	0.00475599	0.000161431	7.94992E-06	0.000136638	0.004263999	0.000195755	6.37483E-05	0.009226986

Table 6.6: The seperation measure between criterion and the negative ideal solution (NIS)

	Cost	Delays	Frequency	Transit Time	Traceability	Damage / Loss	Controllabilty	Flexibility	Location
Road	0.002692927	0.003875395	0.000395619	4.80152E-06	0.000223932	0.004263999	0.000195755	7.97444E-05	0.009226986
Rail	0.00059586	0.00475599	0	7.94992E-06	0	0.000688801	1.42085E-06	0	0.001559687
Water	0	0	5.16191E-05	0	1.07265E-05	0	0	8.94384E-07	0

In this formula C_{i+} represents the relative closeness of an alternaitve to the ideal solution. This equation was applied to the data that was derived from *Stage e*, where the seperation distance of each alternative to the PIS and NIS was determined. The result of this can be found in Table 6.10 in the next section of this chapter.

g) Rank the priority order of the available alternatives (*Stage g*)

By ranking in to descending order the values that were calculated in *Stage f*, the highest value of C_{i+} (the value closest to 1) represents the optimal alternative. This reflects it having the closest distance to the Positive Ideal Solution (Kumar, 2008).

The rankings of the alternatives that were selected for this case study (road, rail, water) were established and can be found in Table 6.10 in the next section of this chapter.

6.4 Results

The case study in this chapter collected qualitative data from logistics industry experts and then subsequently went on to process this data through both the Analytic Hierarchy Process and the Technique for Order Preference by Similarity to Ideal Solution. The results of the case study are represented in section 6.4.1 for AHP and section 6.4.2 for TOPSIS.

6.4.1 Weighting of criteria through the Analytic Hierarchy Process

Through the collection of qualitative data from logistics industry experts and the subsequent processing of this data using the Analytic Hierarchy Process the results of the case study were generated. These are represented in Table 6.7, Table 6.8, Table 6.9 and Fig. 6.3.

Table 6.7: Consistency Ratio (CR) values of pairwise comparisons of criteria

CRITERIA	CONSISTENCY RATIO (CR) VALUE
SERVICE, ROUTE, CARRIER, SHIPPER (A, B, C, D)	0.014

Table 6.8: Consistency Ratio (CR) values of pairwise comparisons of sub-criteria

SUB-CRITERIA	CONSISTENCY RATIO (CR) VALUE
SERVICE (A1, A2, A3, A4)	0.068
ROUTE (B1, B2)	-
CARRIER (C1, C2)	-
SHIPPER (D1)	-

Table 6.9: Sub-criteria weights in the decision making process

RANK	SUB-CRITERIA	GLOBAL WEIGHT	GLOBAL WEIGHT (%)
1	COST	0.268	26.8%
2	DELAYS	0.248	24.8%
3	DAMAGE/LOSS	0.166	16.6%
4	LOCATION	0.151	15.1%
5	TRACEABILITY	0.050	5.0%
6	CONTROLLABILITY	0.035	3.5%
7	FLEXIBILITY	0.034	3.4%
8	FREQUENCY	0.033	3.3%
9	TRANSIT TIME	0.015	1.5%

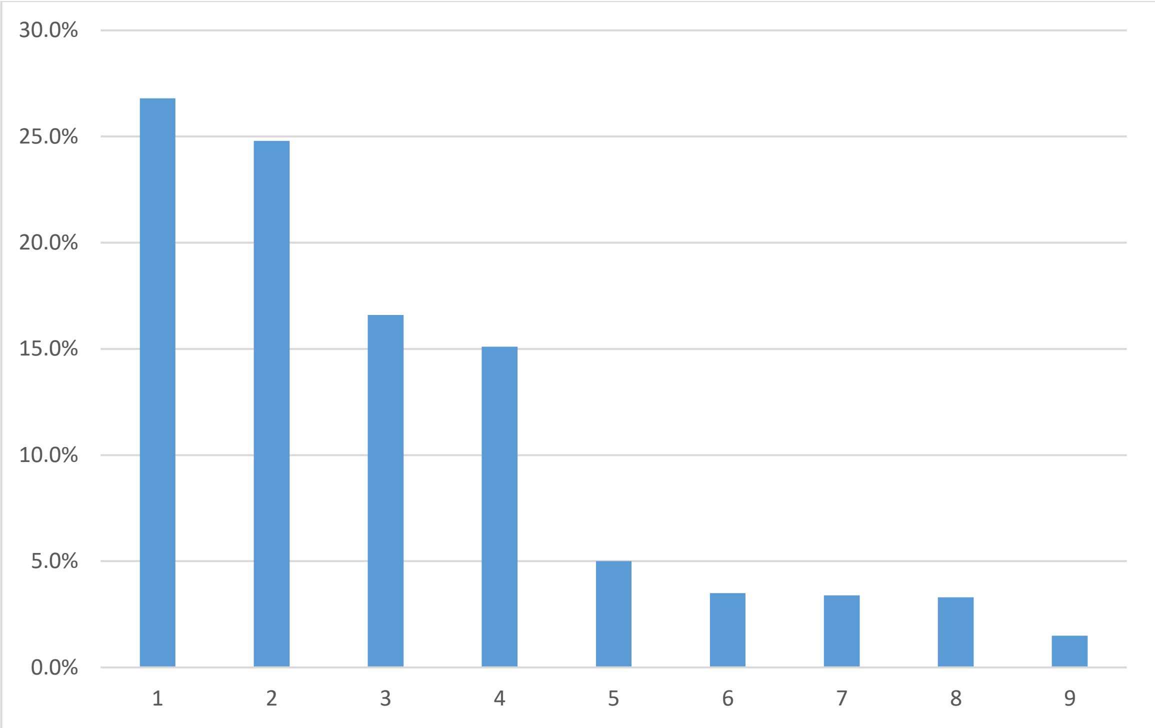


Fig. 6.3: Sub-criteria weights in the decision making process

6.4.2 Ranking of alternatives through the Technique for Order of Preference

The collection of qualitative data from logistics industry experts and the subsequent processing of this data the Technique for Order of Preference by Similarity to Ideal Solution produced the results of this case study. They are represented in Table 6.10 and Fig. 6.4.

Table 6.10: The separation measure between each alternative and the positive ideal solution (PIS) / negative ideal solution (NIS), the relative closeness coefficient and the ranking of alternatives.

	Separation from PIS	Separation from NIS	Relative Closeness Coefficient	Ranking of Alternatives
Road	0.007	0.145	0.956	1
Rail	0.080	0.087	0.523	2
Water	0.147	0.008	0.051	3

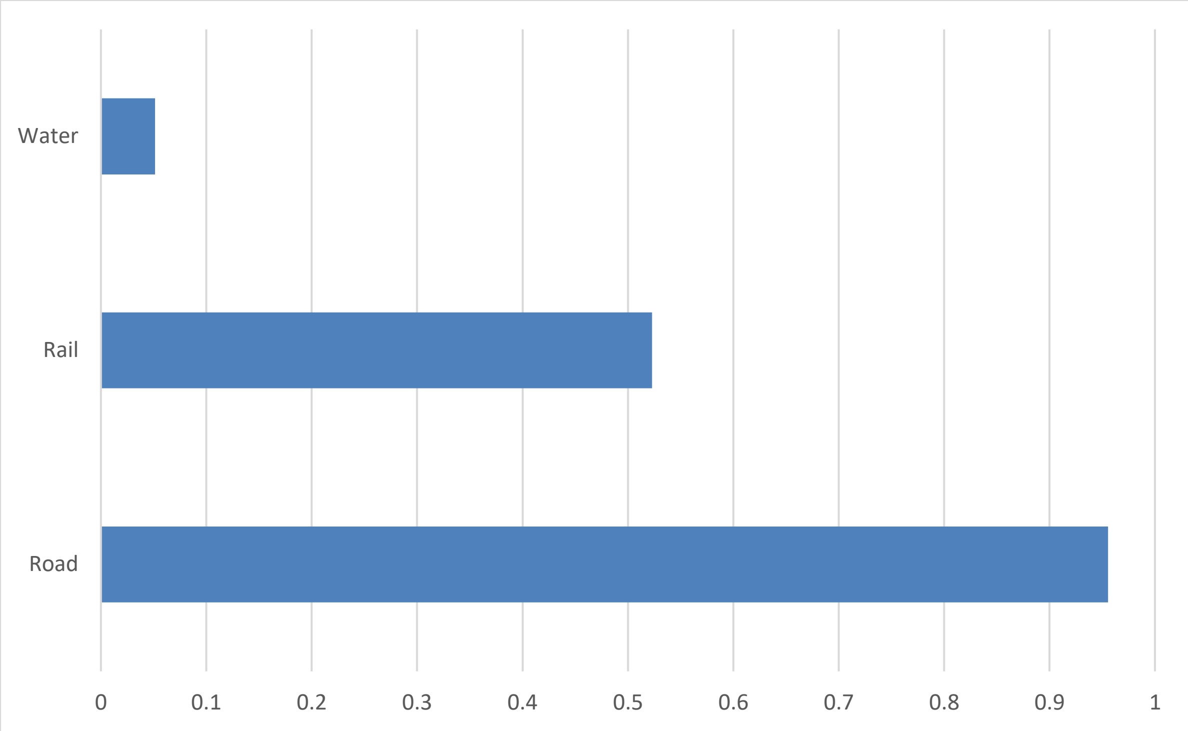


Fig. 6.4: The ranking of alternatives

6.5 Discussion

In this chapter the same hierarchy of goal, criteria and sub-criteria was maintained as was used in Chapter Five. This was done to ensure a measure of coherency across the chapters when it came to the analysis of the modal choice decision making process. A by-product of using the same hierarchy is that when it is populated in this chapter some of the criteria contain a limited number of sub-criteria. An example of this can be found with the Shipper criterion where, in the simplified model used in this chapter, only one sub-criterion can be found (Location). Within AHP the role performed by a Consistency Ratio (CR) is to ensure that the pairwise comparisons provided by industry experts are consistent. Perhaps more important than demonstrating the consistency of expert opinions, CR also identifies inconsistencies in their views that would undermine the analysis. Inconsistency is an unavoidable issue when dealing with large numbers of criteria as experts attempt to mentally juggle the comparisons that they are being asked to consider.

The implications of this chapter's reduced model are felt most significantly in the pair wise comparison calculations that are used as part of the Analytic Hierarchy Process (AHP). These rely upon a minimum number of sub-criteria being allocated to each criteria. Using the same hierarchy across the two separate phases of analysis (found in Chapter Five and Chapter Six) means that in some cases (as is found under the Route and Carrier criteria) a straight comparison between two sub-criteria is all that is required to be performed. In a similar vein, under the Shipper criterion there is no need for a pairwise comparison at all as Location (the only sub-criteria) represents 100% of the weight from that criterion. When considering much smaller numbers of sub-criteria, as is the case with the reduced model that was used in this chapter, finding a value for the CR may become irrelevant. This is the case when considering fewer than three criteria or sub-criteria.

Understandably, when dealing with large numbers of either criteria or sub-criteria it is critical to establish the overall consistency and therefore the reliability of the data provided by experts. In Kauko (2002) it was stated that a CR value of up to and including 0.1 is an acceptable level. As can be seen in Fig. 6.7 and 6.8 the results generated by this work that were complicated enough to require a CR to be calculated produced acceptable CR values. This means that the pairwise calculations that were carried out delivered a valid set of consistent responses. With this confirmed it can be considered that the experts involved in this work have produced a reliable data set that can be used to discuss the modal choice decision making process.

After AHP had allocated weights to each of the criteria in the model the TOPSIS methodology was applied to the qualitative data that had been collected. Billions of Euros have been spent and a range of projects have been completed over almost fifteen years with a view to delivering modal shift in the freight industry. With that in mind it was particularly disappointing to find that the road mode is still, by far, the preferred mode for transporting unitized freight. It was equally dissapointing to see the depth of this dominance when an accompanying sensitivity analysis apportioned alternative weights within the model. No amount of realistic alteration to the weights of diferrent elements made rail a competitive alternative.

6.5.1 Differences between the criteria weights in Chapter Five and Chapter Six.

In Chapter Five the criteria that represented 75.3% of the overall weight in the decision making processs were determined to be, in decreasing order of weight:

1) Delays
2) Cost
3) Traceability
4) Damage/Loss
5) Controllability

6) Location
7) Flexibility
8) Frequency
9) Transit Time

These criteria were used again in Chapter Six to produce a simplified model. After this reduced model was analysed through the Analytic Hierarchy Process the weights of some of the criteria had altered. In the reduced model the order of the criteria was, in decreasing order of weight:

1) Cost
2) Delays
3) Damage/Loss
4) Location
5) Traceability
6) Controllability
7) Flexibility
8) Frequency
9) Transit Time

Cost replaces Delays at the top of the list but the weights of these two criteria were close in Chapter Five, 21.5% and 20.0% respectively. As a result, this swop of positions only represents a small shift in weight. In addition, at the opposite end of the scale Flexibility, Frequency and Transit Time inhabit the same positions in the reduced model of Chapter Six as they did in the larger model of Chapter Five. Transit time did reduce by 48.4% in weight but this only served to reinforce its position at the bottom of the order of criteria.

The main differences in position within the order of criteria allocated in Chapter Five and those allocated in Chapter Six can be found amongst the criteria in the middle order. The smallest alterations are found with the Traceability and Controllabilty criteria. Both of these have decreased in weight. The weight of the Traceability criteria by 29.6% and Controllability by 34.0%. These decreases in weight are small enough that each of these criteria still has a similar weight to that which it had in Chapter Five but the reductions have resulted in Traceability moving down two places and Controllability moving down one place in the order of criteria

The most significant alterations in weight between Chapter Five's full model and Chapter Six's reduced model can be found in the Damage/Loss and Location criteria. Damage/Loss has only moved up one position in the order of criteria but this movement represents a 237.1% increase in the weight of this criteria. However, an even more substantial change comes from the Location criteria. This has moved two positions up the order of criteria representing an increase of 368.3% in weight.

The main significance of these changes is that in the reduced model, used in this chapter, there are now four criteria that make up a significant weight in the decision making process. These criteria are Cost (26.8%), Delays (24.8%), Damage/Loss (16.6%) and Location (15.1%). The next criteria by weight is Traceability (5.0%). In the larger model, used in the previous chapter, Delays (21.5%) and Cost (20.0%) held the majority of the weight by a long way. The next criteria by weight was Traceability (7.1%). These changes have occurred as a result of the substantially different model that is being analysed in this chapter.

6.5.2 Selection of alternatives

The freight transportation modes chosen to represent the options from which the model must provide a selection were road, rail and water as these modes are the ones which carry the most freight by volume but also have a significant role in the transportation of unitized freight in particular. Air was not included as the amount of freight carried by this mode is miniscule when compared to that carried by road, rail and water. In addition, air has an even smaller role to play in the transportation of unitized freight.

6.5.3 Significance of the order of preference of the identified alternatives

Utilising the weights produced through AHP the TOPSIS methodology provided an order of preference to the freight transport modes being considered (Road, Rail, Water). Since the publication of its 2001 transport white paper (European Commission, 2001) the European Union set itself the goal of rebalancing modal split in Europe to 1998 levels. Over the proceeding years Billions of Euros have been spent and a range of projects have been completed with a view to delivering this goal.

With the European Union's goal so clearly identified it was particularly disappointing for this work to find that the road mode is still, by far, the preferred mode for transporting unitized freight (Closeness Coefficient 0.956). Road is followed by Rail (Closeness Coefficient 0.523) and then, at a significant distance, by Water (Closeness Coefficient 0.051). The margin by which Road leads the others shows the degree to which the previous European Union policy of the last decade has failed and also the amount of work that will be needed to be done if modal shift is to be promoted in the future.

6.6 Conclusion

This chapter used a combination of AHP and TOPSIS to analyse qualitative data provided by representatives of the logistics sector. The results of this analysis clearly demonstrated the problem that confronts any one attempting to deliver a modal shift away from road within the freight industry. It was found that within the United Kingdom the perception is that road is the 'best' positioned mode to meet the transport needs of industry. When compared to rail and water, road is believed to have a lower cost, higher frequency of service, greater traceability, lower level of damage or loss to cargo, higher controllability, greater flexibility and it is also believed to be more easily accessible than the other modes.

During the write up phase of this work a unique opportunity presented itself. A conference was taking place that was to be attended by a number of significant figures in the field of North West European logistics. Three of the speakers at the conference were particularly relevant to the question of modal choice. In Chapter Seven attention will be given to some of the observations that were made by the speakers at this conference. They offered some interesting insights in to possible future directions to successfully promote modal shift in the freight industry of North West England's Atlantic Gateway.

Chapter Seven

Industry Opinion

7.1 Introduction

It is important for academic research to have a link to the ‘real’ world. For this research such a connection was established. A conference was held that was to be attended by a number of significant figures in the field of North West European logistics. This provided a unique opportunity to discuss the issues raised through this research with leading people in the logistics field. Three of the speakers at the conference were particularly relevant to the question of modal choice. These were:

Lord Tony Berkeley - The Chairman of the Rail Freight Group, the representative body of the United Kingdom’s rail freight industry. He is a past President and current board member of the European Rail Freight Association and is also a member of the House of Lords and Secretary of the All Party Parliamentary Rail Group. Tony was the Public Affairs Manager of Eurotunnel from 1981 until the end of the construction of the Channel Tunnel in 1994. He is a member of the Institution of Civil Engineers, Fellow of the Chartered Institute of Transport and Honorary Fellow of the Institute of Mechanical Engineers. He is also President of the UK Marine Pilots Association and a Harbour Commissioner for the port of Fowey in Cornwall.

Justin Kirkhope - The National Transport Support Manager for the Co-operative Food’s logistic service. The Co-operative recently won the European Supply Chain Excellence Award for Environmental Improvement thanks to its Logistics Carbon Reduction Programme, which included major initiatives such as fleet initiatives, modal shift (from road to rail freight), network transformation and waste backhaul. Prior to joining the Co-operative Group in 1994 Justin studied Business Organisation at Herriot-Watt University in Edinburgh and in his final year published a joint paper with Professor Dr. Alan McKinnon on improving the fuel efficiency of road freight operations. Following several years as Regional Transport Manager for Scotland, Justin has more recently been working on implementing transport operations in the Co-operative Food’s new composite distribution centre network. Justin has also been responsible for introducing modal shift within the Co-operative’s network, and chairs the Group’s Logistics Carbon Forum.

Astrid Schlewing - The Head of the Logistics Sector in the Directorate-General for Mobility and Transport (DG-MOVE). Astrid is an economist who specialises in transport issues. She has been involved in the Maritime Transport and Logistics unit of DG-MOVE since 2011. In this time she has worked in a variety of areas including: research, technological development, maritime and inland waterway transport, logistics, intermodal transport and the digitalisation of transport.

Whilst the time available to engage with these individuals was limited by the timetable of the conference it wasn't possible to get them to provide detailed individual feedback on the models developed within this work. However, it was possible to get their opinions on how best to go about addressing the problem of modal shift. Their opinions provide valuable insight that adds weight to the research objectives delivered in this work.

7.2 Interviews

Each of these speakers was asked what approach they thought would be most likely to generate the desired modal shift away from the carriage of freight by road in the Atlantic Gateway of North West England.

7.2.1 Lord Tony Berkeley

It is Lord Tony Berkeley's opinion that "Road still largely dominates freight transport and it has the financial and competitive advantage over the other modes." He also feels that "East to West transport links need to be taken in to account as much as North to South transport links and both are in need of further development. Resilience is also very important, what happens when something goes wrong? Both of these factors contribute towards the delivery of bad quality transport services with long waiting times and a high risk of delay. Simply put if a mode has a particularly poor reputation for service then it won't be able to compete with other modes that have a better reputation". So what can be done? "PRIME (the Platform of Rail Infrastructure Managers in Europe) has been formed to address shortcomings in the European rail network. This will help promote the development of rail infrastructure but building our way out of the problem is not a long term solution, we also need to use what we have better through creating a level playing field when it comes to charging. Subsidies for particular modes are a step too far. However, one possible method for producing a level playing field is to take in to account the full range of externalities associated with each mode of transport and then have them included in the cost of using that mode. The current road and rail charging systems stand in opposition to each other. A rail user pays at the point of use whereas a road user pays a lump sum at one point and then has unrestricted access to the road network for the period paid for, typically a year. Neither of these charging mechanisms fully reflects the full range of both internal and external costs attached to each mode but the end result is that the road network is overused and under paid for. Pay as you go being rolled out across all modes would be an improvement to the current situation". A harmonised system for payment does not currently exist and previous attempts to put one in place have failed for a variety of reasons. With this in mind it is worth considering what would be involved. "The cost of congestion would need to be reflected in any payment scheme. Suggestions in the past have included basing this on the time of day, location of the vehicle, the type of vehicle or engine capacity. This would preferably be on a Europe wide scale to avoid problems at borders and help users know what to expect from each country".

7.2.2 Justin Kirkhope

Justin Kirkhope feels that, in the United Kingdom, the alternatives to transporting freight by road are currently restricted by some notable limitations "Rail transport in the United Kingdom has some significant drawbacks that need to be addressed. The first and perhaps the biggest of these is the availability of suitable trains. There simply aren't enough slots in the timetable and freight trains to fill them. This places a limitation on access to the rail network that is of concern to those companies that have been attempting to make a modal shift away from road". Unfortunately that isn't the only problem. "The United Kingdom doesn't have the 24/7 rail service that is required to meet the needs of modern industry. Currently there is lack of a rail freight services on Saturday nights. The limited availability of trains at weekends and also during bank holidays is a major barrier to modal shift. In the eyes of those organisations considering transferring their shipments to rail this is seen as a backwards step in terms of the level of service reliability that they have become accustomed to. If you need to ensure that there is fresh bread, fruit, vegetables and flowers on the shelves of your stores every day then this situation is just not acceptable". Market fragmentation and company competition are barriers to the efficient use of the existing transport infrastructure. However, under the correct circumstances there is the possibility for a significant modal shift towards rail to occur. "Co-opetition is becoming a popular term in the logistics field. Rail is best used when a single organization books a slot and the available train is filled to capacity. That way the full load arrives at its destination in one go rather than staggered out over time. This limits access to rail for many smaller companies and also results in the inefficient use of the network as not all organizations can regularly fill an entire train to its capacity. Co-opetition is the answer to this. In recent years some of the United Kingdom's largest retailer operations, including Sainsbury's and the Co-operative, have taken part in discussions around the subject of consolidating the rail shipments from several organisations to produce a full train where there isn't the quantity from a single company. High level discussions produced a lot of nervousness about working together with people who are competitors. The end result of these discussions was that an independent broker is required to oversee the application of Co-opetition and ease some of the operators' nerves". Industry is always keen to maximise its benefits from a venture and modal shift is no different. "Free advertising is a previously unforeseen benefit to increasing the amount of freight that companies choose to move by rail. The use of more rail means that a company's livery will receive greater exposure across the nation. This will especially be true if freight trains move through stations at peak use times when station platforms are packed with commuters".

7.2.3 Astrid Schlewing

Astrid Schlewing stated that "Logistics is a major driver for the economic development of the European Union and cross modal oriented work is the way forward. However, barriers exist to achieving modal shift in the freight transport industry. These include: issues with cabotage, the quality of transport infrastructure and the quality of transport services". It must not be forgotten that "Logistics is a task of industry, but it needs to operate within the correct framework conditions. The better integration of modes is key to better services being delivered. The current situation where road is the preferred mode is a barrier to improvements being pursued across the other modes". It is the job of industry to produce modal shift but it is possible to assist them in the transition "What is key to bringing about modal shift? Both funding and legislation (a carrot and stick approach). Incentives are useful to promote a shift but they must be geared towards creating a level playing field where the external costs of each mode of transport are internalised within the cost paid by the user. However, modal shift needs to come from logistics operators and logistics procurers (those buying the service) these are the parties that need to be influenced. People have to want to bring long lasting change rather than having it forced down upon them from above, but if the market fails on its own to develop a 'neutral platform' to promote a more even share of modal split then an alternative approach could be taken". Co-modality is a currently popular term with many people believing that it is the way forward. "The majority of cost in transporting freight comes from salaries (50%) and fuel (20%). The introduction of autonomous vehicles will reduce these costs and make it even cheaper to move by road. An example of this could be road trains where ten trucks are driven by only one driver, located in the first vehicle. With developments like these the objective is no longer to bring about a modal shift to rail or water but rather to use different modes of transport for a journey with a view to getting the biggest benefit from each of them so that the overall journey is the most sustainable that it can be. This is Co-modality".

7.3 Conclusions

Leading members of the logistics community feel that the solution to delivering modal shift within the Atlantic Gateway of North West England will come through co-modality and the delivery of a level playing field on which every mode can compete. As increasing numbers of vehicles use the road network it has become apparent that building a never ending number of new roads will not solve the problem of road congestion. Instead, the way forward is to use the transport infrastructure that we already have in a more intelligent way. This may result in ICT taking a lead role with the development of autonomous vehicles but regardless of this users of all modes should pay at the point of use in a similar way to that which rail users currently do. It is inevitable that, where this results in a change to the current system, the increased cost of freight transport will be passed on to customers. Because of this it will be important, although not essential, for both logistics operators and logistics procurers (those buying the service) to concur with the idea.

Chapter Eight

Conclusions and Recommendations

8.1 Conclusions

The aim of this work is to investigate the modal choice decision making process (between road, rail, inland waterways) occurring within the freight transportation industry of North West England's Atlantic Gateway. The hypothesis taken as its starting point is that it is possible to circumvent the limited amount of quantitative data that freight transportation companies make available to researchers by instead analysing qualitative responses provided by key individuals within the logistics sector.

This work has proven this hypothesis to be true. In doing so, a number of models have been constructed. These amount to a novel pathway for informing the development of transport policies within North West England's Atlantic Gateway. If these models are adopted by policy makers, the development of future transport policies will be more likely to achieve the desired modal shift of freight vehicles away from the roads within the region in question.

8.1.1 Research Objectives

To lay the foundation for this work, the limited data made available by North West England's freight transportation industry, along with the inadequacy in publicly available data from mainstream sources is highlighted (Chapter Two and Chapter Four). Subsequently, an effort is made to **identify the prevailing levels of modal split existing in the European Union's EU27.** Analysis of the available data identifies that, since the year 2000, road has been the most widely used method for the transportation of inland freight across the EU. This is followed by rail and then inland waterways. Despite twenty years of the EU's efforts, in the form of a number of high profile interventions, to reduce the modal share of road, the impact has been negligible with the modal split of each mode remaining similar throughout.

Having identified that an issue exists with the modal share of different freight transportation modes it is then necessary to **identify the most effective research methodology for assessing the modal choice decision making process of North West England's Atlantic Gateway.** Having considered the advantages and disadvantages of a range of decision analysis, consumer expectation modelling, and forecasting techniques (Chapter Three) the Analytical Hierarchy Process (AHP) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) were selected to analyse the qualitative data provided by representatives of the logistics sector. Many reasons exists to justify this decision but the factor playing the largest role was the transparency of these methods to industry practitioners.

To construct a model of the modal choice decision making process it is necessary to develop a significant depth of understanding of the industry that is being modelled. To achieve this, a series of workshops were used for data collection (Chapter Four). The objectives of these workshops were to:

- **Identify the key criteria that influence modal choice decision making within North West England's Atlantic Gateway.**
- **Identify organisations that play a significant role in the present day freight industry of the North West region of England.**
- **Identify regionally significant freight handling infrastructure in the North West region of England.**

The workshops were a success, generating a large amount of useful data. As a result, a deeper understanding of the freight transportation industry was established. In addition to this an extensive list of potential factors were identified that the fright industry believes influence the modal choice decision making process. Also, a list of over one hundred key stakeholders were identified that members of North West England's freight industry consider to be the most important to their businesses. This was vitally important as identifying these organisations is key to understanding whose decision making needs to be influenced to deliver a more even modal share across transport modes. Equally important, was a list of freight-handling infrastructure that was generated which provided valuable insight in to why variations in modal split exist within the geographical region in question.

Perhaps less important than these big three workshop outputs, but still significant, are a number of other findings:

- Representatives of the freight industry have a limited understanding of the impact of their business upon the environment.
- Workshops can be used to provide representatives of the freight industry with a greater appreciation of the environmental implications of their activities.

- Representatives of the freight industry have a good understanding of the transport modes that they utilise on a day-to-day basis. However, they have less of an understanding of transport modes that their businesses use less frequently.
- Representatives of the freight industry accept that alternative transport options are available, they accept them as being relevant but they also accept that they do not utilise them to their full potential.
- Workshops can be used to provide representatives of the freight industry with a greater understanding of the capabilities of the various available transport modes.

Interestingly, it was also found that representatives of the freight industry have a low expectation of what academia can provide their businesses. However, promisingly, when offered the opportunity to address their concerns, some of those approached during the workshops were open to exploring how their business could benefit from working with academia in the future.

The insights gained by determining industry's perception of itself are invaluable. Especially when it comes to the development of a modal choice framework. After collecting data on the region's freight transport industry the next step was to **develop a complete modal choice decision making framework specific to North West England's Atlantic Gateway.** Making use of the list of criteria identified through the workshops, along with input from journal papers, and personal experience a concise framework was established to model the modal choice decision making process (Chapter Five). This model is composed of four criteria: service, route, carrier, and shipper. These are in turn populated by a total of twenty six sub-criteria: administration, cost, delays, traceability, controllability, value added services, transit time, frequency, distance, capacity, external impacts, security, finances, damage/loss, claims processing, flexibility, certification, safety record, image of mode, market conditions, location, relationships, previous experience, company policy, cargo characteristics, inventory.

Having constructed this model it was essential to **establish the weight of each criteria within the decision making framework.** Data was collected from experts in the form of a series of pairwise comparisons which were then analysed by way of AHP. From the twenty six sub-criteria included in the framework the top nine were found to represent 75% of the total weight. These nine sub-criteria are: cost, delays, traceability, controllability, transit time, frequency, damage/loss, flexibility, location. Delays and cost make up the largest share of this weight.

This broadly identifies the areas where an effort could be applied by policy makers to bring change to the way that the freight industry uses North West England's existing transport network.

Having identified the most heavily weighted criteria in the first model, time was taken to **construct a simplified model.** The aim of this was to produce a more readily accessible, reduced size, modal choice framework based around only the most influential criteria (Chapter Six). This was achieved by reducing the model size from its initial twenty six sub-criteria to include just the nine sub-criteria that make up the majority of the weight in the first model. Upon completion this produced a model that is much easier to grasp than its predecessor and potentially of greater use to policy makers. As was the case with the initial, full size, model; a separate round of data collection through pairwise comaprison was conducted by AHP analysis. This determined the top two criteria by weight in the simplified version to also be delays and cost. It is a clear finding of this work that these two sub-criteria play the greatest role in influencing the modal choice decision making process of North West England's Atlantic Gateway.

Having established where the weight lies in the modal choice decision making process the TOPSIS technique was employed to examine what this means for modal share within the region in question (Chapter Six). The results are disappointing. Within the Atlantic Gateway, the mode of transportation that is perceived as being the 'best' positioned to meet the needs of the freight transportation industry is road. Despite the availability of alternative options, road is ranked as being much closer to the ideal solution than either of its competitors (0.956 Road, 0.523 Rail, 0.051 Inland Waterways). Subsequently, it can be stated that within the Atlantic Gateway, the perception of representatives of the freight industry is that road is the best-positioned mode to meet their transport needs. When compared to rail and water, road is believed to have a lower cost, higher frequency of service, greater traceability, lower level of damage or loss to cargo, higher controllability, greater flexibility and it is also believed to be more easily accessible than the other modes. This clearly demonstrates how much things still need to change as well as how little progress has been made over twenty years of EU projects that have invested billions of pounds in altering modal share.

8.2 Recommendations

Based on the work carried out the following recommendations for further work are proposed:

1. It is recommended that the effects of the top two sub-criteria by weight (cost and delays) should be further examined within the Atlantic Gateway. This should be done with a view to determining how these criteria can best be used to influence the decision making process to promote alternative freight transportation modes to road within the geographical area covered by this work.

2. Only a limited analysis of data was possible within the context of this work and the available time. As a result, it is recommended that further investigation, to a greater level of resolution, should be carried out in to the effects of the identified criteria and sub-criteria upon the modal choice decision making process occurring within the Atlantic Gateway.

3. During the course of this work a relatively small number of experts were approached for their opinions. It is recommended that the views of additional experts should be sought to either validate or dispute the weights calculated from the data provided by the experts consulted in this work.

4. It is recommended that variants of the models developed in this work be deployed in different gateways across the nation to ascertain the variations in weight of the relevant criteria and sub-criteria. Once this has been completed results will exist that can be meaningfully compared. This will allow comparisons to be drawn between them and address the current problem of non-specific, general statements being the only thing that can be made.

5. Only when valid, gateway specific statements can be made is it then recommended that a figure for the average values of each criteria and sub-criteria be established for the nation as a whole. Variations in the values across different regions (Scotland, England, Northern Ireland, and Wales) should also be established.

6. Upon identifying values for specific gateways, average values for the United Kingdom, and establishing the level of variation across its constituent regions it is recommended that this same procedure then be followed in other nations across Europe or further afield.

7. Once a sufficiently large section of gateways from different nations have been studied using these models it is recommended that comparisons be performed between the identified weights and the results of these used to identify a much broader range of approaches to influencing modal choice than is currently adopted.

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Appendices

Appendix One - Goods Providers of North West England

AB WORLD FOODS web: www.abf.co.uk

A leading UK food manufacturer that produces well-known brands, including: Patak's, Blue Dragon, and Levi Roots. AB World Foods is part of Associated British Foods Plc. (ABF), a major international manufacturer of branded grocery products. Other brands that are part of ABF include: Allied Bakeries, Jordans Ryvita, Primark, Silver Spoon, and Twinings. In 2017, ABF posted revenue of over £15 billion and employed more than 132,000 people worldwide.

AIRCELLE LTD web: www.aircelle.com

The UK operation of Aircelle. Aircelle is a global leader in the manufacture of large and small engine nacelles, thrust reversers, and aero structures. Its products are used on aircraft ranging from private business jets to the A380 double-deck airliner. Aircelle is part of the Safran high-technology group that has interests in aerospace, defence and security. In 2017, Safran employed over 90,000 people worldwide and posted revenue of over £14.5 billion.

ASTRAZENECA LTD web: www.astrazeneca.co.uk

Based on 2017 sales AstraZeneca is the world's eleventh largest pharmaceutical company. AstraZeneca produces a wide range of Cardiovascular, Gastrointestinal, Infection, Oncology, Neuroscience, Respiratory, and Inflammation medicines. In the UK AstraZeneca is a member of the Association of the British Pharmaceutical Industry (ABPI). In 2017, AstraZeneca employed approximately 60,000 people worldwide and posted revenue of over £17 billion.

BAE SYSTEMS web: www.baesystems.com

The world's third largest military contractor, based on 2017 revenues. BAE Systems provides a range of defence, maritime, and aerospace products. Current contracts cover a number of major defence projects, including: the F-35 Lightning II, the Eurofighter Typhoon, the Astute class submarine, and the Queen Elizabeth class aircraft carrier. In 2017, BAE Systems posted revenue of over £18 billion and employed more than 83,000 people worldwide.

BENTLEY MOTORS LTD web: www.bentleymotors.com

A British luxury car company. Bentley is dedicated to developing and crafting the world's most desirable high performance cars. Bentley Motors is part of the Volkswagen Group (as are Volkswagen, Skoda, Audi, and Seat) which, based on 2017 figures, is the world's largest automotive manufacturer by unit sales. In 2017, the Volkswagen Group employed 642,000 people globally and posted revenue of over £201 billion.

THE BOC GROUP PLC web: www.boconline.co.uk

The largest provider of industrial, medical, and special gases in the UK. BOC has been producing gases for over 120 years and has a range of products including thousands of different gases and mixtures, as well as related equipment and services. BOC is a member of The Linde Group, a world leading gases and engineering company. In 2016, The Linde Group posted revenue of £16.9 billion and employed almost 60,000 people worldwide.

BOMBARDIER TRANSPORTATION LTD web: www.bombardier.com

A global leader in the rail industry which has produced over 100,000 pieces of currently operational rolling stock. Bombardier Transportation is part of Bombardier, a global company with interests in aerospace, and rail transportation. Products include: commercial and business jets, rail transportation equipment, systems and services. In 2017, Bombardier employed 69,500 people worldwide and posted revenue of £12.6 billion.

BRENNTAG UK & IRELAND web: www.brenntag.co.uk

The United Kingdom's market leader in bulk and packaged chemical distribution. Brenntag UK & Ireland supplies chemicals for: pharmaceuticals, cleaning products, adhesives, coatings, water treatment, food ingredients, polymer production, and the oil and gas industry. Brenntag UK is part of the Brenntag Group, the global market leader in chemical distribution. In 2017, the Brenntag Group employed over 15,000 people worldwide and posted revenue of more than £10 billion.

BRITISH GYPSUM web: www.british-gypsum.com

The United Kingdom's leading manufacturer of dry lining systems (gypsum plaster, plaster board) for the construction industry. Products include: wall lining, partition, ceiling, flooring, insulation, and fire protection systems. British Gypsum is part of the Saint-Gobain Corporation, a world leader in the design, production, and distribution of construction materials. In 2017, Saint-Gobain employed over 179,000 people globally and posted revenue of £35.7 billion.

BRITISH SALT LTD web: www.british-salt.co.uk

The supplier of over half of the UK's pure white salt requirement (800,000 tonnes annually), including: de-icing, water softening, industrial, and pure dried salts. British Salt is part of Tata Chemicals Europe, which is part of Tata Chemicals Ltd. Tata Chemicals Ltd is the world's second largest producer of soda ash and has interests in the consumer, industrial, and agricultural sectors. In 2017, Tata Chemicals Ltd employed 4,600 people and posted revenue of £1.7 billion.

BSW TIMBER GROUP web: www.bsw.co.uk

The largest sawmilling business in the UK. BSW has a total sawn timber annual production capacity of over 1,000,000 m^3 and supplies sawn timber products to customers in the construction, pallet and packaging, fencing, garden and DIY sectors. BSW is acknowledged by the Timber Trade Federation as a responsible, environmentally aware supplier to the timber trade. In 2017, BSW Timber Group employed over 1,300 people and posted revenue in excess of £163 million.

CAMMELL LAIRD LTD web: www.clbh.co.uk

Possibly the most famous name in ship repairing and shipbuilding in the United Kingdom. Cammell Laird is an internationally recognised brand that specialises in the commercial: repair, upgrade, conversion, heavy fabrication, engineering, and military refit of vessels. Contracts are currently held with the Ministry of Defence to service the requirements of the Royal Navy. In 2017, Cammell Laird posted revenue of nearly £115 million and employed approximately 700 people.

CARGILL INC. web: www.cargill.co.uk

One of the world's largest privately owned companies. Cargill has interests in the food, agriculture, finance, industrial products, and services sectors. The company's main investments are in the production, trading, and distribution of grain, energy, steel, livestock, and food ingredients (starch, glucose syrup, vegetable oils and fats). In 2017, Cargill employed over 150,000 people worldwide and posted revenue of approximately £89 billion.

CARR’S FLOUR MILLS LTD web: www.carrs-milling.com

A UK based flour producer that delivers to bakers, food manufacturers and retailers. Carr’s Flour Mills are part of Carr’s Milling Industries Plc. Carr’s Milling Industries also has interests in engineering (steel fabrication, manipulators, and robotics), agriculture (farm products and livestock feed), and investment. In 2017, Carr’s Milling Industries Plc. posted revenue of over £403 million and employed more than 670 people globally.

CEMEX UK MATERIALS LTD web: www.cemex.co.uk

Amongst the UK’s leading suppliers of: cement, ready-mixed concrete, aggregates, asphalt, concrete sleepers (for the rail industry), concrete blocks, and Pulverised Fuel Ash (PFA) cement additives. Cemex UK is part of the Cemex company, one of the world's largest construction material suppliers and cement producers. In 2017, Cemex posted revenue of £14 billion and employed over 50,000 people worldwide.

CEREAL PARTNERS UK web: www.cerealpartners.co.uk

One of the United Kingdom’s leading cereal manufacturers. They produce a wide range of brands, including: Shredded Wheat, Shreddies, Cheerios, Clusters, Nesquik, Golden Nuggets, Crunch, and Goldham Grahams. Cereal Partners UK is part of Cereal Partners Worldwide (CPW) which is a joint venture between Nestlé S.A. and General Mills Inc. CPW is one of the world’s leading breakfast cereal producers. In 2017, Cereal Partners Worldwide employed over 4,500 people globally and posted revenue in excess of £1.2 billion.

COLGATE-PALMOLIVE web: www.colgate.co.uk

Colgate-Palmolive is a world leading consumer products manufacturer. The company produces and distributes a wide range of products in the household cleaning, health care, and personal hygiene markets. These include: detergent, oral hygiene (toothpaste, toothbrushes), soap, shampoo, and veterinary products (via Hill's Pet Nutrition Inc.). In 2017, Colgate-Palmolive employed approximately 36,000 people worldwide and posted revenue in excess of £11 billion.

DAIRY CREST GROUP PLC web: www.dairycrest.co.uk

A dairy business that manufactures both finished produce (milks, cheeses, drinks, butters, and spreads) and ingredients (powdered milk, whey). Famous brands manufactured by Dairy Crest include: Clover, Utterly Butterly, Country Life, Vitalite, Davidstow, Cathedral City, Country Life Milk, and FRijj. The milk used in the manufacturing process is sourced from UK based farmers. In 2017, Dairy Crest employed over 1,100 people in Europe and posted revenue of over £416 million.

DR. OETKER web: www.oetker.com

A leading international manufacturer of high quality foods, including: ambient (baking, pudding and dessert powders), frozen (pizzas, snacks) and chilled (yoghurt, puddings, creams) ranges. Well-known brands include Chicago Town, and Pizza Ristorante. Dr. Oetker is part of the Oetker-Gruppe which has interests in food, beverages, wine and spirits, banking, and shipping (Hamburg Süd). In 2017, the Oetker-Gruppe posted revenue of more than £9.5 billion and employed approximately 30,000 people.

ELI LILLY web: www.lilly.co.uk

A Global pharmaceutical company at the forefront of product and technology development. Eli Lilly manufactures pharmaceuticals for both humans and animals. Conditions treated by the company's products include: erectile dysfunction, depression, diabetes, tuberculosis, arthritis, cancer, obsessive compulsive disorder, bulimia nervosa, and narcotic drug addiction. In 2017, Eli Lilly posted revenue of over £17 billion and employed more than 40,000 people worldwide.

FORFARMERS web: www.forfarmers.co.uk

The UK's leading animal feed manufacturer. ForFarmers produces over ten million tonnes of compound feed annually. Products are suitable for all of the main livestock groups: pigs, poultry, dairy cows, beef animals, and sheep. ForFarmers is part of the Agricola Group which also has interests in renewable energy, in particular the emerging UK Anaerobic Digester market. In 2017, ForFarmers posted revenue of over £1.9 billion and employed 2,325 people across Europe.

GLAXOSMITHKLINE web: www.gsk.com

The world's fifth largest pharmaceutical company, based on 2010 revenues. GlaxoSmithKline produces medicines and vaccines for the World Health Organization's three priority diseases (HIV/AIDS, tuberculosis, and malaria) as well as: asthma, viral, cancer, infection, mental health, diabetes, cardiovascular, and digestive conditions. In 2017, GlaxoSmithKline posted revenue of more than £30 billion and employed 99,300 people globally.

GLEN DIMPLEX GROUP web: www.glendimplex.com

The world's largest manufacturer of electrical heating appliances. Glen Dimplex also holds significant global market positions in: cooling, ventilation, renewable energy, and domestic appliances. Product development is focused on creating lower carbon systems. As a result, Glenn Dimplex products account for lower CO_2 emissions than competing brands. In 2017, Glen Dimplex posted revenue in excess of £1.5 billion and employed over 8,000 people worldwide.

HALEWOOD INTERNATIONAL LTD web: www.halewood-int.com

The UK's largest independent drinks manufacturer and distributor. Halewood International produces wines, beers, ciders, spirits, and speciality products. Well-known brands manufactured by Halewood include: Lambrini, Lamb's Navy Rum, Tsingtao Chinese Beer, Crabbie's Alcoholic Ginger Beer, Red Square Vodka, and Reloaded. In 2010, Halewood International posted revenue in excess of £158 million and employed more than 1,000 people worldwide.

HANSON PLC web: www.heidelbergcement.com

A leading supplier of heavy building materials to the construction industry. Hanson produces aggregates (crushed rock, sand and gravel), concrete, asphalt, cement, bricks, and a range of building products. Hanson is part of the Heidelberg Cement Group, which has leading global positions in aggregates, cement, concrete, and building products. In 2017, the Heidelberg Cement Group employed 60,000 people worldwide and posted revenue of over £13 billion.

HENKEL LTD web: www.henkel.com

Henkel Ltd is a multinational company that manufactures personal care products. Henkel operates in three business areas: Laundry/Home Care (laundry detergent and dishwashing liquid), Cosmetics/Toiletries (shampoo, toothpaste, hair colorant, shower products) and Adhesive Technologies (glue, sealants, surface treatments). Henkel owns leading brands, including: Persil, Schwarzkopf, Dial, Loctite, Unibond, and Pritt. In 2017, Henkel employed over 53,000 people worldwide and posted revenue exceeding £17.5 billion.

H J HEINZ COMPANY web: www.heinz.com

A world leading food manufacturer producing condiments, frozen foods, soups, beans, pasta meals, and infant food. Heinz is the leading brand of baked beans in the UK and is also famous for its tomato ketchup. The Heinz company also produces some other well-known brands, including: Lea and Perrins, Daddies, and HP. In 2015, Heinz merged with Kraft Foods Group Inc. to form the Kraft Heinz Company the world's fifth largest food and beverage company. In 2017, the Kraft Heinz Company posted revenue exceeding £20.2 billion and employed approximately 39,000 people worldwide.

IGGESUND PAPERBOARD LTD web: www.iggesund.com

Europe´s leading manufacturer of virgin fibre paperboard for the packaging and graphics sectors. Iggesund's product ranges are: Invercote (solid bleached board) and Incada (folding box board). Iggesund is part of the Holmen Group. The Holmen Group has interests in energy production, and forest industry. It manufactures printing paper, paperboard and sawn timber. In 2017, The Holmen Group posted revenue of £1.3 billion and employed over 3,000 people in Europe.

INNOVIA FILMS LTD web: www.innoviafilms.com

A leading global manufacturer of films. Innovia focuses on the production of Biaxially Oriented Polypropylene (BOPP) and Cellulose. Products are used in the packaging (chocolates, biscuits, cheese), labelling (perfume, shampoo, beer), tobacco overwrap, and security (banknote production) markets. Innovia's annual film production capacity is more than 120,000 tonnes. In 2016, CCL Industries Inc. bought Innovia. In 2017, CCL Industries posted revenue in excess of £2.3 billion and employed 20,000 people worldwide.

JAGUAR LAND ROVER PLC web: www.jaguarlandrover.com

A leading automotive company that manufactures luxury cars and four-wheel drive vehicles. Jaguar Land Rover is part of Tata Motors Ltd. Tata Motors is famous for producing the world's cheapest car, the Tata Nano. It also has interests in the commercial vehicle sector, producing trucks (Novus, World) and buses (GloBus, StarBus). In 2017, Tata Motors posted revenue of approximately £33 billion and employed 81,000 people worldwide.

KELLOGG COMPANY web: www.kelloggcompany.com

The world's leading producer of cereal. Kellogg's is also a leading producer of convenience foods, including: cookies, crackers, toaster pastries, cereal bars, fruit-flavoured snacks, frozen waffles, and veggie foods. The company's best known products include: Corn Flakes, Coco Pops, Crunchy Nut, Pop-Tarts, All Bran, Rice Krispies, Special K, and Honey Loops. In 2017, Kellogg's posted revenue of £10 billion and employed 32,900 people worldwide.

KIMBERLEY CLARK LTD web: www.kimberly-clark.com

A leading global manufacturer of paper based consumer products. Kimberley Clark is famous for creating the first facial tissue. One quarter of the world's population purchases Kimberley Clark products every day. Kimberley Clark brands include: Kleenex, Scott, Andrex, Huggies, Cottonelle, Pull-Ups, Good Nites, Little Swimmers, Kotex, Poise, and Depend. In 2017, Kimberley Clark posted revenue of £14.2 billion and employed 42,000 people worldwide.

LAFARGE web: www.lafarge.com

A leading global manufacturer of building materials. Lafarge specializes in cement, aggregates, concrete, and gypsum. In 2011, Lafarge was the world's number one in cement, number two in aggregates, and number three in concrete and gypsum. In 2000, Lafarge signed an ongoing partnership with the World Wildlife Fund to demonstrate its commitment to sustainable development. In 2015 Lafarge merged with Holcim, a Swiss cement company, to form LafargeHolcim. In 2017, LafargeHolcim posted revenue of £20.1 billion and employed 80,000 people worldwide.

LEYLAND TRUCKS LTD web: www.leylandtrucksltd.co.uk

The UK's leading manufacturer of light and medium trucks. The company produces both Leyland and DAF trucks in one of Europe's most advanced assembly facilities. Leyland is part of PACCAR Inc., a global leader in the design and manufacture of light, medium, and heavy trucks. PACCAR also produces trucks under the Kenworth, and Peterbilt brands. In 2017, PACCAR posted revenue of £15.1 billion and employed over 25,000 people globally.

LOFTHOUSE OF FLEETWOOD LTD web: www.fishermansfriend.com

The manufacturer of Fisherman's Friends lozenges. Over 6 billion Fisherman's Friend lozenges are eaten each year. If laid end to end this would stretch around the world 4 times. Fisherman's Friends are now produced in a range of flavours, including: original, aniseed, cherry, mandarin, citrus, lemon, blackcurrant, and mint. In 2017, Lofthouse of Fleetwood posted revenue in excess of £51 million and employed 280 people in the UK.

MCBRIDE PLC web: www.mcbride.co.uk

Europe's leading provider of Household and Personal Care products. As well as their own products (Clean and Fresh, Planet Clean, Surcare, Limelite, Ovenpride) McBride develop and supply laundry liquids, dishwasher tablets, personal care, and air care products for retailers, such as Marks and Spencer, Tesco, Aldi, and Morrisons, to sell under their own brand names. In 2017, McBride posted revenue of £690 million and employed over 5,000 people globally.

MILLIKEN & COMPANY web: www.milliken.com

A privately owned innovation company. Milliken combines science with design and insight to tackle the issues and concerns of today. Milliken's products include: chemicals, protective fabrics, composites, floor coverings, industrial textiles, performance and work wear fabrics, and speciality textiles. Milliken has accumulated over 5,000 patents since its founding in 1865. In 2017, Milliken employed approximately 7,000 people worldwide and declined to reveal its revenue.

NESTLE UK LTD web: www.nestle.co.uk

A leading UK food manufacturer. Nestlé makes some of Britain's best loved brands, such as: Carnation, Kit Kat, Shreddies (via Cereal Partners Worldwide), Nescafé, Smarties, Nesquik, Herta, Rowntree's, Maggi, Häagen-Dazs, Jenny Craig, PowerBar, Buxton, and Go Cat. Nestlé UK is part of Nestlé S.A., the world's largest food and nutrition company. In 2017, Nestlé S.A. posted revenue of £67.6 billion and employed over 320,000 people worldwide.

NEWSPRINTERS LTD web: www.newsprinters.co.uk

The manufacturing division of News International. Newsprinters hold contracts for the printing of: the Sun, the Times, the Daily Telegraph, the Sunday Telegraph, and the Financial Times. Their state-of-the-art printers produce 1.5 billion copies annually. News International is the UK arm of News Corporation, one of the world's largest media conglomerates. In 2017, News Corp. posted revenue of £7.6 billion and employed 28,000 people globally.

NOVARTIS UK web: www.novartis.co.uk

The world's second largest pharmaceutical company, based 2010 on revenues, and the world's fifth largest manufacturer of vaccines. Novartis Vaccines is part of Novartis International; Novartis has interests in pharmaceuticals, generic pharmaceuticals, vaccines and diagnostics, animal health, and over the counter medications. In 2017, Novartis posted revenue of approximately £39 billion and employed about 126,000 people worldwide.

NOV MONO PUMPS LTD web: www.mono-pumps.com

A global manufacturer of pumps, pump parts, grinders, and screens. NOV Mono's products are suitable for the: waste water, chemical, food, beverage, paper, mining, oil and gas, mineral processing, marine, and agricultural sectors. NOV Mono is part of National Oilwell Varco (NOV), a worldwide leader in the design and manufacture of equipment for the oil and gas industry. In 2017, NOV employed 37,000 people globally and posted revenue of £5.6 billion.

PEPSICO UK web: www.pepsico.com

The British operations of PepsiCo International, the world's second largest food and beverage business, based on 2010 revenues, with interests in the manufacturing, marketing, and distribution of their products. Pepsico brands include: Pepsi, Fritos, Chester's, Tropicana, Lay's, Aquafina, 7UP, Walker's, Cheetos, Doritos, Ruffles, Quaker Oats, Schweppes, Canada Dry, Dr. Pepper, and Gatorade. In 2017, Pepsico posted revenue of £49.1 billion and employed 263,000 people worldwide.

PERSTORP UK LTD web: www.perstorp.com

The British operations of Perstorp, a speciality chemicals manufacturer. Perstorp is the largest global producer of organic acids, specialty Polyols (Penta and TMP), plants and catalysts for the production of Formalin. Products are used in the aerospace, marine, coatings, chemicals, plastics, engineering, automotive, agriculture, food, packaging, textile, paper, electronics, and construction industries. In 2017, Perstorp posted revenue of £1.1 billion and employed 1,600 people worldwide.

PILKINGTON GROUP web: www.pilkington.com

The Pilkington Group is a global leader in the manufacturing of glass. Pilkington is part of the Nippon Sheet Glass (NSG) Group, which has interests in the: Automotive (original equipment, and aftermarket replacements), Technical and Architectural (displays, solar energy, optoelectronics, new building, and refurbishment glass) glass sectors. In 2017, the NSG Group posted revenue of approximately £4.2 billion and employed about 27,000 people worldwide.

PREMIER FOODS PLC web: www.premierfoods.co.uk

The UK's largest food producer. Premier Foods makes many of the UK's leading brands, including: Ambrosia, Angel Delight, Batchelors, Birds, Bisto, Campbell's, Crosse and Blackwell, Hartley's, Haywards, Homepride, Hovis, Lyons, Mothers Pride, Mr Kipling, Oxo, Paxo, Quorn, Robertson's, Sarson's, Sharwood's, Smash, and Sun-Pat. In 2017, Premier Foods employed 4,000 people in the UK and posted revenue exceeding £767 million.

PROCTER AND GAMBLE UK LTD web: www.pg.com

The world's third largest packaged consumer goods manufacturer based on 2011 revenue. Procter and Gamble produces beauty and grooming, and household care products. Their bestselling brands include: Gillette, Braun, Pantene, Tampax, Oral-B, Crest, Head and Shoulders, Vicks, Duracell, Bounty, Cascade, Ariel, Pampers, Tide, Febreze, Bold, Wella, Olay, Old Spice, Vidal Sassoon. In 2017, Procter and Gamble posted revenue of £50.3 billion and employed approximately 95,000 people worldwide.

RENOLD PLC web: www.renold.com

A world-class manufacturer of precision engineered chains and gears. The Renold Plc group is composed of Renold Chain, and Renold Torque Transmission. Lifting chain from Renold features in one in three fork lift trucks produced worldwide, as well as: theme park rides, water treatment plants, cement mills, agricultural equipment, and mining facilities. Renold Gears provides gearing and coupling solutions for the energy, transport, and materials handling industries. In 2017, Renold Plc posted revenue of over £180 million and employed people 2,100 people worldwide.

ROLLS ROYCE PLC web: www.rolls-royce.com

A world leading provider of power systems and related services. Rolls Royce has a strong position in a range of markets, including: civil aerospace, defence aerospace, marine, energy, and nuclear. The civil aerospace division currently has over 14,000 engines in service, powering more than 5.5 million flights per year. Their products are found in the smallest of unmanned aerial vehicles right up to the Airbus A380. In 2017, Rolls Royce posted revenue of £16.3 billion and employed 50,000 people around the world.

SPRINGFIELDS FUELS LTD web: www.nuclearsites.co.uk

Springfields Fuels Ltd manufactures fuel products for nuclear power stations. Services provided include the production of AGR and Magnox fuel, conversion services for Uranium Hexafluoride, and the processing of residues. Springfields Fuels is owned by the Westinghouse Electric Company LLC, which is owned by the Toshiba Corporation. In addition to its other operations, Toshiba is a world leader in the nuclear energy sector and a leading supplier of nuclear plant products and technologies. In 2017, the Westinghouse Electric Company LLC employed about 10,000 people worldwide and posted revenue of approximately £2.9 billion.

TRINITY MIRROR PRINTING LTD web: www.trinitymirror.com

One of the UK's largest printing businesses, offering: newspaper and magazine printing, contract publishing, finishing, and distribution services. Trinity Mirror Printing is the print services arm of Trinity Mirror Plc., the UK's largest newspaper publisher. Trinity Mirror Plc. publishes: the Daily Mirror, the Sunday Mirror, the People, and 130 regional newspapers. In 2017, Trinity Mirror Plc. posted revenue of £623 million and employed 5,000 people in the UK.

UNILEVER PLC web: www.unilever.co.uk

The world's third largest consumer goods manufacturer based on 2011 revenue. Unilever produces food, beverages, cleaning agents, and personal care products. Their bestselling brands include: Wall's, Solero, Hellmann's, Stork, Brylcreem, Lipton, Flora, Carte D'Or, Colman's, Vienetta, Peperami, Domestos, Radox, Bertolli, Pond's, Magnum, Cornetto, Surf, Brut, Vaseline, Impulse, Comfort, TRESemme, PG tips, Elmlea, Sure, Knorr, Ben & Jerry's, Persil, Timotei, Lynx, Dove, Pot Noodle, Marmite, and Bovril. In 2017, Unilever posted revenue of approximately £48.5 billion and employed about 169,000 people worldwide.

UNITED BISCUITS web: www.unitedbiscuits.com

A global leader in branded snacks manufacturing. United Biscuits manufactures some of the world's best known sweet and savoury snack brands, including: McVitie's, Jacob's, KP, Hula Hoops, Frisps, Brannigan's, Royster's, Nik Naks, Space Raiders, Twiglets, Phileas Fogg, Skips, Mini Cheddars, McCoy's, Penguin, Fruit & Form, Delacre, BN, and Jaffa Cakes. In 2017, United Biscuits posted revenue exceeding £1 billion and employed approximately 7,000 people in Europe.

VAUXHALL MOTORS LTD web: www.vauxhall.co.uk

A British automotive manufacturing company. Vauxhall produces a range of cars, vans, and SUV's and is the second biggest selling automobile brand in the UK. Their range includes the Vauxhall Astra, one of the top five most popular cars ever sold in the UK. Vauxhall is a subsidiary of Adam Opel AG, which itself is a subsidiary of General Motors. As a result Vauxhall Motors is also known as General Motors UK Ltd. In 2017, General Motors posted revenue of approximately £112.8 billion and employed over 180,000 people worldwide.

WARBURTONS LTD web: www.warburtons.co.uk

A family owned British baking company. Warburtons is the second biggest selling brand in the UK. They produce five categories of products: bread, rolls, bakery snacks, gluten free, and weight watchers. The company has a 24% share of the UK bread market, producing 800 million loaves, wraps, crumpets, pancakes, and bread rolls per year. In 2017, Warburtons employed approximately 4,500 people across Europe and posted revenue of £574 million.

Appendix Two - Service Providers of North West England

ALLPORT web: www.allport.co.uk

Allport is one of the United Kingdom's largest freight forwarding and logistics companies. Every day Allport moves millions of kilogrammes of cargo through its global freight network. Shipments handled include items ranging from clothing to books to advanced medical equipment. Each day the company's UK network manages and transports over 5 million kilogrammes of cargo by land, sea, and air on behalf of about 3,000 customers.

In 2010, Allport merged with its key partner CS Logistics Holdings Ltd and in doing so created a global presence employing over 20,000 people. These people operate out of 450 offices worldwide, packing, handling and transporting cargo every day for 3,000 customers in a range of sectors. In 2017, the group posted combined revenues exceeding £620 million.

ATLANTIC CONTAINER LINE (ACL) web: www.aclcargo.com

ACL was Europe's first containership operator. They are a specialised carrier of project and oversized cargo, containers, heavy equipment and vehicles. Currently the company deploys the world's five largest Roll-on Roll-off/Containerships and is building replacement vessels that are significantly larger, more fuel efficient and more environmental friendly.

ACL is part of the Grimaldi Group. The Grimaldi Group is composed of eight shipping companies, these are: Atlantic Container Line (ACL), Malta Motorways of the Sea (MMS), Minoan Lines, Atlantica di Navigazione, Grimaldi & Suardiaz Lines, Inarme, Grimaldi Compagnia di Navigazione, and Finnlines.

With a fleet of about 100 vessels, Grimaldi Group provides maritime transport services for rolling cargo and containers moving between Northern Europe, the Mediterranean, the Baltic Sea, West Africa, North and South America. In 2017, the Grimaldi Group employed over 1,000 people worldwide and posted revenue of approximately £2 billion.

BIBBY DISTRIBUTION LTD web: www.bibbydist.co.uk

One of the top logistics providers in the United Kingdom, specialising in providing contract logistics, warehousing, distribution, systems integration, and added value services. Operating a core fleet of over 2,000 road vehicles the company is responsible for over 45 million miles of freight traffic movements on the roads of the UK each year.

Bibby Distribution is a subsidiary of the Bibby Line Group. Bibby Line Group has interests in shipping, marine services, contract logistics, financial services, offshore services, and retail. In 2017, Bibby Line Group posted revenue of approximately £1 billion and employed over 4,000 people worldwide.

BISHOPSGATE (TENESO Europe) web: www.bishopsgate.co.uk

Bishopsgate is a European leader in specialist transportation and distribution. The company is part of the TENESO (TEchnical NEtwork SOlution) network. Bishopsgate provides delivery, positioning, installation, storage, and integrated logistics expertise for fragile, sensitive or outsized equipment for the IT, telecommunications, banking, medical, office, and fitness industries. The company handles in excess of 100,000 consignments each year.

Bishopsgate is a wholly owned subsidiary of the UK based, and highly acclaimed home removals company, Anthony Ward Thomas Master Removers. In 2017, Anthony Ward Thomas Master Removers employed approximately 300 people and posted revenue of over £22 million.

CEVA LOGISTICS web: www.cevalogistics.com

One of the world's leading logistics companies. CEVA provides a range of services, including: freight forwarding, contract logistics, transportation management, and distribution management. The company has significant experience in the automotive and tyres, technology, industrial, consumer and retail, publishing, energy, aerospace, and healthcare sectors. In 2017, CEVA Logistics employed more than 56,000 people worldwide and posted revenue of over £6.9 billion.

CHINA AIRLINES CARGO web: https://cargo.china-airlines.com

China Airlines Cargo is an airfreight carrier that operates worldwide. Besides general cargo the company also carries: dangerous goods, live animals, perishables, valuable cargo, antiques, and precision equipment. China Airlines Cargo is the freight arm of China Airlines, the flag carrier airline of the Republic of China.

China Airlines is owned by China Airlines Group (a conglomerate of transport and related service companies) which is owned by the China Aviation Development Foundation, which is owned by the government of the Republic of China. In 2017, China Airlines posted revenue of approximately £3.5 billion and employed over 12,500 people worldwide.

COLAS RAIL web: www.colasrail.co.uk

Colas Rail is a national rail freight operator scheduling over 50 freight trains per day. At present they operate freight transport in both the United Kingdom and France. Currently their focus is on the movement of bulk products, aggregates, and raw materials. However, their service also extends to intermodal, general, and specialist freight.

Colas Rail is part of the Colas Group, a global leader in infrastructure construction and maintenance. The Colas Group is in turn part of the French multi-national industrial group Bouygues. In 2017, the Colas Group employed over 55,000 people worldwide and posted revenue of £11.7 billion.

DIRECT RAIL SERVICES (DRS) web: www.directrailservices.com

DRS are one of the United Kingdom's leading rail operators. They provide specialist freight, intermodal freight, third party maintenance, infrastructure support, resource hire, training, and consultancy services. Direct Rail Services has industry leading expertise in the movement of spent nuclear fuel, decommissioning waste, and nuclear construction support.

Direct Rail Services are the only operator in the UK with approval to carry nuclear material by rail. Since the company started to transport nuclear materials by rail, shipments have been carried over 10 million miles without any incident involving the release of radioactive material.

DRS also operates in the general freight market where its reputation for delivering a safe, secure, and reliable service has been acknowledged by some of the key stakeholders in the region. At present, or in the recent past, DRS have serviced contracts for JG Russell, Tesco, the Malcolm Group, Asda, the Royal Navy, and Sellafield Ltd.

Direct Rail Services are a wholly owned subsidiary of the Nuclear Decommissioning Authority (NDA). In 2017, DRS employed over 400 people in the UK and posted revenue of about £75 million.

DSV web: www.dsv.com

DSV is a provider of transport, freight forwarding, and logistics solutions. The company has its own global network as well as an international network of partners. DSV is divided into three divisions, these are: road, air & sea, and solutions.

DSV Road is one of the three leading logistics providers in Europe. With more than 17,000 trucks they are able to carry goods in a fast, efficient, flexible manner throughout Europe. DSV Air & Sea offers a wide variety of air and sea routes as well as a range of flexible schedules to and from all parts of the world. Annually they handle more than 730,000 TEUs of sea freight and 260,000 tons of air freight.

In comparison, DSV Solutions works with partners to specifically design and deliver logistics solutions to meet niche requirements which are not addressed by DSV's other divisions. DSV Solutions also adds value to its clients' supply chains by increasing operational and cost efficiency. In 2017, DSV posted revenue of approximately £9.3 billion and employed about 47,000 people worldwide.

EDGE WORLDWIDE LOGISTICS (EWL) web: www.edgewl.com

Edge Worldwide Logistics is a UK based independent freight forwarder. The company provides a range of services, including: sea freight, air freight, UK & European road and rail freight, UK distribution and warehousing, reefer logistics, supply chain consultancy, shipment consolidation, product sourcing and placement.

EWL specialises in the import and export of frozen foods as well as the, customs, duty issues and services associated with this trade. In addition to this the company has implemented bespoke logistics solutions for customers in a range of specialist markets, including: foodstuffs, toys and giftware, fashion, and chemicals.

As well as general cargo, EWL also has experience in delivering roll-on roll-off, heavy lift, break bulk, out of gauge, hazardous, and restricted cargoes. In 2017, Edge Worldwide Logistics posted revenue of over £23 million and employed a total of 40 staff in the United Kingdom and Thailand.

FRANCE LINE INTERNATIONAL LTD web: www.francelinetransport.co.uk

France Line International Transport Ltd is an independent company specialising in the transportation of goods in full or part loads between the United Kingdom and France. France Line advertises itself as "The French Road Freight Specialist". They offer freight services to all of the countries in Europe but, with 30 years of experience in the French market, France is the heart of their business.

France Line was initially set up to organise the back loading to France of empty trailers in the UK that belonged to French haulage companies. They now work directly with a number of manufacturers and freight forwarders in both France and the United Kingdom. The company has specific expertise in the chemicals, foodstuffs, pharmaceuticals, packaging, retail goods, aerospace, plastics, machinery, steel and other metals, building products, and electronics sectors.

France Line tailors their transport services to the needs of its customers. They have an extensive network of agents and depots throughout France and offer a comprehensive freight service. In 2017, France Line employed 5 people and posted revenue of about £1.6 million.

GB RAILFREIGHT (GBRf) web: www.gbrailfreight.com

GB Railfreight is a rail freight operator in the United Kingdom. The company offers a broad range of services, including: the testing of locomotives and delivery of rolling stock for manufacturers, handling rail freight on industrial sites (oil, chemical, steel, automotive), delivering rail equipment (ballast, sleepers and rail) for Network Rail, maintenance of equipment (de-icing, leaf clearance), and rail freight transport on a national and international scale.

Freight shipments transported by GBRf include: metals, bulk cargoes (coal, steel), construction materials, petrochemicals, and intermodal cargoes. GBRf is a leading provider of intermodal container transport to and from ports all across the United Kingdom. Currently GB Railfreight’s intermodal services range from long term, contracted movements to spot booking services on a ‘turn up and go, book today for a train tomorrow’ basis.

Around 60% to 70% of all containers moved by the company are delivered ‘door-to-door’, direct to the customer. GBRf’s strategic vision for its intermodal network is to expand to cover more ports in the United Kingdom. This expansion will be done with the view of including more ports in the North West and North East of England. When complete an improved level of national coverage will be delivered.

GB Railfreight is part of Europorte SAS, a group that offers a range of integrated rail services under one brand at a European level. It is composed of: Europorte France, Socorail, Europorte Proximité, Europorte Channel, and GB Railfreight. Europorte SAS is the rail freight division of the Eurotunnel Group. In 2017, Europorte SAS employed 777 people in Europe and posted revenue of approximately £118 million.

GEFCO UK LTD web: http://uk.gefco.net

A large international logistics company ranked among Europe's top ten transport and logistics firms. GEFCO specialises in logistics for the automotive sector. They imported approximately 220,000 vehicles in to the United Kingdom during 2017. The company's logistics expertise is also available to the broader manufacturing industry. At present they have contracts with organisations in the: aeronautics, capital goods, and specialised retail sectors.

GEFCO UK is part of the GEFCO Group. The GEFCO Group operates over 600 international routes and is a wholly owned subsidiary of PSA Peugeot Citroën. In 2017, PSA posted revenue of approximately £57 billion and employed about 184,000 people worldwide.

HAPAG LLOYD (UK) LTD web: www.hapag-lloyd.com

Hapag Lloyd (UK) is the British arm of one of the world's largest container shipping companies. Hapag Lloyd operates liner services to all continents of the world. These services are provided by a fleet of over 220 container ships accompanied by an estimated container stock of more than 1,500,000 TEUs, including one of the world's largest and most modern reefer container fleets.

The owners of Hapag-Lloyd are the Albert Ballin consortium (77.96%, consisting of the City of Hamburg, Kühne Maritime, Signal Iduna, HSH Nordbank, M.M.Warburg Bank and HanseMerkur) and the TUI AG (22.04%, Europe's leading travel and tourism group). In 2014, Hapaq Lloyd merged with Compania Sud Americana de Vapores (CSAV) and in 2017 they merged with the United Arab Shipping Company (UASC). In 2017, Hapag Lloyd employed over 13,000 people worldwide and posted revenue of approximately £8.7 billion.

KUEHNE + NAGEL LTD web: www.kn.portal.com

Kuehne + Nagel Ltd are a global transportation and logistics company. The services they provide include: sea freight, air freight, road and rail logistics, contract logistics and integrated logistics. Kuehne + Nagel are amongst the top six European providers of road and rail logistics, the top 3 global sea and air freight forwarders, and the top three global contract logistics providers.

Kuehne + Nagle provide logistics services to a variety of sectors, including: aerospace, automotive, fast moving consumer goods (FMCG), high tech and consumer electronics, retail, industrial goods, oil and gas, pharmaceuticals and healthcare. In 2017, Kuehne + Nagel Ltd posted revenue of about £14.4 million and employed approximately 76,000 people worldwide.

LLW REPOSITORY LTD web: www.llwrsite.com

The Low Level Waste Repository (LLWR) is the United Kingdom's national low level radioactive waste disposal facility. The role of the LLWR is to ensure that low level radioactive waste generated in the UK is disposed of in a way that protects people and the environment. The LLWR has safely disposed of low level waste for over 50 years.

Low level waste arises mainly from the civil nuclear industry during power generation and decommissioning activities. It is also generated by research, healthcare, defence, oil and gas industries. Low level waste consists of a wide range of materials used in a radioactive operating environment such as paper, cardboard, plastic, protective clothing, soil, rubble, and metal.

The LLWR site is owned by the Nuclear Decommissioning Authority (NDA) but managed by LLW Repository Ltd on their behalf. LLW Repository Ltd is part of UK Nuclear Waste Management Ltd, a consortium of URS (one of the world's largest nuclear waste programme management contractors), Studsvik (a Radiation Protection Advice body), Areva (the world's largest nuclear service provider), and Serco (a British government services company).

More than £100 million has been invested in the infrastructure of the site over the past decade to maintain the facility's operation. From the present day to 2080, when the final site clearance is achieved, £252 million (at present day values) will need to be invested to accommodate the storage of LLW. In 2017, LLW Repository Ltd employed about 130 people in the UK and contributed approximately £5 million to the local economy.

<u>MACANDREWS</u> (CMA CGM GROUP) web: www.macandrews.com

MacAndrews is a provider of ocean and land transportation services, specialising in 45 foot high cube pallet wide containers. The company's container fleet is made up of over 9,000 TEUs in a wide array of sizes and configurations. This allows them to provide supply chain solutions tailored to the individual needs of customers.

MacAndrews has a particular emphasis on the short sea, Intra-European intermodal market. Their core geographical sectors are the United Kingdom, Ireland, Spain, Portugal, Holland, Poland, Scandinavia, and Russia. The company is the largest user of the Spanish Rail Network (RENFE) where they specialise in the fresh and frozen produce industries and handle daily collections from a number of suppliers.

MacAndrews is part of the CMA CGM group. CMA CGM is the world's third largest container shipping group and France's number one. CMA CGM regularly services a network of over 170 worldwide shipping routes. They were one of the first global shipping operators to take control over the whole logistics chain offering a door-to-door service. In 2017, the CMA CGM Group employed 29,000 people worldwide and posted revenue of £21.1 billion.

<u>MAGNOX LTD</u> web: www.energysolutions.com

Magnox Ltd is the management and operations contractor responsible for 10 nuclear sites and one hydroelectric plant in the United Kingdom. They are responsible for electricity generation on these sites, where they operate under contract to the site owner, the Nuclear Decommissioning Authority.

The objective of Magnox is to maximise the value obtained from its remaining electricity generating sites and safely bring to an end 50 years of Magnox electricity generation in the United Kingdom. This will be achieved through the completion of a programme to deal with the remaining spent fuel and in so doing avoid leaving behind a legacy of this material.

Magnox is a Site Licence Company (SLC) owned by Reactor Sites Management Company Ltd, which is in turn owned by EnergySolutions. EnergySolutions is an international nuclear services company specialising in the safe recycling, processing, and disposal of nuclear materials. In 2017, EnergySolutions employed over 1,500 people, mostly in the United Kingdom and the United States, and posted revenue of about £347 million.

MAERSK LINE (UK) LTD web: www.maerskline.com

Maersk Line (UK) is the British arm of Maersk Line, the world's largest ocean carrier of containerised freight. The Maersk Line fleet is made up of over 600 vessels accompanied by an estimated container stock of 3,800,000 TEUs. This ensures a reliable and comprehensive worldwide coverage. Maersk Line is consistently recognized as the most reliable container shipping company.

Maersk Line is part of the A.P. Moller - Maersk Group, a worldwide conglomerate. In addition to owning one of the world's largest shipping companies the Maersk Group are also involved in a wide range of activities in the energy, logistics, retail, and manufacturing industries. In 2017, the A.P. Moller - Maersk Group employed about 88,000 people worldwide and posted revenue of approximately £24 billion.

MALCOLM GROUP web: www.malcolmgroup.co.uk

The Malcolm Group is a logistics company based in Scotland. Through its Malcolm Logistics and Malcolm Rail divisions, the group offers fully integrated road, rail, warehousing, and supply chain and terminal management services. These services are provided in the United Kingdom, France, Holland, Belgium, and Germany.

The Malcolm Group offers a range of intermodal services handling UK and European rail and road movements for customers in the manufacturing, logistics, and retail sectors. These include: ASDA, Ikea, Diageo, Sainsbury's, British Gypsum, and UPM Kymmene. Rail services provided by the group are done so in co-operation with Direct Rail Services.

Other group activities include construction and vehicle maintenance. The maintenance services provided include: MOT testing, tachograph and road speed limiter installation, engine and bodywork repair, and recovery for vans, minibuses, buses, lorries, and specialized vehicles. In 2017, the Malcolm Group employed about 2,000 people and posted revenue of over £150 million.

MEDITERRANEAN SHIPPING COMPANY web: www.mscuk.com

The Mediterranean Shipping Company (MSC) is a privately owned, Switzerland based company. It is the second largest container shipping company in the world. It has a fleet of over 430 vessels that serve 270 of the world's major ports. The company offers its customers a wide range of services through its global network of agents. Services provided include: transport, distribution, warehousing, customs clearance, and a range of value added services.

Mediterranean Shipping Company (UK) Ltd is the United Kingdom's MSC agent. In addition to the standard services provided by MSC, Mediterranean Shipping Company (UK) Ltd also offers supply chain management, cargo consolidation, and independent road and rail transportation services. In 2017, MSC employed about 28,000 people globally and generated revenue of approximately £21.9 billion.

P&O FERRIES web: www.poferries.com

P&O Ferries is one of Europe's leading providers of tailor made transportation and logistics services, specialising in the design and delivery of innovative, flexible, supply chain solutions. Through an extensive network of operational bases spread throughout Europe, as well as a network of specialist partners, the company provides a mix of services, including: freight management; warehousing services; road, deep sea, air, and intermodal freight.

P&O Ferries operates a range of intermodal freight services with both European and global reach. Sectors served, include: automotive, chemicals, fast moving consumer goods (FMCG), waste management, industrial, retail, paper and packaging. Two thirds of the total intermodal volume of freight handled by the company each year is carried by rail.

The modern trailer fleet operated by P&O Ferries has a variety of specifications, including: Euroliners (for high value goods and chemicals), Reefers (for temperature controlled goods), Mega High Cubes (for automotive) and Tautliners (for general cargo).

The company is owned by Dubai World. Dubai World is an investment company that manages the Dubai government's portfolio of projects and businesses. In 2017, Dubai World employed over 5,000 people and posted revenue of approximately £14 billion.

SEA TRUCK FERRIES web: www.seatruckferries.com

Seatruck is the only dedicated freight ferry company on the Irish Sea. The company has experience handling unaccompanied and accompanied trailers, trade vehicles, hazardous cargo, abnormal loads, as well as passengers. Seatruck's fleet on the Irish Sea is composed of seven purpose built high speed, high capacity, freight vessels.

Seatruck Ferries is part of the Clipper Group, a leading international shipping company. Clipper owns, operates, and manages a fleet of about 200 vessels. These vessels are mainly in the bulk, multi-purpose, project, chemical, and product transportation sectors. In 2017, the Clipper Group employed 200 shore based people, more than 1,400 seafarers and posted revenue of approximately £210 million.

STENA LINE web: www.stenalinefreight.com

Stena Line is one of the world's largest ferry operators. The company operates ferries in the Baltic Sea, the North Sea, and the Irish Sea. The 37 vessels operated by Stenna Line connect nine countries through twenty two ferry routes. Stena Line is owned by Stena AB, an international group that runs passenger and freight services, together with activities in offshore, shipping, property, and finance.

Stena AB is itself a part of the Stena Sphere. The Stena Sphere consists of three wholly owned companies, these are: Stena Sessan AB (involved in pharmaceuticals, electronics, tanker shipping, and ferries), Stena Metall AB (involved in recycling and waste processing) and Stena AB. In 2017, the Stena Sphere posted revenue of approximately £1 billion and employed about 5,000 people in Europe.

SWISSPORT CARGO SERVICES UK web: www.swissportuk.com

Swissport Cargo Services UK is the freight handling division of the British arm of Swissport International. Swissport International is itself owned by PAI partners, a major European private equity house and the leading private equity investor in the French market.

Swissport International offers a range of value adding airport services to its customers. The complete list of services provided by Swissport International is extensive. These include, but are not limited to: aircraft maintenance, aircraft servicing and cleaning, airport security, aircraft handling, cargo and mail handling, passenger and baggage handling, flight operations and crew administration, aircraft loading, and load planning.

Swissport International is globally active. Each year they provide ground services for over 70 million passengers and 3.2 million tonnes of cargo for 650 client companies. One of these clients is Virgin Atlantic. Swissport provides Central Load Planning services, across the world, for Virgin Atlantic's fleet. In 2017, Swissport International employed over 68,000 people and posted revenue of approximately £2.5 billion.

VIRIDOR LTD web: www.viridor.co.uk

Viridor Ltd is one of the leading UK recycling, renewable energy, and waste management businesses. Each year the company recycles two million tonnes of materials and produces over 760 gigawatt hours of renewable energy. In total Viridor transports and manages over eight million tonnes of materials for customers from all sectors across the United Kingdom.

Viridor Ltd is part of the Pennon Group Plc. The Pennon Group also owns South West Water who provide water and sewerage services in parts of Cornwall, Devon, Dorset, and Somerset. In 2017, the Pennon Group employed over 4,750 people in the UK and posted revenue of approximately £1.4 billion.

WINCANTON PLC web: www.wincanton.co.uk

A UK supplier of transport, warehousing, and specialist services, including: packing, fleet management, production logistics, retail store support, and 4PL. These services cover the supply chain from raw materials to returns management in the consumer goods, construction, defence, energy, public sector, water, milk, and bulk food sectors.

Wincanton's fleet is composed of 8,000 vehicles, including: trucks, trailers, and specialist skeletal trailers, tankers, and construction vehicles. In 2017, Wincanton employed 17,700 people in the United Kingdom and posted revenue of approximately £1.2 billion.

Appendix Three - Infrastructure Providers of North West England

ASSOCIATED BRITISH PORTS web: www.abports.co.uk

The United Kingdom's leading ports group. Associated British Ports (ABP) plays a major role in serving the United Kingdom's container and roll-on roll-off trade. The company owns twenty one ports across the United Kingdom as well as a range of transport related businesses. These include Hams Hall the country's busiest inland rail terminal.

Located near Birmingham, Hams Hall is one of the UK's most important intermodal freight terminals, handling approximately 200,000 TEUs per year. Of the total twenty one ports owned by ABP sixteen are linked to the national rail network. On average these ports generate approximately 100 rail freight movements per day.

Within the North West region of England ABP owns the Port of Silloth, Port of Barrow, Port of Garston, and Port of Fleetwood. These ports handle a range of cargoes, including: general cargo, dry bulk, green energy, steel, forest products, and liquid bulk. In 2017, ABP posted revenue of £544 million and employed about 2,500 people across the UK.

CUMBRIA COUNTY COUNCIL web: www.portofworkington.co.uk

Cumbria County Council owns the Port of Workington and its associated rail freight terminal. The council itself is a local government body composed of elected representatives. In 2011, approximately 9,000 people in the Cumbria region of England were employed by the council, making it one of the region's biggest employers. This number is expected to decrease over the next few years as budget cuts to regional government take effect.

Cumbria County Council is responsible for providing a range of services for local people, visitors, and businesses within the Cumbria region of North West England. Services provided by the council include, but are not limited to: education, libraries, road maintenance, social services, waste disposal, and recycling. The 2017/18 controllable budget provided for the council to deliver these services was approximately £383 million.

DB SCHENKER web: www.dbschenker.com

DB Schenker is comprised of DB Schenker Rail and DB Schenker Logistics. Based on revenues and performance, they are Europe's largest rail freight company and the world's second largest transportation and logistics services provider respectively. DB Schenker Logistics holds top positions in the global air, ocean, and road freight sectors. Each year it transports over 1.1 million tons of air freight and over 1.7 million TEUs of ocean freight.

DB Schenker Rail has a fleet comprised of around 109,000 freight cars and 3,587 locomotives. In 2017, this fleet shipped over 450 million tons of rail freight. Within the North West region of England, DB Schenker Rail owns a rail freight terminal at Trafford Park (Manchester). This is part of a global network that links a variety of markets through seamless, environmentally friendly, intercontinental logistics chains.

The longest corridor in DB Schenker's rail network connects Leipzig (Germany) and Shenyang (China). This route transports automotive parts, over 11,000 kilometers, on behalf of BMW. In total, DB Schenker Rail moves about 250 trains with finished vehicles and supplier parts through Europe each day. This adds up to 3 million vehicles being delivered by the company each year.

The automobile, building materials, chemicals, consumer goods, industrial, metals and coal, mineral oil, and intermodal sectors are DB Schenker Rail's core areas. In addition to this, the company also has its own companies, subsidiaries, affiliates, and joint ventures providing rail based transport solutions to an even broader range of markets.

DB Schenker is the transportation and logistics division of Deutsche Bahn AG. The Deutsche Bahn Group's other interests are in the passenger transport industry where Europe-wide its trains and buses carry over ten million passengers daily. In 2017, Deutsche Barn AG posted revenue of about £36 billion and employed approximately 295,000 people worldwide.

FREIGHTLINER GROUP web: www.freightliner.co.uk

Freightliner Group is the United Kingdom's largest containerized rail traffic operator. Freightliner is an intermodal rail freight and logistics company that provides a complete port to door service through its fleet of over 130 locomotives, 3500 rail wagons, and 300 road vehicles. Sectors catered for include: intermodal containers, minerals, aggregates, and bespoke heavy haul.

Freightliner handles 65% of the UK's rail borne containers, that is 700,000 containers per year. Within the North West of England, Freightliner operates terminals at the Port of Garston

(Liverpool), Seaforth Container Terminal (Liverpool), and Trafford Park (Manchester). In 2017, Freightliner Group posted revenue of £607 million and employed approximately 2,500 people in the United Kingdom, Poland, and Australia.

HALTON BOROUGH COUNCIL web: www.merseygateway.co.uk

A local government body composed of elected members representing the Borough of Halton. Halton is part of the Liverpool City Region. In 2017, approximately 6,000 people were employed by Halton Borough Council. However, this number is expected to decrease over the next few years as budget cuts to regional government take effect.

Halton Borough Council is responsible for providing a range of services for local people, visitors, and businesses within the Halton area of the Liverpool City Region. Services provided by the council include, but are not limited to: education, libraries, road maintenance, social services, waste disposal, and recycling. The total 2017/18 budget provided for the council to deliver these services was about £110 million.

Halton Borough Council is responsible for the maintenance of the Silver Jubilee Bridge. The bridge is a four lane road bridge of 482 metres in length. It crosses both the River Mersey and the Manchester Ship Canal, joining Runcorn on the south side of the Mersey with Widnes on the north side. The Silver Jubilee Bridge, also known as the Runcorn Bridge, has been designated by English Heritage as a Grade two listed structure.

When the Silver Jubilee Bridge was built in 1961 it was designed to accommodate approximately 8,000 vehicles per day. In 1971, the bridge was expanded to alleviate congestion. Its new design was expected to handle approximately 40,000 vehicles per day. Today, the bridges level of use has increased to such a degree that 80,000 vehicles use it each day. Ten times the number that it was originally designed for.

The Silver Jubilee Bridge is subject to frequent congestion. To alleviate the current situation a new river crossing, known as the Mersey Gateway Bridge, was constructed in 2017. The Mersey Gateway is a one kilometre long, six lane, toll, road bridge located upstream of the Silver Jubilee Bridge. The new bridge accommodates a significantly higher level of traffic than the existing one and forms the centrepiece of a ten kilometre long route that links Merseyside with the national motorway network in Cheshire. The cost for the project was £600 million.

HIGHWAYS ENGLAND web: www.highways.gov.uk

Highways England operates in England on behalf of the Secretary of State for Transport. They operate, maintain, and improve the strategic road network. This network is made up of motorways and major 'A' roads valued at over £88 billion. England's strategic road network carries a third of all road traffic and two thirds of all heavy goods vehicle (HGV) traffic transported within the nation.

The total budget allocated to Highways England for carrying out its responsibilities varies from year to year. In 2017/18 the organisation spent £3.4 billion. In 2017, Highways England employed approximately 4,700 people across England.

LANCASTER PORT COMMISSION web: n/a

Lancaster Port (Glasson Dock) is a Trust Port that is run by the Lancaster Port Commission. Trust Ports differ from company or local authority owned ports in that they are independent bodies, each governed by their own legislation, and controlled by an independent board. There are no shareholders or owners and any monetary surplus is put back into the port for the benefit of the stakeholders of the trust.

The trust stakeholders are the port's employees and all those who use its facilities; as well as all the individuals, organisations, and groups who have an interest in the operation of the port. Unfortunately, Lancaster Port Commission's employee numbers and revenue data for recent years is not publicly available.

MANCHESTER AIRPORTS GROUP web: www.magworld.co.uk

Manchester Airports Group (MAG) is the largest UK-owned airport operator, handling over half a million tonnes of air freight every year. The group also owns car parking, security, fire fighting, engineering, advertising, and motor transport businesses at its airports. In the North West region of England MAG owns Manchester Airport.

Manchester Airport is the global air gateway to the North of England. Manchester Airport has direct flights to 200 destinations worldwide. The World Freight Terminal located at the airport regularly handles freight for over 100 logistics companies. MAG also owns airports elsewhere in England, the most significant of which is East Midlands Airport.

East Midlands Airport is the United Kingdom's busiest pure freight airport, with direct flights to more than 90 destinations. It is a major air hub for Royal Mail, as well as a distribution centre for DHL and UPS. MAG's core cargo business is at East Midlands Airport. The airport represents 70% of the group's cargo business by volume.

MAG also includes the commercial property company, MAG Developments. This has a £350 million portfolio of over 200 properties covering 5,000 acres across the three airports owned by MAG. MAG Developments is a leading party in the £650 million 'Airport City' project at Manchester Airport. This project will from the core of the newly designated Manchester Airport Enterprise Zone.

Manchester Airports Group is privately managed on behalf of its shareholders, the ten local authorities of Greater Manchester. These are: Manchester City Council (55%), Salford City Council (5%), the Borough Councils of Bolton, Bury, Oldham, Rochdale, Stockport, Tameside, Trafford, and Wigan (5% each).

In 2017, Manchester Airport Group employed about 40,000 people directly and posted revenue of approximately £740 million. However, the group's activities supported a further 130,000 jobs across the United Kingdom and contributed £3.2 billion to the nation's economy.

NETWORK RAIL web: www.networkrail.co.uk

Network Rail owns, operates, maintains, and develops most of the rail infrastructure in Great Britain. It does not own or operate any rolling stock, and is not responsible for railway infrastructure in Northern Ireland or for the majority of track used by London Underground.

The rail infrastructure in question includes: 20,000 miles of track and accompanying signals, 40,000 bridges and tunnels, over 2,500 stations, and innumerable level crossings and viaducts. Most of the stations are leased to train operators but 17 major stations are operated by Network Rail. Within the North West region of England these include Liverpool Lime Street and Manchester Piccadilly.

Network Rail operates within a mandate from the Government to improve the safety, reliability, and efficiency of the railway. Route Utilisation Strategies (RUSs) have been produced to balance supply and demand and set out a long term vision for improvements across the network. Between 2009 and 2014 a £24 billion programme of investment in the railway took place.

Every year approximately 100 million tonnes of freight is transported on Britain's railways. Network rail employs approximately 37,000 people to provide the infrastructure that makes this possible. In 2017, Network Rail posted revenue of over £6.5 billion.

THE STOBART GROUP web: www.stobartgroup.co.uk

The Stobart Group is a national leader in the United Kingdom's multimodal logistics, warehousing, and biomass fuel sectors. In addition the group also operates in the property development, port, airport, and civil engineering sectors. With regards to the provision of freight handling infrastructure in the North West region of England Stobart Air and Stobart Rail are the divisions of the Stobart Group of the most significance.

Stobart Air owns the Carlisle Lake District Airport. Improvement plans for the development of the airport are aimed at producing a strategic northern transport centre serving Scotland and the Borders region. This will provide a northern link for scheduled services to and from Stobart's other airport at London Southend.

Within the North West region of England, Stobart Rail owns a rail freight terminal in Widnes that is often referred to as the Mersey Multimodal Gateway (3MG). The terminal is a world class distribution centre connecting the markets of the North West of England by rail to the other key ports in the country as well as the Channel Tunnel.

Stobart Group is highly successful; it is one of the United Kingdom's best known businesses. In 2017, Stobart employed about 1,600 people across the United Kingdom and posted revenue of approximately £130 million.

THE PEEL GROUP web: www.peel.co.uk

The Peel Group is a leading infrastructure, transport and real estate investment company in the United Kingdom. The group has investments in ports, airports, media, energy, land developments, environmental assets, hotels, utilities, and advertising.

Major Peel Group developments in the North West of England include: The Castlefield Basin scheme, Ellesmere Quays, Ince Park, Liverpool 2, MediaCityUK, Ocean Gateway, Peel International Trade Centre, Peels Water, Port Salford, Salford Quays, and The Trafford Centre.

The Peel Group's main focus at present is the £50 billion Ocean Gateway development. This is a regeneration initiative spanning 50 years and aimed at planning and delivering major infrastructure projects in a 50 mile corridor connecting Manchester and Liverpool, the two biggest cities in the North West region of England.

With regards to the provision of freight infrastructure in the North West of England the Peel Ports and Peel Airports divisions of the Peel Group are of the most significance. Peel Airports owns Liverpool John Lennon Airport. Peel Ports owns the United Kingdom's second largest group of ports.

Peel Ports owns a number of strategically located gateways that serve the whole of the United Kingdom. In the North West region of England these include: Heysham Port, the Port of Liverpool, and the Manchester Ship Canal. Elsewhere in the country these gateways include: Clydeport, Medway, Belfast, and Dublin. These are connected to the rest of Europe by a number of shipping companies including the group's own short sea shipping lines (BG Freight Line and Coastal Container Line).

In 2017, Peel Group employed approximately 2,500 people across the United Kingdom. In the same year the group owned and/or managed assets approaching £7 billion in value as well as controlling an assorted portfolio of investments amounting to approximately £500 million in value.

Appendix Four - Maritime Infrastructure of North West England

PORT OF LIVERPOOL web: www.peelports.co.uk

Located at the mouth of the River Mersey the Port of Liverpool is located at the focal point of four of the regions motorways (M53, M62, M58, M57). These links allow ready access to major population centres throughout the country. In 2017, the Department for Transport recorded that the port handled 32,500,000 tonnes of freight.

Liverpool is owned and operated by the Peel Ports Group. The site has over 485 hectares of operational docks on both banks of the River Mersey. These facilities are capable of handling the full spectrum of vessels involved in modern freight transportation. This includes ferries operating in the Irish Sea trade and container ships from North America, China, India, Africa, Australia, the Middle East, and South America.

Capable of handling approximately 700,000 TEUs, the Port of Liverpool is ranked amongst the United Kingdom’s and Europe’s major container ports. The port is also involved in the handling of roll-on roll-off cargo. In 2017, the Department for Transport recorded that the Port of Liverpool handled 537,000 units of unitised cargo.

Liverpool is the United Kingdom’s leading gateway for imports of grain and animal feed, and the export of metal for recycling. In addition, the port handles: timber and forest products, crude oil (for the Stanlow Refinery in Cheshire), coal (for Fiddlers Ferry Power Station), edible oils and fats, cocoa, steel, copper, aluminium and other metals, granite, chemicals, and general cargo.

The port was extended in 2016 to include a deep water, container terminal built in the River Mersey at a cost of £350 million. This development (Liverpool2) is able to simultaneously accommodate two of the new generation 13,500 TEU Post-Panamax container ships. With the addition of the new facility Liverpool's container capacity is increased to 1,500,000 TEUs. In 2017, the Department for Transport recorded that the port handled 700,000 TEUs of lift-on lift-off cargo.

The Port of Liverpool is also home to the United Kingdom's largest free zone, Liverpool Freeport. The zone currently has over 3 million sq ft of warehousing, with another 400,000 sq ft planned. When completed the port will have a total area over 4 million sq ft set aside for logistics operations.

MANCHESTER SHIP CANAL web: www.peelports.co.uk

The Manchester Ship Canal joins the two neighbouring cities of Liverpool and Manchester. The combined populations of these cities, not including their outlying settlements, total approximately 1 million people. In addition, there are ten motorways located within 10 miles of the canal. In 2017, the Department for Transport recorded that the Manchester Ship Canal handled 6,789,000 tonnes cargo.

The Manchester Ship Canal is owned by the Peel Ports Group. The canal begins 8 miles upriver from the Port of Liverpool (located at the mouth of the River Mersey) and ends 36 miles further east at Salford Quays in the heart of Greater Manchester. The Peel Ports Group often promotes the Port of Liverpool and the Manchester Ship Canal as a single entity.

The canal was originally built to accommodate the largest ocean going ships. However, ship sizes have since outgrown the canal. The maximum characteristics of a vessel currently able to reach the end of the canal (in Manchester) is length 161.5m, width 19.3m, and draught 7.3m.

The Canal provides bespoke and general berths and terminals along its full length. These handle cargoes such as containers, coal, chemicals, oils, and grain. Clusters of activity at Ellesmere Port, Runcorn Docks, Irlam, and Salford form focal points for freight operations. Companies that have recently been active in moving freight on the canal include: Essar, Tesco, Ineos, Cargill, Rank Hovis, Proctor and Gamble, BP, and Kingsland Wines.

A multi-million pound investment programme is currently being undertaken by the Peel Ports Group to create new developments at key points along the canal. This is being produced with a view to stimulating further growth in the waterborne trade sector of the region. Upon completion these developments will make the Manchester Ship Canal the North West's most comprehensive, inland, intermodal, solutions provider.

HEYSHAM PORT web: www.portofheysham.com

Located in Lancashire on the east coast of Morecombe Bay, Heysham Port is close to the United Kingdom's main west coast motorway (the M6) and has trunk road links to the motorway network. These links allow ready access to major population centres throughout the country. In 2017, the Department for Transport recorded that 4,630,000 tonnes of freight was handled by the port.

Heysham Port is owned and operated by the Peel Ports Group. The site covers an area of 48.5 hectares and has a 91m wide entrance leading to a harbour which is 213m wide, 730m long, and has a minimum depth of 4.1m. Heysham has three roll-on roll-off berths, two of which are equipped with ship-to-shore linkspan bridges for faster and smoother discharge and loading.

Heysham offers comprehensive facilities for a diverse range of cargo, but roll-on roll-off is the main cargo type moving through the port. In 2017, Heysham handled 452,400 units of unitized freight. With this in mind the port has separate marshalling areas capable of accommodating over 1,000 trailers and 550 cars.

The round-the-clock access that the port provides to Irish Sea ferry services from the Steam Packet Company, Seatruck Ferries, and Stenna Line makes Heysham key to the flow of freight from Ireland to the United Kingdom, and vice versa.

Heysham Port is also is home to one of Europe's major offshore industry supply bases. It provides logistics support to one of the largest gas fields in UK waters. The port allows 24 hour access for platform supply vessels and standby safety vessels. It also provides: 5,100m^2 of warehousing; cement, barite, bentonite silos; bunkering; carnage; workshops; storage compounds; and a helipad.

Among the major names in the offshore oil and gas industry to use the port are: Esso, Conoco, Fina, Kelt, BP, Hamilton Brothers, Marathon, Elf, Ranger, Global Marine, BHPP and Burlington.

PORT OF GARSTON web: www.abports.co.uk

Positioned on the north bank of the River Mersey, the Port of Garston is an ideal gateway to the North West of England’s industrial heartlands. The port is positioned at a hub in the motorway network, but also has access to the nationwide rail network through Freightliner’s Liverpool rail terminal.

The Port of Garston is owned and operated by Associated British Ports. The site covers an area of 80 hectares, with 40,000m2 of covered storage. The port can accommodate ships of up to

152.4m length, 19.2m beam, and 9m draft. Handling facilities are provided for dry bulk cargo (grain, ore, sand), general cargo, steel products, and scrap metal.

In 2017, the Department for Transport recorded that 613,000 tonnes of freight was handled by the port. Garston has a proven track record for meeting the requirements of major local companies such as Frank Armitt, and NW trading. The ability of the port to offer bespoke value added services is an additional string to their bow.

PORT OF BARROW web: www.abports.co.uk

Positioned on the south west coast of Cumbria, Barrow is served by both the national road and rail networks. The port has a history of ship building, especially submarines. It is also a significant feature of Britain's "Energy Coast". In this capacity it supports the offshore oil, gas, and renewable energy industries of the Irish Sea.

The Port of Barrow is owned and operated by Associated British Ports. The site covers an area of 55 hectares, with 20 hectares of secure open storage. The port can accommodate ships of up to 200m length, 35m beam, and 10m draft. Handling facilities are provided for dry bulk cargo (wood pulp, sand, aggregates), nuclear materials, timber and paper, oil and liquids, and renewable energy.

In 2017, the Department for Transport recorded that 167,000 tonnes of freight was handled by the port. A contract with Kimberley Clark's Barrow Mill has meant that 60,000 tonnes of wood pulp are shipped through the port each year rather than being road hauled. This has removed 600,000 miles of truck movements from Britain's roads.

PORT OF SILLOTH web: www.abports.co.uk

Positioned on the north west coast of Cumbria, Silloth looks out across the Solway Firth towards the Scottish lowlands. The port is near to the city of Carlisle and has good connections to the main north-south M6 motorway. In 2017, the Department for Transport recorded that 128,000 tonnes of freight was handled by the port.

The Port of Silloth is owned and operated by Associated British Ports. The site covers an area of 17 hectares and can accommodate ships of up to 95m length, 13.5m beam, and 6.5m draft. The port provides handling facilities for dry bulk cargo, timber and paper, oil and liquids, and general cargo.

The main type of cargo moved through Silloth is dry bulk. The port is located in a rural setting and this is reflected by the single largest commodity it handles being Fertiliser. Prime Molasses, a major supplier of the animal feed industry in the UK, uses the Port of Silloth as its base in the North West of England.

Specially selected grain is imported and discharged directly in to Carr's Flour Mill, located within the port. Silloth's forest product trade includes quantities of wood pulp for use at the nearby plant of Innovia Films Ltd.

LANCASTER PORT web: N/A

Located in Lancashire on the south coast of Morecombe Bay, Lancaster Port (also known as Glasson Dock) is situated on the south bank of the mouth of the River Lune. The port has long been established in international trade and is owned by the Lancaster Port Commission.

The port is near to the city of Lancaster and has good connections to the main north-south M6 motorway. In 2017, the Department for Transport recorded that 145,000 tonnes of freight was handled by Lancaster Port (Glasson Dock).

Glasson Dock can accommodate ships of up to 90m long, 14m beam, and 4.6m draft. The port has 5 berths equipped with a range of cranes and cargo handling equipment for dry bulk, general cargo, and containers.

The port has 80,000 square feet of undercover, quayside storage; 42,000 square feet of undercover storage in the dock vicinity; and quayside stockpiling facilities for bulk cargoes. Computerised stock control, packaging facilities, freight forwarding, and transport facilities are also available on site.

PORT OF WORKINGTON web: www.portofworkington.co.uk

Positioned on the eastern side of the Solway Firth at the mouth of the River Derwent, the port allows easy access by sea to markets in Scotland, Ireland, the Isle of Man, and the UK's western sea board. The Port of Workington is owned by the Cumbria County Council. In 2017, the Department for Transport recorded that 278,000 tonnes of freight passed through the port.

The Port's principal cargo handling activities occur around the Prince of Wales Dock. This is a modern enclosed dock with a total water area of 2.6 hectares and a quay frontage of 773 metres. The dock provides a total of seven berths and a roll on-roll off facility and can accommodate ships of up to 137.2m length, 20.4m beam, and 9.5m draft.

Cargo handled includes: dry bulk (gypsum, perlite, cement, aggregates, fertilisers, animal feeds), liquid bulk (chemicals, fuels), project cargo, forest products (wood pulp, wood logs), break bulk, recyclables (glass), roll on-roll off, and container freight. In addition, the Port is also used by the offshore wind industry to undertake their operations and maintenance activities.

Workington is close to the city of Carlisle and has good connections to national road, and rail infrastructure. A trunk road connection to the M6 motorway provides reliable access to the rest of England, and Scotland. Whereas the port's internal rail network serves all berths and links them through a main line connection to the rest of the UK.

The Port of Workington is part of 'Britain's Energy Coast'. This initiative brought £5.7 million pounds of investment to the port. The investment is aimed at delivering a regeneration programme which will allow the port to deliver new and improved services.

Proposed improvements include: the construction of a new container handling facility, the introduction of a scheduled weekly container feeder service to Rotterdam, and the installation of a new harbour crane.

The Port of Workington has a strategic partnership with Direct Rail Services Ltd. The objectives of this partnership are to involve the port more closely in European multi-modal logistics, develop the port into a logistics hub for the North West region of the U.K., and provide a more sustainable end to end logistics option for Cumbria.

Appendix Five - Aviation Infrastructure of North West England

MANCHESTER AIRPORT web: www.manchesterairport.co.uk

Located south west of Manchester, with a maximum runway length of 3,050 metres, this is the principle international airport for the North West of England. Manchester Airport is owned by the Manchester Airports Group (MAG) and operated by Manchester Airport plc.

In 2017, the Civil Aviation Authority recorded 120,181 tonnes of freight as having moved through the airport. This makes Manchester the 4th busiest freight airport in the United Kingdom. However, airport authority's claim that their 'World Freight Terminal' is capable of handling over 170,000 tonnes of freight per year.

The World Freight Terminal has world class facilities, including: 550,000 square feet of warehouse and office space, a dedicated chiller unit, a border inspection post, three maintenance aircraft hangers, five transit shed operators, and facilities for abnormal load cargoes.

In 2012, the UK government identified 21 enterprise zones across the country whose goal is to stimulate economic growth and employment. Manchester airport's "Airport City" project is one of these zones. It aims to attract to the airport businesses involved in: logistics, freight forwarding, manufacturing, research and development.

LIVERPOOL JOHN LENNON AIRPORT web: www.liverpoolairport.com

Located south east of Liverpool on the north bank of the River Mersey, with a maximum runway length of 2,285 metres, this airport serves the Liverpool area. Liverpool John Lennon Airport is owned by Peel Airports, part of the Peel Group, and operated by Liverpool Airport plc. In 2017, the Civil Aviation Authority recorded 123 tonnes of freight as having moved through the airport.

This airport is currently focusing on discount passenger traffic via Easy Jet, Flybe, and Ryan Air. The number of passengers moving through the airport has increased from 2,253,000 in 2001 to 4,897,000 in 2017. However, over the same period of time freight movements have decreased from 22,821 tonnes in 2001 to 123 tonnes in 2017.

Fortunately, U.K. government policy, set out in the White Paper 'The Future of Air Transport', published in 2003, endorses the long term growth of the airport. This includes expansion of both passenger and cargo facilities as well as an extension to the runway. It is proposed that this master plan will be completed by 2030.

Appendix Six - Road Infrastructure (Motorways) of North West England

<u>M6</u>

This is the longest and busiest motorway in the United Kingdom. The Department for Transport states that this road carries an average of 115,000 vehicles per day. As the main north-south motorway it is often referred to as the "Backbone of Britain." The M6 links Rugby (M1, Junction 19) to Carlisle, where it becomes the A74(M). This connects the England/Scotland border with the South West of England (via the M5) and the South East of England, including London (via the M1).

The M6 has 51 junctions; of this total, junctions 16 to 45 are within the North West of England. The majority of the length of the road has three lanes in each direction. The exceptions to this are Junction 7 to 8 (Birmingham), Junction 20 to 21 (The Thelwall Viaduct), Junction 30 to 32 (Preston, termination of the M61) which have four lanes in each direction.

<u>M53</u>

This links Wallasey, on the Wirral peninsula, with the A55 at Chester and also provides the main link to the Mersey Road Tunnel (Kingsway Tunnel) from the Wirral side. The M53 has 12 junctions all of which are within the North West of England. Junction 11 is where the M53 crosses the M56 (M56, Junction 15).

The M53 is a combination of three lanes and two lanes in each direction. The two lane sections are located between junction 5 and junction 10, and between junction 11 and the motorway's termination, where it becomes the A55.

<u>M55</u>

Known as the Preston Northern Bypass, the M55 links the M6 (Junction 32, Preston) with Blackpool, where it becomes the A5230. The M55 has only 3 junctions, all of which are within the North West of England. The majority of the length of the road has three lanes in each direction. The exception to this is between Junction 1 and the motorway's start at its junction with the M6. This section of road has four lanes in each direction.

M56

Known as the North Cheshire Motorway, the M56 links the M60 (M60, Junction 4) to the Welsh border (via Cheshire), where it becomes the A494, just before crossing the border in to Wales. The M56 has 16 junctions, all of which are within the North West of England. Two of the more noteworthy of these junctions are Junction 9 where the M56 crosses the M6 (M6, Junction 20) and Junction 15 where the M56 crosses the M53 (M53, Junction 11).

The majority of the length of this road has three lanes in each direction but there are exceptions: two sections of two lanes in each direction, and one section of four lanes in each direction. The two lane sections exist initially between the motorway's origin and Junction 3A, and then between Junction 15 and the motorway's termination. The four lane section is between Junction 3A and Junction 6, where Manchester Airport is located.

M57

Known as the Liverpool Outer Ring Road, the M57 acts as a bypass road for the city of Liverpool. It links Junction 6 (Huyton) of the M62 to the beginning of the M58 (Switch Island, Aintree). The M57 has 7 junctions in total, all of which are within the North West of England. The majority of this road is composed of three lanes in each direction.

M58

The M58 links the north of Liverpool (Switch Island, Aintree), via Skelmersdale, to the M6 (Junction 26, Wigan). It has 4 junctions, all of which are within the North West of England. The majority of the length of this road has three lanes in each direction. The exceptions to this are the approaches to the roads terminating roundabouts. These sections of road have two lanes in each direction.

M60

Known as the Manchester Orbital Motorway, this road encircles Manchester and serves as a ring road. The M60 has 27 junctions, all of which are within the North West of England. Some of the more noteworthy of these junctions are: Junction 4 where the M60 joins the M56, Junction 12 where the M60 joins the M62 and M602, Junction 15 where the M60 joins the M61, Junction 18 where the M60 joins the M62 and M66, Junction 24 where the M60 joins M67. The entire length of this road is a combination of 3 lane and 4 lane sections.

M61

The M61 links the M60 (Junction 15, Manchester) to the M6 (Junction 30, Bamber Bridge). It has 9 junctions, all of which are within the North West of England. Of these junctions, Junction 9 stands out as it is where the M61 crosses the M65 (M65, Junction 2).

The majority of the length of this road has three lanes in each direction. The exceptions to this are the approach to its terminus with the M6 which has two lanes, and the approach to its terminus with the M60 where the road has four lanes in each direction.

The section of road at the M61's terminus with the M60, known as the Worsley Braided Interchange, is a collection of slip roads, motorway carriages, and fly overs. This is one of the most complicated arrangements in the North West of England. It is also one of the most complicated arrangements in the world and has a place in the Guinness Book of World Records for the most traffic lanes side by side (17 in total).

M62

The M62 links Liverpool (Merseyside) and Hull (Yorkshire). This forms the main Trans-Pennine link for England, crossing the country from East to West. The Highways Agency states that the M62 carries an average of 78,000 vehicles per day.

The M62 has 36 junctions in total, 18 of these (Junctions 4 to 21) are within the North West of England. Some of the more noteworthy of these junctions are Junction 10 where the M62 crosses the M6 (M6, Junction 21A) and the section of road between Junctions 12 and 18 (Manchester) where the M62 forms part of the M60.

The majority of the length of this road has three lanes in each direction but there are exceptions. Between Junction 8 (Warrington West) and 10 (where the M62 crosses the M6) the road has four lanes in each direction and this is also the case between Junction 18 (where the M62 separates from the M60) and Junction 19 (Middleton).

M65

The M65 links the M6 (Junction 30, Preston) to Colne. In total it has 14 junctions, all of which are within the North West of England. Two of the more noteworthy junctions are Junction 1 where the M65 crosses the M6 (M6, Junction 29) and Junction 2 where the M65 crosses the

M61 (M61, Junction 9). The entire length of this road is a combination of 2 lane and 3 lane sections.

M66

The M66 links the M60 (Manchester Ring Road) to Ramsbottom. It runs north to south and provides part of the link between the M60 (M60, Junction 18) and the M65 (M65, Junction 8). The remaining part of this link is provided by the A56. The M66 has 5 junctions, all of which are within the North West of England. The entire length of this road is a combination of 2 lane and 3 lane sections.

M67

The M67 links the M60 (Manchester Ring Road) to Hattersley. It is an urban motorway running east to west. The M67 has 5 junctions, all of which are within the North West of England. The road is mostly composed 3 lanes but reduces to 2 lanes on the approaches to its terminating roundabouts.

M602

The M602 links the M62 (M62, Junction 12) to central Manchester. The M602 is an urban motorway that acts as a bypass for the town of Eccles and allows access to central Manchester and Salford from the surrounding motorway network. The M602 has 4 junctions, all of which are within the North West of England. The entire length of this road is a combination of 2 lane and 3 lane sections.

Appendix Seven - Road Infrastructure ('A' Roads) of North West England

A55

Links the end of the M53 (M53, Junction 12) to the Welsh Border. This acts as a bypass road for Chester. This section of road is approaching motorway standard and composed of two lanes in each direction.

A56

Links the end of the M66 at Ramsbottom to the M65 (M65, Junction 8) near Burnley. This section of road is approaching motorway standard and composed of two lanes in each direction.

A66

Links the M6 (M6, Junction 40) at Penrith to Workington. This section of road varies from two lanes in each direction (separated into dual carriageways) to a standard single lane in each direction.

A69

Links the M6 (M6, Junction 43) at Carlisle to the Yorkshire border. This forms a minor Trans-Pennine link as the road is mostly composed of a standard single lane in each direction.

A494

Links the end of the M56 (M56, Junction 16) to the Welsh border. This section of road is approaching motorway standard and composed of two lanes in each direction.

A556

Links the M6 (M6, Junction 19) at Knutsford to the M56 (Junction 7 and 8) at Altrincham. This section of road is composed of a standard two lanes in each direction.

A585

Links the M55 (M55, Junction 3) to Fleetwood. This road is composed of a standard single lane in each direction.

A580

Links Walton in Liverpool to Salford in Manchester. This road is also known as the East Lancashire Road or the East Lancs. When constructed in the 1930's the primary aim of this road was to improve the flow of goods between the factories of East Lancashire and the Liverpool docks. This section of road is a dual carriageway consisting of two lanes in each direction.

A590

Links the M6 (M6, Junction 36) at Crooklands with Barrow-in-Furness. This section of road varies from approaching motorway standard with two lanes in each direction to a standard single lane in each direction.

A595

Links the centre of Carlisle (near Junctions 42 to 44 of the M6) to the A590 (near Barrow-in-Furness). This road runs the entire length of the Cumbrian coastline, an area which is often referred to as 'Britain's Energy Coast'. The A595 is mostly composed of a standard single carriageway in each direction.

A628

Links the end of the M67 at Hattersley to the Yorkshire border. This forms a minor Trans-Pennine link as the road is mostly composed of a standard single lane in each direction.

A5036

Links the start of the M58 (M58, Junction 1) at Switch Island to the end of the M57 (M57, Junction 8) at Switch Island and the Seaforth Docks area of Liverpool. This section of road varies between two to three lanes in each direction (separated into dual carriageways).

Appendix Eight - Rail Infrastructure of North West England

WEST COAST MAIN LINE (WCML)

Crossing the country from South to North the West Coast Main Line connects London, Birmingham, Manchester, Liverpool, Glasgow and Edinburgh. It is Britain's most important rail link, carrying over 40% of all UK rail freight traffic and also serving a population of over 24 million people along its length. The WCML is electrified.

Whilst being one of the most important rail routes in Britain, the WCML is also one of the busiest freight routes in Europe. The WCML is part of the UK's principal rail freight corridor with the European mainland. This comes through the Channel Tunnel and provides direct routes to the deep sea container ports in the south of England (Felixstowe, Southampton) before moving through London and South East England to the West Midlands, North West England and the Central Belt of Scotland.

According to the European Union's definition the WCML is considered an upgraded high speed line. The line has also been declared a strategic European route and is considered part of the Trans-European Transport Network (TEN-T).

WEST COAST MAIN LINE – LIVERPOOL BRANCH

This links the West Coast Main Line, between Frodsham and Runcorn East, to Liverpool (Merseyside). The line's route crosses the River Mersey at the Runcorn Rail Bridge (also known as the Ethelfleda Bridge, Queen Ethelfleda Viaduct or Britannia Bridge) before connecting with the Mersey Multimodal Gateway (3MG) Logistics Park (at Ditton) and also the Liverpool John Lennon Airport. The 3MG site also offers rail access to the Ditton-Warrington line, which provides connections to Trans-Pennine routes.

3MG is currently served by five freight trains per day. Over the course of a year this equates to approximately 60,000 containers being carried by rail. The terminal is already capable of handling trains of up to twenty four wagons in length (approximately 500m trailing length) but proposed new sidings will increase the rail capacity of the site to allow it to handle up to sixteen trains per day per direction. The new 775m siding length will also allow 3MG to handle full length trains via the Channel Tunnel.

TYNE VALLEY LINE

Links Carlisle (Cumbria) to Newcastle upon Tyne (Tyne and Wear). The Tyne Valley Line is also known as the Hadrian's Wall Line and is one of England's most scenic railways. This Line forms an East / West trans-Pennine link across England allowing the ports around Newcastle to be joined to both the East Coast Main Line and the West Coast Main Line. The Tyne Valley Line is not electrified.

SETTLE TO CARLISLE LINE

Links the West Coast Main Line at Carlisle (Cumbria) to Leeds (Yorkshire), following the same route as the Leeds to Morecambe Line from Settle (Yorkshire) to Leeds. The Settle-Carlisle Line runs through remote, scenic regions of the Yorkshire Dales and the North Pennines. In recent years, increasing levels of congestion on the WCML have led to freight traffic using the Settle-Carlisle Line more and more.

In addition to its usual traffic, the line is also used to accommodate temporary diversions from the WCML when engineering works produce operational constraints or other events lead to the WCML being closed. Unfortunately, at present the Settle-Carlisle Line is not electrified so electric trains diverted on to this line need to be hauled by a diesel locomotive.

KIRKBY BRANCH LINE

Links Kirkby (Merseyside) to the West Coast Main Line at Wigan (Greater Manchester). The partly single track of this line is broken by a large buffer stop at Kirkby Station. The buffer separates the electrified line in to Liverpool from the diesel-run services that connect Kirkby with Wigan. Prior to arriving at Kirkby this line has a branch which serves the railhead at Potter Logistics Knowsley Distribution Centre.

LIVERPOOL TO WIGAN LINE

Links Liverpool (Merseyside) to the West Coast Main Line at Wigan (Greater Manchester) via Saint Helens (Merseyside). In the vicinity of Wavertree Technology Park the Canada Dock Branch (also known as the Seaforth Container Terminal Branch or the Bootle Branch) leaves the main Liverpool to Wigan line to provide a rail connection for the Port of Liverpool.

It has been estimated that over 50% of the North West of England's freight passes through the Port of Liverpool. The Canada Dock Branch line combined with the Liverpool to Wigan Line provides a (currently non-electrified) link through which much of this freight can reach the WCML. The WCML can then, if necessary, distribute it across the country.

CALDERVALE LINE

Links Leeds (Yorkshire) to Blackpool (Lancashire) via Huddersfield (Yorkshire), Manchester (Greater Manchester) and Preston (Lancashire). At its terminus in Leeds the Caldervale Line crosses the East Coast Main Line and in Preston it crosses the West Coast Main Line. This provides one of the main trans-Pennine routes. At present the Caldervale Line is not electrified.

CREWE TO MANCHESTER LINE

Links Crewe (Cheshire) to Manchester (Greater Manchester). At Crewe the line leaves the West Coast Main Line. For most of its length it runs through rural Cheshire before reaching Stockport (Greater Manchester) where it joins the Mid-Cheshire Line from Chester, the Hope Valley Line from Sheffield and the Manchester to Buxton Line. The Crewe to Manchester Line is electrified.

STYAL LINE

The Styal Line leaves the Crewe to Manchester Line at Wilmslow (Cheshire) and re-joins it at Manchester (Greater Manchester). Between Heald Green and Styal it has a spur that serves Manchester Airport. Although the Styal Line is electrified most of the trains now using it are diesel powered.

HOPE VALLEY LANE

Links Manchester (Greater Manchester) to Sheffield (Yorkshire). The Hope Valley Line provides one of the main trans-Pennine links. Freight operations through the valley are extensive and complex. In particular, the Hope cement works sends out considerable tonnages every day.

The Hope cement works can produce as much as 1.3 million tonnes of cement each year, and most of this will go out by rail. In combination with the fuel which is brought in by rail to heat the cement kilns a total of over nine trains per day will visit the works. These are moved by diesel locomotives as the line is not electrified.

The Hope Valley Line also carries much of the aggregates extracted from the quarries located around Buxton. These quarries have a massive output, carried by up to seventeen trains per day on the already stretched infrastructure. All of this activity produces a dense mix of express, local passenger and heavy haul freight trains.

Appendix Nine – Representative Papers

In chronological order:

1) Transport chain choice modelling in freight transport demand models (Huber, 2017).

2) The role of environmental sustainability in the freight transport mode choice: A systematic literature review with focus on the EU (Bask and Rajahonka, 2017).

3) Port and Inland Mode Choice from the Exporters' and Forwarders' Perspectives: Case Study – Java, Indonesia (Nugroho, Whiteing, and Jong (de), 2016).

4) Mode Choice Analysis: the data, the models and the future ahead (Minal and Chalamuri, 2014).

5) Modal choice in freight transport: a combined MCDA-GIS approach (Meers, Macharis and Lier (van), 2013).

6) An Analysis of Interstate Freight Mode Choice between Truck and Rail: A Case Study of Maryland, United States (Wang, Ding, Liu and Xie, 2013).

7) The impact of value of time on mode choice of freight intermodal transport (Liu, Zhao and Liu, 2012).

8) Modeling Freight Mode Choice in Greece (Moschovou and Giannopoulos, 2012).

9) Mode Choice: Road transport versus intermodal transport: An analysis applied to the Port of Genoa and the port of Antwerp (Grosso, 2011).

10) A stated preference analysis of Spanish freight forwarders modal choice on the south-west Europe Motorway of the Sea (Feo, Espino and Garcia, 2011).

11) The importance of the inland leg of containerised maritime shipments: An analysis of modal choice determinants in Spain (Feo-Valero, Garcia-Menendez *et al.*, 2011).

12) Hinterland transportation in Europe: Combined transport versus road transport (Fremont and Franc, 2010).

13) A method for transportation mode choice (Gursoy, 2010).

14) Freight Modal Choice Study: Behavioural barriers and factors influencing modal choice - Final Report (Department for Transport, 2010).

15) European Common Transport Policy and Short-Sea Shipping: Empirical Evidence Based on Modal Choice Models (Garcia-Menendez and Feo-Valero, 2009).

16) Analysing qualitative attributes of freight transport from stated orders of preference experiment (Beuthe and Bouffioux, 2008).

17) Evaluation of factors for carrier selection in the China Pearl River delta (Wong, Yan and Bamford, 2008).

18) Motor Carriers' and Shippers' Perceptions of the Carrier Choice Decision (Premeaux, 2007).

19) The core shipper concept: a proactive strategy for motor freight carriers (Dobie, 2005).

20) Logistics managers' stated preferences for freight service attributes (Danielis, Marcucci and Rotaris, 2005).

21) A Simultaneous SP/RP Analysis of Modal Choice in Freight Transport in the Region Nord – Pas-de-Calais (Vellay and Jong, 2003).

22) Motor carrier selection criteria: perceptual differences between shippers and motor carriers (Premeaux, 2002).

23) Freight mode choice and adaptive stated preferences (Shinghal and Fowkes, 2002).

24) Identifying Relevant Variables and Modelling the Choice Process in Freight Transportation (Mangan, Lalwani and Gardner, 2001).

25) Time Valuation in Freight Transport: Methods and Results (Jong (de), Gommers and Klooster (2000).

26) The competitiveness of the river-sea transport system: market perspectives on the United Kingdom-Germany corridor (Konings and Ludema, 2000).

27) Identifying influential attributes in freight route/mode choice decisions: a content analysis (Cullinane and Toy, 2000).

28) Performance Perceptions, Satisfaction, and Intention: The Intermodal Shipper's Perspective (Evers and Johnson, 2000).

29) International containership carrier selection criteria (Kent and Parker, 1999).

30) Modelling Freight Transport Costs: A Case Study of the UK-Greece Corridor (Beresford, 1999).

31) Carrier selection: do shippers and carriers agree, or not? (Murphy, Daley and Hall, 1997).

32) A longitudinal assessment of motor carrier-shipper relationship trends, 1990 vs. 1996 (Crum and Allen, 1997).

33) Time-based strategy and carrier selection (Murphy and Farris, 1993).

34) Factors Influencing Freight Service Choice for Shippers and Freight Suppliers (Matear and Gray, 1993).

35) Carrier Selection in a RO/RO ferry trade. Part 2: Conceptual framework for the decision process (D'Este, 1992).

36) Carrier Selection in a RO/RO ferry trade. Part 1: Decision factors and attitudes (D'Este and Meyrick, 1992).

37) Motor carrier selection criteria: Perceptual differences between shippers and carriers (Abshire and Premeaux, 1991).

38) Motor carrier selection in a deregulated environment (Bardi, Bagchi and Raghunathan, 1989).

39) A comparative evaluation of freight transportation choice models (McGinnis, 1989).

40) Shipper Attitudes Towards Freight Transportation Choice: A Factor Analytical Study (McGinnis, 1979).

Appendix Ten – Sub-Criteria Related Terms

1. ADMINISTRATION

- Access to data
- Administrative issues
- Availability of computerized billing
- Booking facilities
- Carriage documentation
- Communication
- Computerized billing
- Computerized services
- Contracts
- Customs clearance
- Document completion
- Documentation
- Efficiency of the administration process
- Electronic data interchange (EDI)
- Electronic proof of delivery
- Government licence approvals
- Information provision
- Information (ICT)
- Invoices
- Management of orders
- Online pickup and delivery services
- Provision of extensive electronic data interchange
- Service provision information
- Web-enhanced electronic data interchange

2. CAPABILITY

- Ability to reduce backhauls due to consignee location
- Ability to reduce backhauls due to shipper location

- Accessibility of the transport mode
- Availability of equipment
- Availability of freight space
- Availability of infrastructure
- Availability of origin and destination port
- Availability of logistics services
- Availability of logistics services suitable to the commodity
- Availability of specialised equipment
- Availability of vessels
- Capacity
- Cargo capacity
- Carrier transportation equipment designed to facilitate easy and fast loading and unloading
- Condition of equipment
- Congestion
- Existence of alternative or substitute routes
- Extra space
- Geographical coverage
- Infrastructure availability
- Infrastructure constraints
- Intermodal integration
- Intermodal links
- International service
- Loading availability
- Multimodal capabilities
- Physical facilities
- Quay space
- Space
- Specialised equipment
- Supply chain infrastructure

3. CARGO CHARACTERISTICS

- Actual shipment size
- Average shipment size
- Characteristics of the goods
- Characteristics of the commodity being transported
- Contamination risk
- Dangerous goods
- Goods in parcels
- Goods not in parcels
- Goods not on pallets
- Goods on pallets
- Hazardous cargo
- Nature of cargo
- Nature of commodity
- Non-perishable cargo
- Out of gauge cargo
- Package characteristics
- Perishable cargo
- Project cargo
- Shipment density
- Shipment shelf life
- Shipment size
- Shipment value
- Size
- Temperature controlled
- Type of commodity (food, metal, petrol, agriculture)
- Value density of shipment
- Value of the shipment
- Weight

4. CERTIFICATION

- Conforms with regulatory issues
- Formal quality programs
- Government licence approved
- ISM Code
- ISO14000 environmental management systems
- ISO9000 quality management certification
- Port pilotage exemption

5. CLAIMS PROCESSING

- Claim settlement procedure
- Ease of claim settlement (Loss/Damage)
- Overcharge claims service
- Time taken to settle a claim

6. COMPANY POLICY

- Bias towards a particular mode of transport
- Commercial obligations
- Commitments
- Company owns its own vehicles
- Contractual arrangements
- Frequency of review of transport choice
- Shippers preference

7. CONTROLLABILITY

- Ability to control shipment after dispatch
- Control
- Diversion privileges
- Reconsignment privileges
- Stoppage in transit

8. COST

- Capital carrying cost in transit
- Cheap
- Competitive rates
- Cost (door to door movement)
- Cost to provide required service
- Demurrage
- Direct cost
- Door to door transportation rates
- Expensive
- Freight charges
- Freight rates
- Generalised transport cost
- Handling cost
- Intangible service costs
- Low freight rate
- Low price
- Order cost
- Port costs
- Price
- Rate
- Rate level
- Shipping charges
- Shipping cost
- Storage cost
- Total cost per shipment
- Transport cost
- Transport service price
- Transportation charge
- Transportation cost
- Value for money

9. **DAMAGE / LOSS**

- Avoidance of damage
- Avoidance of loss
- Care in handling
- Damage / loss reputation
- Damage to the consignment
- Freight loss and damage
- Handling quality
- History of loss and damage
- Loss and damage performance
- Over, short, and damaged
- Percentage of shipments that suffer losses or breakages
- Reliability in terms of losses and breakages
- Risk of damage
- Risk of loss
- Susceptibility to loss or damage
- Theft

10. **DELAYS**

- Ability to meet estimated pick-up and delivery times
- Average length of delay
- Consistent on time service
- Delivery time reliability
- Dependability
- On time collection
- On time delivery
- On time loading and unloading
- On time performance
- Percentage of consignments arriving within the scheduled time
- Percentage of shipments that suffer delays
- Probability of delay

- Punctuality
- Reliability in terms of time
- Risk of delay
- Service time consistency
- Transit time consistency
- Trip time reliability

11. DISTANCE

- Door to door distance
- Door to door port distance
- Directness
- Distance of shipment
- Length of haul
- Port to door distance
- Proximity to destination
- Proximity to origin
- Proximity of port to destination
- Proximity of port to origin
- Road distance
- Short sea crossing
- Transport distance

12. EXTERNAL IMPACTS

- Air pollution
- Carbon footprint
- Chemical spills
- Climate change
- Environmental concerns
- Environmental impacts
- Global warming
- Land pollution
- Light pollution

- Noise pollution
- NOx
- Oil spills
- Particulate matter
- Species invasion
- SOx
- Visual pollution
- Water pollution

13. FINANCES

- Carrier financial stability
- Commercial acumen
- Firm size

14. FLEXIBILITY

- Ability to perform unanticipated urgent deliveries
- Accommodate customer requirements
- Assistance in obtaining classification changes
- Assistance in obtaining rate changes
- Attitude towards acceptance of small shipments
- Flexible contracts
- Honouring routing requests
- Leadership in offering more flexible rates
- Quick reaction to unforeseen requests
- Rescheduling at short notice
- Special order handling
- Variable lead times
- Willingness to negotiate price
- Willingness to negotiate rate changes
- Willingness to negotiate service changes

15. <u>FREQUENCY</u>

- Convenience
- Convenient schedules
- Frequency of service
- Frequency of shipments
- Frequency of similar shipments to the same client
- Mode frequency
- Number of shipments
- Number of shipments per year
- Regularity of shipments
- Sailings per year
- Schedule
- Service frequency
- Shipment frequency

16. <u>IMAGE OF MODE</u>

- Financing of the mode
- General perceptions of the mode
- Image of the mode most commonly associated with a carrier
- Incentives to use the mode
- Investment in the mode
- Lack of awareness of the mode
- Marketing of the mode
- Perceived relevance of the mode
- Promotion of the mode
- Government commitment to the mode

17. <u>INVENTORY</u>

- Annual sales
- Costs related to level of stocks
- Inventory carrying costs at destination

- Inventory cost

18. <u>LOCATION</u>

- Easy access to rail for shipper / receiver
- Shipper / receiver is located in a port
- Shipper / receiver is located near a motorway

19. <u>MARKET CONSIDERATIONS</u>

- External market influences
- Lack of market to generate adequate traffic
- Market characteristics
- Market competitiveness
- Market conditions

20. <u>PREVIOUS EXPERIENCE</u>

- Ability of service provider's representatives
- Courtesy of vehicle operators
- Customer satisfaction
- Feedback from the consignee to the shipper about the quality of service given by specific carriers
- Lack of confidence in service provider
- Lack of experience
- Misunderstandings
- Negative experience with the service provider
- Past performance of the service provider
- Quality of personnel
- Quality of salesman
- Quality of customer service
- Quality of dispatch personnel
- Quality of operations personnel
- Recommendations of employees of other firms
- Satisfaction

- Service consistency
- Service providers knowledge of shippers needs
- Shippers previous experience
- Skills of personnel
- Staff expertise
- Staff knowledge
- Specialised shipping personnel
- Specially trained personnel

21. RELATIONSHIPS

- Carrier's co-operation with shipper's personnel
- Co-operation between the shipper and the carrier
- Customer influence
- Familiarity with carriers
- Good relationship with carrier
- Shipper relationships
- Influence of customer
- Personal relationship with the carrier
- Preferred carrier
- Regular calls by carrier sales representative
- Transport preference of trading partner

22. SAFETY RECORD

- Accidents
- Carriers historical performance in emergencies
- Carrier safety record
- Collisions
- Fatalities
- Fires
- Groundings
- Injuries
- Response of carrier to an emergency

23. SECURITY

- National security issues
- Perceived level of risk
- Physical security
- Port security
- Regional security issues
- Transport security
- Security of load
- Security level
- Security measures in place
- Storage security
- Supply chain security
- Vehicle security

24. TRACEABILITY

- Radio frequency identification (RFID)
- Real time tracking
- Tracing capability
- Tracing service
- Tracking
- Shipment tracing

25. TRANSIT TIME

- Delivery time
- Door to door transit time
- Handling time
- Port to port transit time
- Road transit time
- Shipping speed
- Short transit time
- Speed of transit

- Speed of transport
- Storage time
- Time
- Timescale
- Total door to door transit time
- Total transit time for the shipment
- Total transport time
- Total wait time
- Transport time

26. VALUE ADDED SERVICES

- Additional services
- Availability of pick-up service
- Consolidation of shipments
- Extension to allowable loading / unloading times
- Delivery service
- Discount programs
- Distribution service
- Door to door service
- Fabrication in transit privileges
- Free services
- Non-core services
- Pickup service
- Port entry priority
- Reduced dwell times
- Shipment expediting

Appendix Eleven – First Pairwise Comparison Questionnaire

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11th July 2012

To: WHOM IT MAY CONCERN

A research project entitled "Modal Choice in Unitized Freight Supply Chains" is currently being carried out at Liverpool John Moores University. The aim of this research is to investigate the decision making process that occurs when a shipper decides how they will move their cargo from its origin to its destination. The final output of this research is to be a model which can be used by policy makers. This model will allow them to better focus their efforts at influencing the decision making process.

The criteria to be assessed have already been identified. The next step in the process is to employ pairwise comparison to identify a weight for each criterion. Your input in to this process will contribute to the formulation of an industry wide base of expert opinion.

Previous experience in data gathering has demonstrated to us that organisations do not want to provide information that could be of use to their rivals to gain a competitive advantage. Liverpool John Moores University enforces a robust data protection policy. The anonymity of respondents to this questionnaire is assured.

With this in mind, I would be grateful if you could spend some time to complete the accompanying questionnaire and email it to me at the address shown above.

Regards

Alan Bury
Research Assistant

COMPLETING PAIR WISE COMPARISON QUESTIONNAIRES

To complete a pair wise comparison questionnaire an expert is required to use their expertise and experience to offer their judgement on a comparison of two criteria. To do this it is necessary to understand the scale of measurement used. The numerical assessment values and their associated meanings are identified below.

IMPORTANT

1	Equally Important
2	↓
3	Slightly Important
4	↓
5	Moderately Important
6	↓
7	Very Important
8	↓
9	Extremely Important

UNIMPORTANT

1	Equally Important
2	↓
3	Slightly Unimportant
4	↓
5	Moderately Unimportant
6	↓
7	Very Unimportant
8	↓
9	Extremely Unimportant

An example of how these values are employed is demonstrated on the next page with an excerpt from a piece of work looking at “selecting the most important part of a computer”.

<u>Goal</u>: **Selecting the most important part of a computer**

<u>Criteria</u>: **Monitor**

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
Vs MOUSE															**X**		
Vs KEYBOARD											**X**						
Vs CPU	**X**																

This excerpt looks at the importance of the monitor in comparison to other parts of the computer. In this case identified criteria are: Monitor, Mouse, Keyboard, CPU. As a result, the pairwise comparisons are: Monitor vs. Mouse, Monitor vs. Keyboard, and Monitor vs. CPU.

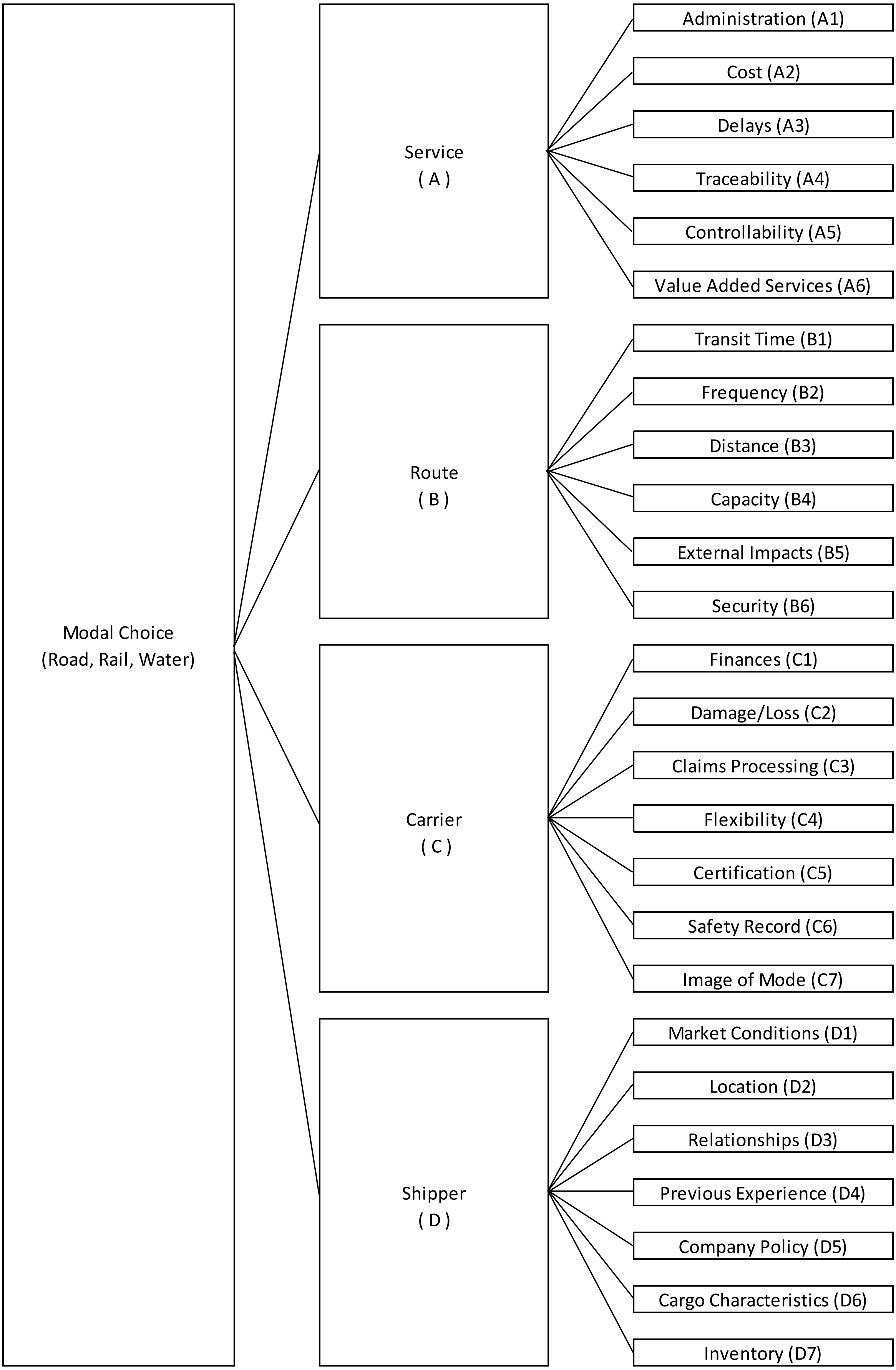
The expert opinion of a computer technician determined that:

- The monitor is 7 times “more important” than the mouse. We can still use a computer without the mouse. If the mouse is broken then the short cut system (Ctrl+P to print, Ctrl+S to save) can be used to access a file or document in the computer by using the keyboard.

- The monitor is 3 times “more important” than the keyboard. We can still use a computer without a keyboard. If the keyboard is broken then the mouse can be used to access files through My Document. The only thing that cannot be done is typing.

- The monitor is 9 times “less important” than the CPU. We cannot use a computer without the CPU. If the CPU is broken then the monitor is of no use at all.

MODAL CHOICE DECISION MAKING FRAMEWORK



DEFINITIONS OF SUB-CRITERIA

A. SERVICE CRITERIA

A1. ADMINISTRATION – The timeliness, efficiency, and accuracy of the administrative processes involved with moving a shipment from its origin to its destination.

A2. COST – The total cost of moving a shipment from its origin to its destination.

A3. DELAYS – The punctual arrival of shipments at their destination.

A4. TRACEABILITY – The real time tracking of cargo after it has been dispatched.

A5. CONTROLLABILITY – The ability to control a shipment after it has been dispatched.

A6. VALUE ADDED SERVICES – The ancillary service options offered to compliment the core service. These are something extra that are typically provided at no additional charge.

B. ROUTE CRITERIA

B1. TRANSIT TIME – The time taken to move a shipment from its origin to its destination.

B2. FREQUENCY – The number of journeys carried out by a transport mode between a shipment's origin and destination over a given period of time.

B3. DISTANCE – The distance travelled by a shipment from its origin to its destination.

B4. CAPABILITY – The physical facilities and processes available to meet the needs of the shipper.

B5. EXTERNAL IMPACTS – The pollution and other externalities resulting from the movement of a shipment from its origin to its destination.

B6. SECURITY – The security of the supply chain between the shipments origin and destination.

C. CARRIER CRITERIA

C1. FINANCES – The size of the carrier company and its financial stability as perceived by its users.

C2. DAMAGE/LOSS – The carrier's history of shipment loss and damage.

C3. CLAIMS PROCESSING – The ease by which the carrier finalises settlements to cover loss, damage, over charge, or other complaints.

C4. FLEXIBILITY – The ability of the carrier to accommodate the varying requirements imposed upon them by customers.

C5. CERTIFICATION – The management systems that are in place within the carrier organisation and which are recognised by ISO (or equivalent) awards.

C6. SAFETY RECORD – The carrier's history of injuries, fires, fatalities, collisions, groundings, and any other accidents resulting from the transportation of shipments between their origin and destination.

C7. IMAGE OF MODE – The public image of the transport mode most commonly associated with the carrier.

D. SHIPPER CRITERIA

D1. MARKET CONSIDERATIONS – What is going on in the shippers chosen market? The market factors that influence the decision maker from outside the shipper's organisation.

D2. LOCATION – The position of the shipper with regards to freight transport infrastructure and the level of access that this offers to each mode.

D3. RELATIONSHIPS – The condition of existing relationships that the shipper has with its existing (but also potential) suppliers, carrier companies, and customers.

D4. PREVIOUS EXPERIENCE – The shipper's level of satisfaction with the outcome of previous cargo shipments.

D5. COMPANY POLICY – The company policies that influence the decision maker internally within the shipper's organisation.

D6. CARGO CHARACTERISTICS – The nature of the cargo being transported. Is it hazardous, perishable, out of gauge, likely to contaminate other cargoes, etc.

D7. INVENTORY – The inventory levels held by the shipper. Is the shippers supply chain push or pull focused?

PAIRWISE COMPARISON WITHIN THE SERVICE CRITERION

ADMINISTRATION

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs COST																	
Vs DELAYS																	
Vs TRACEABILITY																	
Vs CONTROLLABILITY																	
Vs VALUE ADDED SVC.																	

COST

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs DELAYS																	
Vs TRACEABILITY																	
Vs CONTROLLABILITY																	
Vs VALUE ADDED SVC.																	

DELAYS

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs TRACEABILITY																	
Vs CONTROLLABILITY																	
Vs VALUE ADDED SVC.																	

TRACEABILITY

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs CONTROLLABILITY																	
Vs VALUE ADDED SVC.																	

CONTROLLABILITY

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs VALUE ADDED SVC.																	

PAIRWISE COMPARISON WITHIN THE ROUTE CRITERION

TRANSIT TIME

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs FREQUENCY																	
Vs DISTANCE																	
Vs CAPACITY																	
Vs EXTERNAL IMPACTS																	
Vs SECURITY																	

FREQUENCY

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs DISTANCE																	
Vs CAPACITY																	
Vs EXTERNAL IMPACTS																	
Vs SECURITY																	

DISTANCE

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs CAPACITY																	
Vs EXTERNAL IMPACTS																	
Vs SECURITY																	

CAPACITY

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs EXTERNAL IMPACTS																	
Vs SECURITY																	

EXTERNAL IMPACTS

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs SECURITY																	

PAIRWISE COMPARISON WITHIN THE CARRIER CRITERION

FINANCES

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs DAMAGE/LOSS																	
Vs CLAIM PROCESSING																	
Vs FLEXIBILITY																	
Vs CERTIFICATION																	
Vs SAFETY RECORD																	
Vs IMAGE OF MODE																	

DAMAGE/LOSS

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs CLAIM PROCESSING																	
Vs FLEXIBILITY																	
Vs CERTIFICATION																	
Vs SAFETY RECORD																	
Vs IMAGE OF MODE																	

CLAIMS PROCESSING

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs FLEXIBILITY																	
Vs CERTIFICATION																	
Vs SAFETY RECORD																	
Vs IMAGE OF MODE																	

FLEXIBILITY

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs CERTIFICATION																	
VS SAFETY RECORD																	
Vs IMAGE OF MODE																	

CERTIFICATION

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs SAFETY RECORD																	
Vs IMAGE OF MODE																	

SAFTEY RECORD

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs IMAGE OF MODE																	

PAIRWISE COMPARISON WITHIN THE SHIPPER CRITERION

MARKET CONSIDERATIONS

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs LOCATION																	
Vs RELATIONSHIPS																	
Vs PREV. EXPERIENCE																	
Vs COMPANY POLICY																	
Vs CARGO CHAR...TICS																	
Vs INVENTORY																	

LOCATION

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs RELATIONSHIPS																	
Vs PREV. EXPERIENCE																	
Vs COMPANY POLICY																	
Vs CARGO CHAR...TICS																	
Vs INVENTORY																	

RELATIONSHIPS

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs PREV. EXPERIENCE																	
Vs COMPANY POLICY																	
Vs CARGO CHAR…TICS																	
Vs INVENTORY																	

PREVIOUS EXPERIENCE

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs COMPANY POLICY																	
Vs CARGO CHAR…TICS																	
Vs INVENTORY																	

COMPANY POLICY

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs CARGO CHAR…TICS																	
Vs INVENTORY																	

CARGO CHARACTERISTICS

			UNIMPORTANT						EQUALLY IMPORTANT				IMPORTANT					
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs INVENTORY																	

PAIRWISE COMPARISON OF CRITERIA

SERVICE

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs ROUTE																	
Vs CARRIER																	
Vs SHIPPER																	

ROUTE

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs CARRIER																	
Vs SHIPPER																	

CARRIER

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs SHIPPER																	

Appendix Twelve – Second Pairwise Comparison Questionnaire

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11th July 2012

To: WHOM IT MAY CONCERN

A research project entitled "Modal Choice in Unitized Freight Supply Chains" is currently being carried out at Liverpool John Moores University. The aim of this research is to investigate the decision making process that occurs when a shipper decides how they will move their cargo from its origin to its destination. The final output of this research is to be a model which can be used by manufacturers, distributors, infrastructure providers, governing bodies, or policy makers. This model will allow them to better focus their efforts at influencing the decision making process.

The criteria to be assessed have already been identified. The next step in the process is to employ pairwise comparison to identify a weight for each criterion. Your input in to this process will contribute to the formulation of an industry wide base of expert opinion.

Previous experience in data gathering has demonstrated to us that organisations do not want to provide information that could be of use to their rivals to gain a competitive advantage. Liverpool John Moores University enforces a robust data protection policy. The anonymity of respondents to this questionnaire is assured.

With this in mind, I would be grateful if you could spend some time to complete the accompanying questionnaire and email it to me at the address shown above.

Regards

Alan Bury
Research Assistant

COMPLETING PAIR WISE COMPARISON QUESTIONNAIRES

To complete a pair wise comparison questionnaire an expert is required to use their expertise and experience to offer their judgement on a comparison of two criteria. To do this it is necessary to understand the scale of measurement used. The numerical assessment values and their associated meanings are identified below.

IMPORTANT

10 Equally Important
11 ↓
12 Slightly Important
13 ↓
14 Moderately Important
15 ↓
16 Very Important
17 ↓
18 Extremely Important

UNIMPORTANT

10 Equally Important
11 ↓
12 Slightly Unimportant
13 ↓
14 Moderately Unimportant
15 ↓
16 Very Unimportant
17 ↓
18 Extremely Unimportant

An example of how these values are employed is demonstrated on the next page with an excerpt from a piece of work looking at “selecting the most important part of a computer”.

<u>Goal</u>: **Selecting the most important part of a computer**

<u>Criteria</u>: **Monitor**

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
Vs MOUSE															**X**		
Vs KEYBOARD											**X**						
Vs CPU	**X**																

This excerpt looks at the importance of the monitor in comparison to other parts of the computer. In this case identified criteria are: Monitor, Mouse, Keyboard, CPU. As a result, the pairwise comparisons are: Monitor vs. Mouse, Monitor vs. Keyboard, and Monitor vs. CPU.

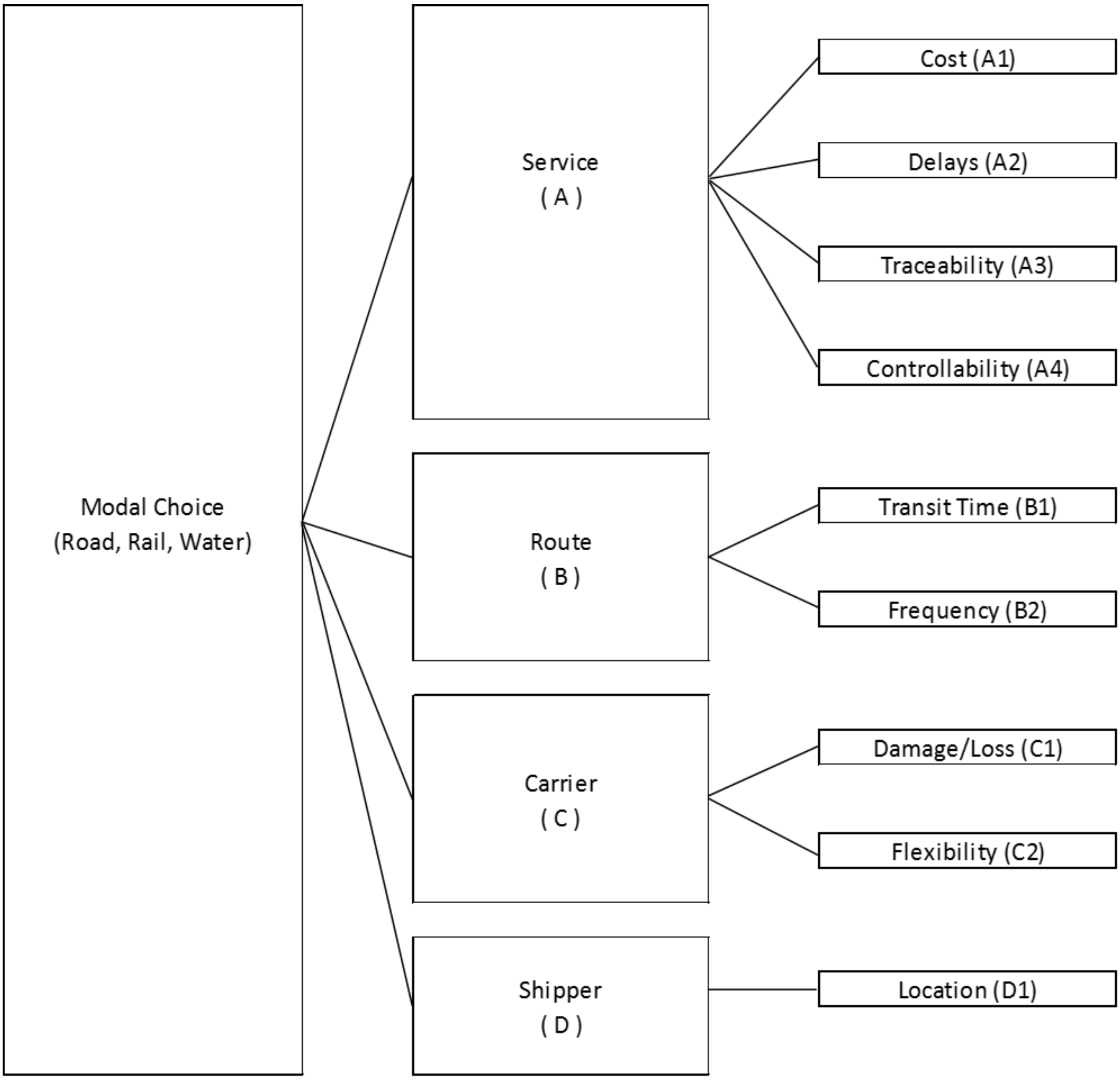
The expert opinion of a computer technician determined that:

- The monitor is 7 times “more important” than the mouse. We can still use a computer without the mouse. If the mouse is broken then the short cut system (Ctrl+P to print, Ctrl+S to save) can be used to access a file or document in the computer by using the keyboard.

- The monitor is 3 times “more important” than the keyboard. We can still use a computer without a keyboard. If the keyboard is broken then the mouse can be used to access files through My Document. The only thing that cannot be done is typing.

- The monitor is 9 times “less important” than the CPU. We cannot use a computer without the CPU. If the CPU is broken then the monitor is of no use at all.

MODAL CHOICE DECISION MAKING FRAMEWORK



GOAL

The modal choice (road, rail, water) decision making process has been modelled as containing a series of criteria (see previous page). Determine the relative importance of the criteria within the model.

CRITERIA DEFINITIONS

E. SERVICE CRITERIA

A1. COST – The total cost of moving a shipment from its origin to its destination.
A2. DELAYS – The punctual arrival of shipments at their destination.
A3. TRACEABILITY – The real time tracking of cargo after it has been dispatched.
A4. CONTROLLABILITY – The ability to control a shipment after it has been dispatched.

F. ROUTE CRITERIA

B1. TRANSIT TIME – The time taken to move a shipment from its origin to its destination.
B2. FREQUENCY – The number of journeys carried out by a transport mode between a shipment's origin and destination over a given period of time.

G. CARRIER CRITERIA

C1. DAMAGE/LOSS – The carrier's history of shipment loss and damage.
C2. FLEXIBILITY – The ability of the carrier to accommodate the varying requirements imposed upon them by customers.

H. SHIPPER CRITERIA

D1. LOCATION– The position of the shipper with regards to freight transport infrastructure and the level of access that this offers to each mode.

PAIRWISE COMPARISON OF THE SERVICE CRITERIA

COST

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs DELAYS																	
Vs TRACEABILITY																	
Vs CONTROLLABILITY																	

DELAYS

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs TRACEABILITY																	
Vs CONTROLLABILITY																	

TRACEABILITY

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs CONTROLLABILITY																	

PAIRWISE COMPARISON OF THE ROUTE CRITERIA

TRANSIT TIME

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs FREQUENCY																	

PAIRWISE COMPARISON OF THE CARRIER CRITERIA

DAMAGE/LOSS

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs FLEXIBILITY																	

PAIRWISE COMPARISON OF CRITERIA

SERVICE

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs ROUTE																	
Vs CARRIER																	
Vs SHIPPER																	

ROUTE

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs CARRIER																	
Vs SHIPPER																	

CARRIER

	UNIMPORTANT								EQUALLY IMPORTANT	IMPORTANT							
	1/9	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1	2	3	4	5	6	7	8	9
Vs SHIPPER																	

Appendix Thirteen - TOPSIS Questionnaire

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11th September 2013

To: WHOM IT MAY CONCERN

A research project entitled "Modal Choice in Unitized Freight Supply Chains" is currently being carried out at Liverpool John Moores University. The aim of this research is to investigate the decision making process that occurs when a shipper decides how they will move their cargo from its origin to its destination. The final output of this research is to be a model which can be used by policy makers. This model will allow them to better focus their efforts at influencing the decision making process.

The criteria to be assessed have already been identified and assigned a weight in the decision making process. The next step is to determine how each of these criteria are perceived in relation to the selected modes of transport. Your input in to this process will contribute to the formulation of an industry wide base of expert opinion.

Previous experience in data gathering has demonstrated to us that organisations do not want to provide information that could be used by their rivals to gain a competitive advantage. Liverpool John Moores University enforces a robust data protection policy. The anonymity of respondents to this questionnaire is assured.

With this in mind, I would be grateful if you could spend some time to complete the accompanying questionnaire and email it to me at the address shown above.

Regards

Alan Bury
Research Associate

GOAL

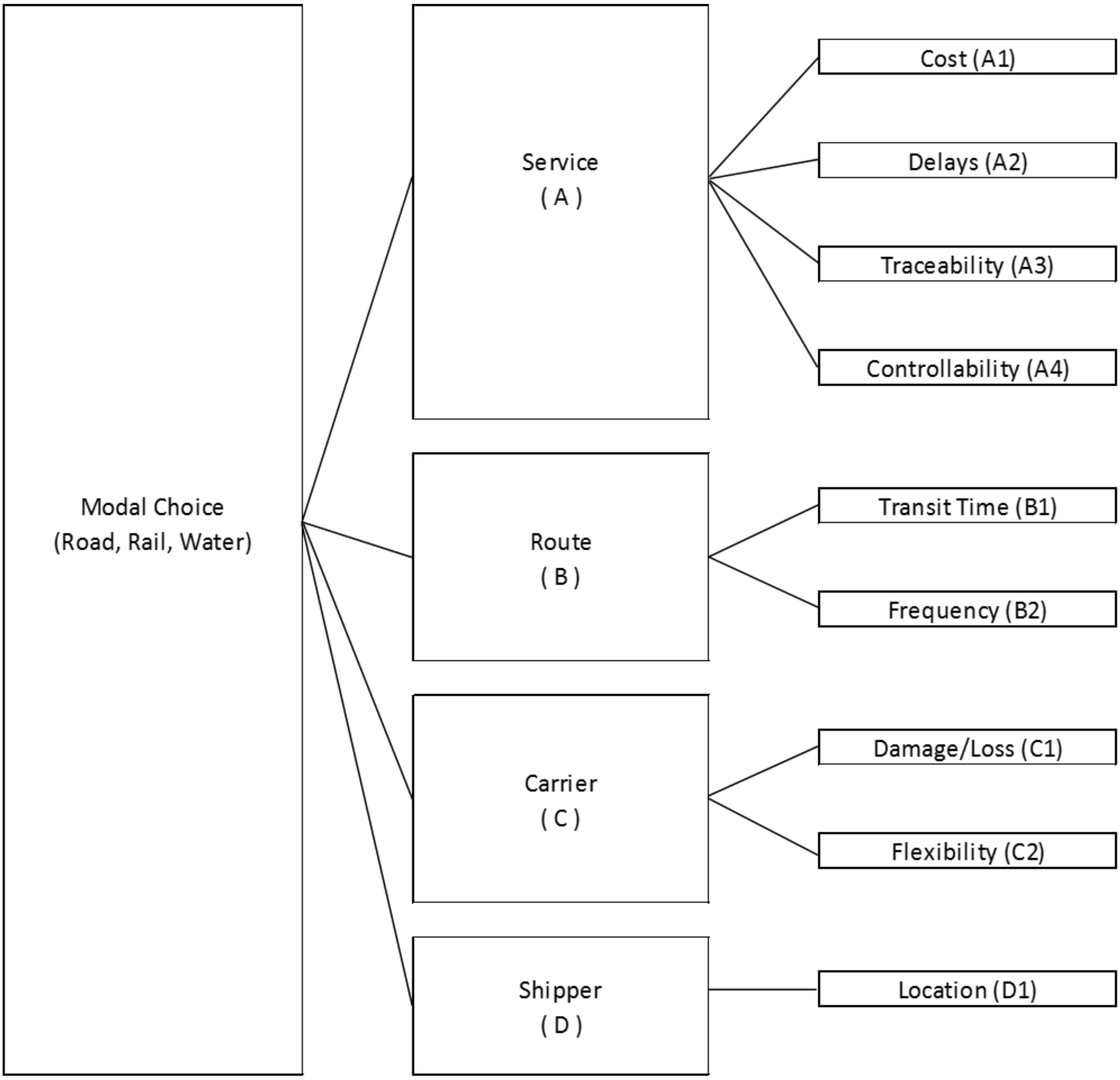
The modal choice (road, rail, water) decision making process has been modelled as containing a number of criteria (page 3 of this questionnaire). Measure how you perceive the relationship of each of these criteria to each of the given modes of transport.

COMPLETING THIS QUESTIONNAIRE

To complete this questionnaire an expert is required to use their experience to offer a judgement on each criterion versus each mode of transport. To do this it is necessary to understand the scale of measurement in use. In this case the scale is a linear 1 to 5 (best to worst) measurement as demonstrated below.

1	BEST
2	
3	↓
4	
5	WORST

MODAL CHOICE DECISION MAKING FRAMEWORK



DEFINITIONS OF CRITERIA

A1. **COST** – The total cost of moving a shipment from its origin to its destination.

A2. **DELAYS** – The punctual arrival of shipments at their destination.

A3. **TRACEABILITY** – The real time tracking of cargo after it has been dispatched.

A4. **CONTROLLABILITY** – The ability to control a shipment after it has been dispatched.

B1. **TRANSIT TIME** – The time taken to move a shipment from its origin to its destination.

B2. **FREQUENCY** – The number of journeys carried out by a transport mode between a shipment's origin and destination over a given period of time.

C1. **DAMAGE/LOSS** – The carrier's history of shipment loss and damage.

C2. **FLEXIBILITY** – The ability of the carrier to accommodate the varying requirements imposed upon them by customers.

D1. **LOCATION** – The position of the shipper with regards to freight transport infrastructure and the level of access that this offers to each mode.

ROAD

CRITERIA	RANK 1	2	3	4	5
COST	V. LOW	LOW	AVERAGE	HIGH	V. HIGH
DELAYS	V. SHORT	SHORT	AVERAGE	LONG	V.LONG
FREQUENCY	V. INFREQUENT	INFREQUENT	AVERAGE	FREQUENT	V. FREQUENT
TRANSIT TIME	V. SHORT	SHORT	AVERAGE	LONG	V. LONG
TRACEABILITY	V. BAD	BAD	AVERAGE	GOOD	V. GOOD
DAMAGE / LOSS	V. LOW	LOW	AVERAGE	HIGH	V. HIGH
CONTROLLABILITY	V. LOW	LOW	AVERAGE	HIGH	V. HIGH
FLEXIBILITY	V. LOW	LOW	AVERAGE	HIGH	V. HIGH
LOCATION	V. NEAR	NEAR	AVERAGE	FAR	V.FAR

RAIL

CRITERIA	RANK 1	2	3	4	5
COST	V. LOW	LOW	AVERAGE	HIGH	V. HIGH
DELAYS	V. SHORT	SHORT	AVERAGE	LONG	V.LONG
FREQUENCY	V. INFREQUENT	INFREQUENT	AVERAGE	FREQUENT	V. FREQUENT
TRANSIT TIME	V. SHORT	SHORT	AVERAGE	LONG	V. LONG
TRACEABILITY	V. BAD	BAD	AVERAGE	GOOD	V. GOOD
DAMAGE / LOSS	V. LOW	LOW	AVERAGE	HIGH	V. HIGH
CONTROLLABILITY	V. LOW	LOW	AVERAGE	HIGH	V. HIGH
FLEXIBILITY	V. LOW	LOW	AVERAGE	HIGH	V. HIGH
LOCATION	V. NEAR	NEAR	AVERAGE	FAR	V.FAR

WATER

CRITERIA	RANK 1	2	3	4	5
COST	V. LOW	LOW	AVERAGE	HIGH	V. HIGH
DELAYS	V. SHORT	SHORT	AVERAGE	LONG	V.LONG
FREQUENCY	V. INFREQUENT	INFREQUENT	AVERAGE	FREQUENT	V. FREQUENT
TRANSIT TIME	V. SHORT	SHORT	AVERAGE	LONG	V. LONG
TRACEABILITY	V. BAD	BAD	AVERAGE	GOOD	V. GOOD
DAMAGE / LOSS	V. LOW	LOW	AVERAGE	HIGH	V. HIGH
CONTROLLABILITY	V. LOW	LOW	AVERAGE	HIGH	V. HIGH
FLEXIBILITY	V. LOW	LOW	AVERAGE	HIGH	V. HIGH
LOCATION	V. NEAR	NEAR	AVERAGE	FAR	V.FAR