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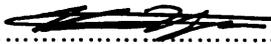
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UNCERTAINTIES AFFECTING THE
ECONOMIC AND ENVIRONMENTAL
PERFORMANCE OF FREIGHT
TRANSPORT OPERATIONS

by

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*A Thesis Submitted in Fulfillment of the Requirements for the Degree of
Doctor of Philosophy of Cardiff University*

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Abstract

A considerable amount of research on uncertainty in supply chain management has been undertaken, but in such works transport has been regarded as a marginal activity within supply chains. Also, the link between the supply chain and the environmental performance of transport operations has been established at a macro level. Supply chain uncertainty can have a significant impact on the efficiency of transport operations at the micro level. Inefficiencies in road freight transport operations can have a knock-on effect on the cost of transport and the level of CO₂ emissions in supply chains. Therefore, the mitigation of supply chain uncertainty within transport operations can minimise the risk of disruptions in the delivery process, so transport resources can be utilised in the most efficient and least polluting manner. Furthermore, in logistics research, there has been a focus on measuring the absolute and/or average performance of road transport operations. One aspect of performance measurement that appears to be under-researched is the impact of unexpected events upon transport performance.

The overall aim of this thesis is to link the uncertainties originated within the supply chain and externally with the economic and environmental performance of road freight transport operations and also to identify potential mitigation tools and/or approaches to minimise their effects. This aim has been achieved in two research stages, the first one deductive and the second stage inductive.

In the deductive stage, a conceptual model was developed by adapting existing manufacturing-focused uncertainty frameworks. This model has been refined through the application of focus groups and confirmed in a structured questionnaire-based survey. The outcome of this stage of the research was the four main uncertainty clusters that affect more transport operations in UK. These uncertainty clusters are: delays, variable demand and/or inaccurate forecast, delivery constraints and insufficient supply chain integration and coordination. Furthermore, the main uncertainty cause found in the focus groups was unplanned road congestion.

In the inductive stage, uncertainty evaluation assessments in three FMCG distribution networks were undertaken to evaluate the effects that different uncertainty causes have on the economic and environmental performance of such operations. An 'extra distance' measure was developed for these assessments, further complemented by including the time dimension of performance in two of them. As a result of this, a new and innovative transport uncertainty evaluation tool has been developed. According to the empirical findings of the case studies, the main uncertainty clusters found in the deductive stage of the research are the uncertainty clusters that contribute more to the generation of unnecessary kilometres run within the distribution networks assessed. Moreover, delays at loading and/or unloading bays are the main cause of additional time within the delivery process.

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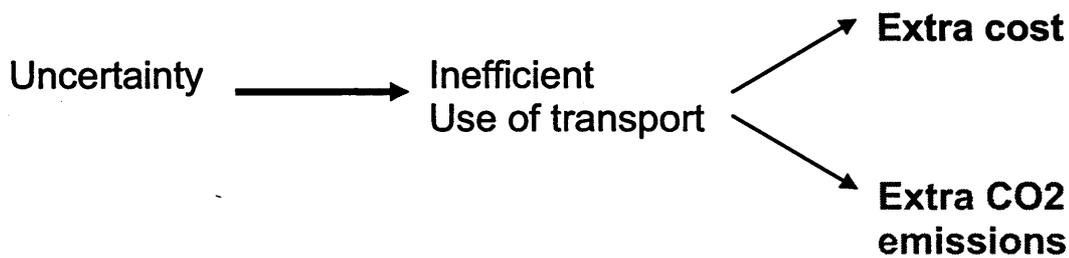


Figure 1.1 Underlying concept of the thesis

In this chapter, the research problems encountered at the beginning and throughout the research will be introduced, together with the objectives of this PhD. The chapter also outlines the methodology undertaken to address the gaps identified in the literature on uncertainty and transport performance. Finally, a summary of the findings will be presented.

1.1 Theoretical perspectives of the thesis

Before introducing the problem proposition and objectives of the thesis, it is pertinent to discuss about the wider theories considered for undertaken the research project and also other theories that were not considered, but can be linked to the research topic. There are a number of theories that have been considered to develop this thesis. They are process-based orientation, network and systems theories. Also, the PhD topic can be linked to other relevant fundamental theories that have been applied in logistics and supply chain management. These theories are transaction cost economics and the resource dependency theory.

Several authors recommend applying a process-based orientation to evaluate and improve the performance of organisations (Porter 1985, Davenport and Short 1990, Hammer 1996, Grover et al. 1995, Walton 1996). A process-based view involves identifying both the external elements, processes executed to respond to macro- and task-environment impacts, and internal factors, processes driven the strategy of the organisation and determining the organisational structure, of the organisation's environment that affect processes (Kiraka and Manning, 2005). In the case of this PhD, the supply chain process considered is freight transport, this process include

1.0 Introduction to the thesis

Scientists at the Mauna Loa observatory in Hawaii say that CO₂ levels in the atmosphere now stand at 387 parts per million (ppm), up almost 40% since the industrial revolution and the highest for at least the last 650,000 years (<http://www.esrl.noaa.gov/gmd/ccgg/trends/>). According to DEFRA (2006), freight transport contributes 6% of the total CO₂ emissions of the UK. However, within the transport sector, road freight transport represents 22% of the total UK CO₂ emissions (Department for Transport, 2007). Hence, freight transport has become a relatively far more important supply-chain function than in the past, due to its impact on the environment. There is a need for freight transport to be used in more flexible and responsive ways, to respond effectively to customer demand (Narus and Anderson, 1996) while at the same time minimising the impact of transport on costs and on the environment (Morash and Clinton, 1997; Duclos et al, 2003). The overall aim of this PhD is to:

Link the uncertainties originated within the supply chain and externally with the economic and environmental performance of road freight transport operations and also to identify potential mitigation tools and/or approaches to minimise their effects.

In order to achieve this aim, it is important to introduce the underlying concept of this thesis, which is shown in Figure 1.1. Uncertainty should be linked with inefficiency in transport operations. Uncertainty originated within the supply chain and externally can generate extra or unnecessary transport movements within distribution networks and delays within the delivery process. This can increase the total transport cost and the CO₂ emissions of the network. However, when uncertainty generates delays within the delivery process without causing vehicles to miss the next load scheduled for them, 'extra time' is added to the transport plan. 'Extra time' increments the total transport cost, but it does not increase the total CO₂ emissions of distribution networks.

through synergistic relationships between the network members' (Bolumole et al., 2007). These two theories have been applied in the thesis to firstly define the boundaries of the conceptual model (the five sources of uncertainty affecting transport operations) and secondly select the unit of analysis for the thesis (the logistics triad as the minimum network arrangement of any supply chain).

Transaction cost economics is other theoretical perspective that can be linked to the research topic of the thesis. Transaction cost economics is based on the economic assumption that decisions regarding a company's ownership are focused on reducing the sum of its transaction and production costs (Coase 1937; Williamson 1975) and any excessive costs may generate transactions that can be transferred to the company's partners (Bolumole et al., 2007). Companies can achieve their main goal, maximising profits, by participating in three different governance structures: the market (one-off transactions for standard investments), hierarchical structures (vertical integration through direct ownership); and hybrid structures (combining elements of the market and hierarchical mechanisms) (Bolumole et al., 2007). According to Williamson (1975), 'production costs can be defined as the cost of building and running an "ideal" machine, while transaction costs as the costs which are generated by departures from perfection, such as friction'. In transaction cost economics, there are three key variables: frequency, uncertainty and asset specificity (Halldorsson et al., 2007). The application of a transaction-based view has been found in a number of recent logistics research studies, e.g. restructuring of supply chains (Croom, 2001), logistics outsourcing activities (Halldorsson, 2002), and buyer-supplier relationships (Mikkola, 2003). Uncertainty can prevent manufacturing and freight transport operations within logistics triads to achieve their target costs, since unexpected events can make these operations to deviate from their initial plans. Transaction cost economics as a theoretical perspective was not considered for the development of the research topic of this PhD, but it can be linked to the results of the thesis. Since, analogies of the Williamson's (1975) definition of production and transaction costs can be made from the transport costs originally planned by transport operations and the transport costs incurred after uncertainty events occurred.

Other theoretical perspective that can be linked to the thesis is the resource dependency theory. This theory focuses on competitive advantages generated by the ownership of heterogeneous assets (financial, physical, human, technological, organizational, and reputational) and capabilities (combination of two or more assets) (Grant, 1991; Penrose, 1959; Prahalad and Hamel, 1990). As Halldorsson et al. (2007) stated, this theoretical perspective is the starting point for many strategic supply chain decisions. As the theory of logistics outsourcing emphasizes (Boyson et al., 1999), the role of 3PL within supply chains is based on the need that manufacturers and retailers have of focusing on their core competences. In the thesis, the 3PL (transport operation) as the entity that take most of freight transport decisions acts as a buffer for most of the demand uncertainty and operational inefficiency generated by their partners. Also, the 3PL (transport operation) outsources to road freight transport subcontractors unexpected increases in volume required to be moved at short notice in an attempt to minimise the negative effects of demand uncertainty originated by their customers.

In the beginning of the thesis, the process-control, network and system theories have been considered to develop the research topic as opposed to the other theoretical perspectives mentioned because of the fact that the main aim of the researcher was to identify and measure high frequency and low-to-medium impact events that affect road freight transport at tactical and operational levels. Transaction cost economics and the resource dependency theory were not considered since they relate more to the strategic planning of logistics and freight transport. However, they can be implicitly linked to the research topic developed in this PhD.

1.2 Problem proposition and objectives

A considerable amount of research on uncertainty in supply chain management has been undertaken (Davis, 1993; Mason-Jones and Towill, 1998; Van der Vorst and Beulens, 2002; Geary et al, 2003; Peck et al, 2003), but in such works transport has typically been regarded as a marginal activity within supply chains (Stank & Goldsby, 2000) and has not been considered explicitly. To start addressing these shortcomings, it is necessary to determine what forms of uncertainty affect transport

The first stage of the research is deductive in nature, since the research objectives are derived from the literature. These objectives are outlined in Chapter 2. These objectives are to:

- Determine the uncertainty causes affecting freight transport operations by adapting and translating existing manufacturing-focused uncertainty frameworks to make them suitable for the analysis of uncertainties affecting transport operations
- Evaluate the causes of supply chain uncertainty that impact on the environmental and economic performance of the road freight transport sector
- Clarify how transport operations mitigate uncertainty..

The second stage of the research is inductive in nature, because the research objectives were derived from the first two case studies (Chapters 7 and 8). These objectives are to:

- Introduce the concept of 'extra distance' as a means of assessing the marginal impact that deviations from the transport plan have on the economic and environmental performance of road freight transport operations
- Evaluate the uncertainty causes affecting freight transport operations in terms of their impact on the environmental and economic performance of these operations and identify potential mitigation tools and/or approaches to minimise their effect
- Develop a decision-making tool, based on a combined assessment of 'extra distance' and 'extra time', for the diagnosis of the effects that different causes of uncertainty have on the performance of road freight transport operations, in terms of cost and CO₂ emissions.

1.3 Outline of the methodology

The literature on the topic of this thesis is at a conceptual stage, since little empirical research has been developed so far. In logistics, there have been two main epistemological perspectives, positivism and critical realism. The epistemological perspective taken in this PhD is critical realism, since the research topic needs to be

operations. Previous, research has introduced the concept of the logistics triad (Beier, 1989; Bask, 2001). The logistics triad is formed by three entities, the shipper, the carrier and the customer, working together to deliver value to the end consumer while keeping the total cost of the supply chain down. Only when the various different sources of uncertainty affecting the use of transport in the logistics triad have been identified will it become possible to determine what their relative impact is on transport performance. Following such diagnosis, it becomes possible to improve the performance of logistics operations within supply chains.

Recently, the link between the supply chain and the environmental performance of transport operations has been established at a macro level. McKinnon (2007) developed a framework where six sustainability ratios link the supply chain processes with CO₂ emissions generated by freight transport operations. However, these ratios can also be influenced by uncertainty in freight transport at operational level. Supply chain uncertainty can have a significant impact on the efficiency of transport operations. Inefficiencies in road freight transport operations can have a knock-on effect on the cost of transport and the level of CO₂ emissions in supply chains. Therefore, the mitigation of supply chain uncertainty within transport operations can minimise the risk of disruptions in the delivery process, so transport resources can be utilised in the most efficient and least polluting manner.

In addition, in logistics research, there has been a focus on measuring the absolute and/or average performance of road transport operations (Fowkes et al, 2004; McKinnon and Ge, 2004). One aspect of performance measurement that appears to be under-researched is the impact of unexpected events upon transport performance (for example, Department for Transport, 2007). In effect, the marginal impact of supply chain uncertainty on freight transport performance at an operational level has not yet been explored. There is evidence of performance measures detailing the number of incidents that occur, and also macro-level measures of planned versus actual distance travelled. However, there have not been any studies that have assessed the impact of supply chain uncertainty in terms of the extra movements and extra time required within the transport network.

explored first at a superficial level and subsequently explained at a micro level. At the beginning of this PhD, the topic was clarified at a macro level through the application of methods that include practitioners and simultaneously using quantitative methods to generalise their perceptions. Therefore, the topic was explored first at a conceptual level and later refined through the application of focus groups. The findings from the focus groups were confirmed in an online structured questionnaire-based survey.

The research topic also needed a great deal of explanation at a micro level to develop diagnostic tools that could inform future decision making in companies, supply chains and industry. In achieving that, the researcher explored what occurs in real-world scenarios, so the case study method was applied by mixing qualitative and quantitative data collection techniques taking a similar approach to the work of Van der Vorst and Beulens (2002). Thus, in the final stage of the research, uncertainty causes were evaluated in three (Fast Moving Consumer Goods) FMCG distribution networks. Also, in these three case studies, a decision-making tool for the diagnosis and mitigation of uncertainty causes was developed.

1.4 Outline of the thesis

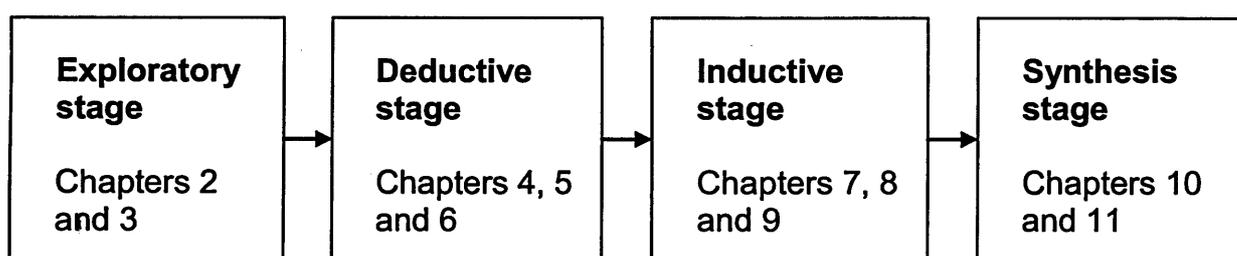


Figure 1.2 Research stages of the rest of the thesis

This section presents an outline of the rest of the thesis to give a clear structure to the reader. Figure 1.2 summarises the research stages of the PhD. The following is a list of the chapters together with their overall content:

- In Chapter 2, the gaps in the literature on supply chain uncertainty and transport are explored. In this chapter, the three objectives from the deductive stage of the PhD are formulated
- Chapter 3 presents a discussion of the methodology and methods applied in undertaking the research
- Chapter 4 includes a conceptual model of uncertainty and transport developed from the literature. This model is the theoretical foundation of the thesis. It categorises transport uncertainty in five sources: shipper, customer, carrier, control systems and external uncertainty.
- In Chapter 5, the conceptual model developed in the previous chapter is refined through the application of seven focus groups. In the focus groups, four main clusters of uncertainty were found: delays, variable demand and/or inaccurate forecast, delivery constraints and insufficient supply chain integration and coordination.
- Chapter 6 presents the application of a structured questionnaire-based survey used to confirm the findings from the focus groups. The four main clusters identified in the focus groups were confirmed in this survey
- In Chapter 7, the definition of 'extra distance' is developed in a case study based on a primary distribution network from the UK FMCG sector. In this case study, the uncertainty causes identified are evaluated in terms of their economic and environmental impact and their frequency
- In Chapter 8, the 'extra distance' measure is complemented by introducing an 'extra time' measure. A combined assessment of 'extra distance' and 'extra time' is undertaken in a secondary distribution network from the South African FMCG sector. In this case study, the uncertainty causes identified are evaluated in terms of their economic and environmental impact and their frequency
- Chapter 9 presents the third case study of this PhD. In Chapters 7 and 8, due to the fact that the two distribution networks assessed do not make available to the researcher appropriate telematics data, the effects of route diversion due to unplanned road congestion and road restrictions could not be measured. In Chapter 9, the assessment undertaken in Chapter 8 is repeated but in addition includes route diversion in the 'extra distance' assessment

- Chapter 10 presents a synthesis of the findings from the deductive and inductive stages of the thesis. This chapter aims to highlight the overall contribution of the PhD. Also, based on the findings from the two stages of the research, in this chapter, a refined decision-making framework for the diagnosis and mitigation of uncertainty in road freight transport operations is developed and discussed
- Finally, Chapter 11 includes statements to link the objectives from the two stages of the research, which have been outlined in this chapter, with the overall findings of the thesis. Additionally, this chapter highlights the limitations and further enquiries and/or opportunities of for future research derived from this thesis.

complexity of supply networks, and as a result, can impact on relevant supply-chain factors, e.g. information visibility and communication between partners.

Also, at the asset and inter-organisational levels, due to globalisation pressures, the geographical dispersion of supply network has considerably increased in the last 20 years (Peck et al, 2003). In parallel, Warburton and Stratton (2005) identify that risks with globalisation can affect supply chain performance: “The decision to move to low-cost offshore supply resulted in the responsiveness of supply chain deteriorating and the accumulation of expensive excess inventory, markdowns and even write-offs”. From a transport perspective, uncertainty can arise from the increase of outsourcing and geographical dispersion within the supply network. In addition, Rossi (2009) determined that a more centralised network could present lower risks in several regards, such as technology, supply chain, process, demand, and risk of exposition.

Previous, research has introduced the concept of the logistics triad (Beier, 1989; Bask, 2001). As shown in Figure 2.1, the logistics triad is formed by three entities, the shipper, the carrier and the customer, working together to deliver value to the end consumer while keeping the total cost of the supply chain down. The shipper is the entity that ships and supplies the goods, the carrier is the logistics provider. In research on the logistics triad, the role of the carrier is often considered to be passive or marginal (Mason and Lalwani, 2004). The organisations responsible for supplying or demanding goods (i.e. suppliers and/or customers) are assumed to be the prime decision makers and hold almost all power in the relationships (Mason et al, 2007).

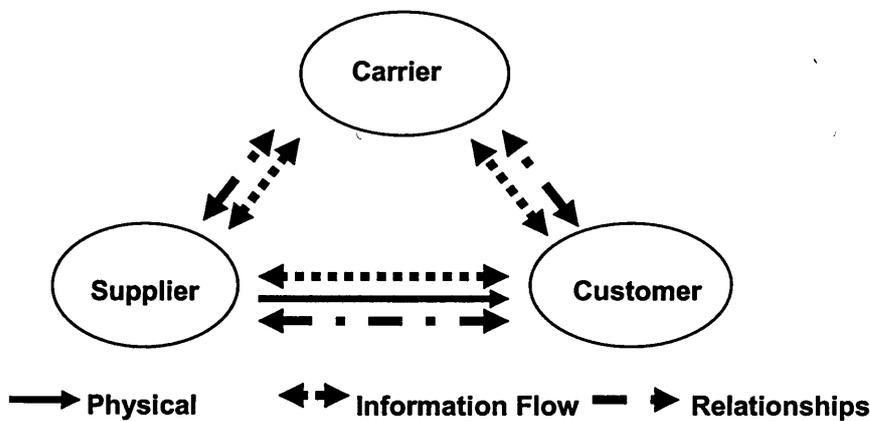


Figure 2.1 Logistics triad (adapted from Bask 2001)

holding and obsolescence costs (Mason-Jones and Towill, 1999). Either way, uncertainty can lead to increased total costs. The supply chain partners can either invest in state-of-the-art ICT systems to keep the level of inventory down and control the transport movements with their distribution networks, or they can also have slack capacity to help them respond to any variation of demand. Traditionally, in the supply-chain uncertainty literature, little attention has been paid to the causes and consequences of uncertainty within freight transport operations. Uncertainty affecting transport operations can lead to unnecessary transport movements within distribution networks, and as a consequence, it can increase the cost and CO₂ emissions of such operations. Therefore, in this thesis, the objective is to address this gap in the literature.

Successful managers today need to take a broad view of the role and responsibilities of transportation management in an integrated supply chain (Stank and Goldsby, 2000). Recently, transport has become a relatively far more important supply-chain function than in the past due to its impact on the environment. In order to cope with the uncertainties originated within the supply chain and externally, there is a need for freight transport to be used in more flexible and responsive ways, to respond effectively to customer demand (Narus and Anderson, 1996) while at the same time minimising the impact of transport on costs and on the environment (Morash and Clinton, 1997; Duclos et al, 2003). Seen in this light, it is clear that, whilst effective transport operations can enable the delivery of customer value to an extent where integration of transport operations into the overall supply chain is critical to improving supply chain performance (Stank and Goldsby, 2000; Mason and Lalwani, 2004), to date there appears to have been a failure in properly integrating transport into supply chains. As a result, the economic and environmental effects of uncertainty on freight transport operations are likely to be greater, since the supply chain is less responsive to unexpected events.

This thesis considers transport uncertainty in terms of variations in a number of factors, including transit times, schedules (for example, to take into account delivery windows), volume and transport mode. A traditional approach to investigating the logistics impact of uncertainty is the use of 'Inventory Theoretic' models following Baumol and Vinod (1970). Typically, these models identify the total costs of transport

2.4 Uncertainty and risk in supply chains

Sometimes the term uncertainty is confused with risk, so it is important to clarify how these two concepts differ. Risk is a function of outcome and probability and hence is something that can be estimated qualitatively most of the time and in some cases quantitatively. If the probability that an event could occur is low but the outcome of that event can have a highly detrimental impact on the supply chain, the occurrence of that event represents a considerable risk for the chain. Uncertainty occurs when decision makers cannot estimate the outcome of an event or the probability of its occurrence. However, uncertainty increases the risk within supply chains, and risk is a consequence of the external and internal uncertainties that affect a supply chain.

Increases in the uncertainties in supply and demand, globalisation, reduction in product and technology life cycles, and the use of outsourcing in manufacturing, distribution and logistics resulting in more complex supply networks, can lead to higher exposure to risks in the supply chain (Christopher and Lee, 2004). Haywood and Peck (2004) highlight that “a number of managerial trends including JIT delivery, supplier rationalisation programmes and widespread outsourcing of non-core activities have all served to increase the efficiency of supply networks”, but at the same time, “there are concerns that these measures appear to have increased supply chain vulnerability” (Svensson, 2000).

Peck et al (2003) have developed a risk framework where they define risk at four levels:

- Linear pipeline level
- Asset or infrastructure level
- Inter-organisational level, and
- Wider macroeconomic level.

In the linear pipeline, quality failures, suboptimal performance, volatility in demand or changing market place requirements can increase risk. At both the asset and inter-organisational levels, the ownership of the asset or infrastructure is an essential factor that contributes to supply chain risk. Outsourcing can lead to increases in the

between carriers within a distribution network due to lack of horizontal communication within the network. Parallel uncertainty can lead to an increase of empty miles within distribution networks. Unforeseen uncertainty is the consequence of deterministic chaos and long-term planning. In this case, a supply chain can have a very good long-term planning process, but many things can change that are unforeseen when the long-term plan is undertaken, so contingency planning needs to be included in the long-term plan. These contingencies can lead to an increase in the fixed cost of transport. More recently, Peck (2009) established that one of the main causes of supply chain risk is that business contingency planning tends to extend only as far as the ability of an organisation to maintain its own core operations under otherwise normal external conditions. Furthermore, chaotic uncertainty is general, non-deterministic chaos that cannot be predicted by a mathematical function.

Macro Level	Micro Level
General Variation	Variable, multi-goal and constraints
Foreseen Uncertainty	Amplification and parallel
Unforeseen Uncertainty	Deterministic chaos and long-term planning
Chaotic Uncertainty	General non-deterministic chaos

Table 2.1 Micro-level Types of Uncertainty in Supply Chains (Prater 2005)

Prater's (2005) framework categorises uncertainty in terms of its predictability. The overall aim of this thesis is to link the uncertainties originated within the supply chain and externally with the economic and environmental performance of road freight transport operations and also to identify potential mitigation tools and/or approaches to minimise their effects. However, it is first necessary to define supply chain uncertainty. According to Van der Vorst and Beulens (2002),

Supply chain uncertainty refers to decision making situations in the supply chain in which the decision maker does not know definitely what to decide as he is indistinct about the objectives; lacks information about its environment or the supply chain; lacks information processing capacity; is unable to accurately predict the impact of possible control actions on supply chain behaviour; or, lacks effective control actions.

and inventory, and how these vary according to choice of transport mode or transport carrier. Most relevant here is the fact that the issue of uncertainty is addressed through the cost of increased safety stock held to prevent stock-outs due to variability in transit times. Such methods are still used, as for example by Swan and Tyworth (2001) in their study of the impact of unreliability in American rail freight services. However, this thesis measures the effect of uncertainty in terms of the two dimensions of transport performance, time and distance, rather than its impact on inventory levels within the supply chain.

A large body of research employing a wide range of methods continues to highlight the inventory impact of transport-related uncertainty. Closs et al. (2003), for example, investigated rail wagon delays specifically in the chemical sector, and concluded that even quite small changes in rail transit times and, more relevantly here, transit time variability, could significantly reduce safety stock levels for the shippers concerned. Stank and Crum (1997) examined the impact of border delays between Mexico and the USA, on both Just-in-Time (JIT) and non-JIT sectors. Amongst their conclusions they identified that, particularly in the JIT sector, some possible inventory reductions were being foregone to achieve greater transport reliability, for example through the use of more consolidated services implying larger consignment sizes than firms would consider ideal. In an analysis of transit times and their variability on ocean liner shipping routes, Saldanha et al. (2006) suggested that the issue of variability over-rode that of absolute speed, and hence carriers may be better off adding slack time into their published schedules in order to achieve better reliability. In this thesis, the overall aim of the researcher is to link the uncertainties originated within the supply chain and externally with transport performance in terms of unnecessary time and distance.

Whilst such a focus on trade-offs between transport costs and inventory costs is still highly relevant in many circumstances, the research studies in supply chain management previously mentioned tend to be based on a traditional paradigm of individual actions by supply chain players acting in a non-co-operative environment. There is a need for alternative approaches that build on more modern supply chain thinking, which emphasises the potential benefits of co-operation between supply chain partners to prevent actions by one player causing spill-over effects elsewhere

2.0 Literature Review

2.1 Introduction

There is a need to give much more attention to the transport functions of the supply chain. In current times, this has become even more important, since transport operations have a considerable impact on the environment. The focus of this thesis is on clarifying the relationship between supply chain uncertainty and the performance of freight transport operations. In order to achieve this, it is necessary first to explore the existent literature on manufacturing and supply chain uncertainty, together with the relationship between supply chain uncertainty and risk. Also, it is important to establish the links between supply chain uncertainty and green logistics. Consequently, in this chapter, a literature review will be undertaken to link supply chain uncertainty and risk with the environmental performance of freight transport operations.

The chapter first presents a background on the literature developed in the topic. It then proceeds by defining uncertainty in broader terms based on the degree of predictability of different types of uncertainty. Following that, a section on supply chain risk, vulnerability and uncertainty is presented to clarify the relationship between these topics of research. Subsequently, the relevant literature on supply chain uncertainty is introduced and the first three research objectives of the thesis are derived from this literature. Subsequently, the links between supply chain uncertainty and the environmental performance of freight transport operations are drawn.

2.2 Background to the topic

Uncertainty affecting different operations within supply chains presents a major obstacle to the delivery of superior customer value (Davis, 1993; Mason-Jones and Towill, 1999). Faced with such uncertainty, manufacturing, logistics and retail companies in the supply network will typically either aim to track the variations, hence leading to increased on-costs, or else buffer themselves against such variations through inventory, thereby, as a consequence, risking additional stock

in the chain. One of the potential benefits of co-operation between supply chain partners is that when the carrier is properly integrated into the supply chain, the freight transport operation is likely to be more responsive to uncertainty.

Recent UK research, for example Lalwani et al. (2004), have highlighted the fact that freight transport planning and procurement can be the responsibility of either the supplier or the customer, depending on the terms on which business is transacted. The traditional nature of relationships within the logistics triad is that the carrier does not take a strategic role in the decision making process within the supply chain. However, due to growing adoption of practices such as 'factory gate pricing', where retailers effectively purchase ex-works from their suppliers and co-ordinate collection of goods with their existing outbound transport movements to improve vehicle utilisation, it is increasingly common for transport to be arranged and managed by the customer (Potter et al., 2007). Models based on the logistics triad, therefore, need to be able to accommodate the effects of different arrangements of responsibility for the organisation, procurement, management and control of freight transport operations.

2.3 What is uncertainty?

As Table 2.1 depicts, Prater (2005) developed an uncertainty framework that can be used to classify different uncertainty causes by establishing their degree of predictability. This framework classifies uncertainty from macro to micro level. At a macro level, uncertainty is typified as general variation, foreseen uncertainty, unforeseen uncertainty and chaotic uncertainty. General variation consists of variable, multi-goal and constraint uncertainties, which can be defined as the general variation that a process has. This is the most predictable type of uncertainty.

Foreseen uncertainty is caused by amplification and parallel interactions. An example of amplification is the demand amplification that usually occurs from customers to their suppliers due to insufficient information visibility. Demand amplification can force road freight transport operations to run unnecessary transport movements, and as a consequence, this can have a negative effect on cost and CO₂ emissions. Also, an example of parallel uncertainty is the potential duplication

Rapidly changing circumstances on the part of suppliers or their customers result in significant uncertainties for carriers who must respond to such changes, often at short notice (Boughton, 2003). As a result, carriers may build considerable amounts of flexibility into their service offerings, perhaps in terms of volume, route, fleet mix and time, with cost implications. It appears that there are low levels of understanding and consideration of how the actions of one triad member impact on the operations (and the costs, revenues and profits) of the others. One important benefit of the model developed in the following chapter is that it will help logistics triads to assess the impacts of supply chain and external uncertainties on logistics operations. The model will also be a foundation framework for the diagnosis and reduction of uncertainty affecting the logistics triad.

2.4.1 Frameworks for assessing uncertainty

Table 2.2 shows the most recent uncertainty frameworks considered for developing the conceptual model for the thesis. Most of them have as a unit of analysis a dyad formed by the supplier and its customer. Also, some of them consider networks of suppliers, warehouses and retailers (Wilding 1998a, Wilding 1998b, Peck et al. 2003). Furthermore, Geary et al. (2003) and Van der Vorst and Beaulens (2002) consider a manufacturing process affected by its supply chain as a single entity as their unit of analysis. The most relevant aspect from all these frameworks is that with the exception of Waters (2007) all of them do not consider transport, at least not explicitly, into their analysis of uncertainty. In this PhD, the aim is to explore of how uncertainty affects transport as one of the main process of the supply chain. Hence, in selecting the uncertainty framework for developing the thesis conceptual model, the researcher was influenced by three wider theoretical perspectives: the process-control, system and network theoretical perspectives.

The reason for taking a process-based orientation is that it was necessary to treat transport as a process that in reality is planned, monitored and controlled from a central planning office in most of distribution networks. Transport is not considered in any of the uncertainty frameworks shown in Table 2.2. As mention in Chapter 1, a typical transport operation plan and execute deliveries for its customers centrally and

Authors	Brief description	Unit of Analysis	Inclusion of transport	Supply chain level
Waters (2007)	It classifies uncertainty in two sources: internal and external uncertainty and recommend mitigation strategies to respond to these two sources.	Supply chain	Yes at the strategic level	Strategic
Wilding (1998a)	It classified three sources of uncertainty affecting the supply chain: demand amplification, parallel interactions and deterministic chaos.	Network	No	Operational
Wilding (1998a)	It is an extension of the Wilding's (1998a) but focusing on deterministic chaos.	Network	No	Operational

Table 2.2 Frameworks for assessing uncertainty

As it have mentioned in Chapter 1, the application of a network theoretical perspective is reflected on the fact that the unit of analysis throughout the thesis is, as Figure 2.1 shows, the logistics triad (supplier, carrier and customer) proposed by Bask (2003). The logistics triad (Bask 2003) influences highly on the development of the conceptual model. It facilitates the transition between the supply-chain-based uncertainty framework and the conceptual transport-based framework developed in the thesis. In most distribution networks, the transport planning office in a typical distribution network communicates and deals with a network formed by suppliers and customers. Furthermore, as discussed in Chapter 1, the boundaries of the conceptual model were defined by applying a system theoretical perspective. In both, the deductive and inductive stages of the thesis, a network view was taken to identify the main causes of uncertainty affecting transport operations within supply chains, but these main causes of uncertainty were categorised based on the boundaries of the conceptual model.

Various uncertainty frameworks have been considered to develop the conceptual model since transport as a process is affected considerable by uncertainty originated by suppliers, customers and external sources. Hence, the Uncertainty Circles (Mason-Jones and Towill 1999) shown in Figure 2.2 were selected because the initial objective was to identify sources of uncertainties which can affect transport operations. Although this framework is aimed at monitoring and controlling supply chain variation impacting on a manufacturing process, its generic principles can be

in the presence of failures in the network the transport planning the transport operation by re-planning the initial transport plan. Hence, a process-based orientation is suitable to explore and measure transport uncertainty in a distribution network.

Authors	Brief description	Unit of Analysis	Inclusion of transport	Supply chain level
Davis (2003)	The framework links supplier performance and demand uncertainty with manufacturing inefficiency. It is focused primarily in medium impact events that occur very frequently at operational level.	Dyad	No	Operational
Geary et al (2002)	This uncertainty framework aims at linking uncertainty causes from each source of uncertainty of the Uncertainty Circle (Mason-Jones and Towill, 1999) framework with different types of effects.	Process	No	Operational
Mason-Jones & Towill (1998)	It includes four main sources of uncertainty affecting manufacturing operations: the supplier, the demand, the factory and control systems. This framework is an extension of the Davis's (1993) uncertainty model.	Supply chain	No	Operational
Peck et al. (2003)	It proposes four levels of supply chain risk, process/value stream, asset and infrastructure dependencies, organisational and inter-organisational networks, and the environment. It is linked to the Mason-Jones and Towill (1999) framework as well.	Network	No	Strategic and operational
Prater (2005)	It categorises uncertainty affecting supply chain in four main categories: general variation, foreseen uncertainty, unforeseen uncertainty and chaotic uncertainty. The boundaries of these frameworks include the strategic and operational levels.	Dyad	No	Strategic and operational
Svensson (2000)	It classified uncertainty into two categories: sources and categories of disturbances. Sources of disturbances can be classified as direct or indirect disturbances and categories of disturbances are divided into quantitative and qualitative disturbances.	Dyad	No	Operational
Svensson (2001)	It includes two dimensions of uncertainty: time- and relationship dependence.	Dyad	No	Operational
SCOR Model 7.0	It includes plan, source, make and deliver as the main source of uncertainty. This framework can be applied at either strategic or operational.	Dyad	Not explicitly	Strategic and operational
Van der Vaart (1996)	It attempts to identify all the uncertainty sources that could affect a materials procurement function in the supply chain.	Process	No	Operational
Van der Vorst & Beaulens (2002)	It adds three dimensions to the Uncertainty Circles from Mason-Jones and Towill (1999): quantity, quality and time. This framework has been based on the Uncertainty Circles, (Mason-Jones and Towill, 1999).	Dyad	No	Operational

the logistics triad – the set of relationships between the supplier of the goods, the customer for the goods and the logistics provider (or carrier) (Figure 2.1). As has been mentioned previously, the conceptual model developed for this thesis has its roots in previous research on the logistics triad where it has been argued that this represents the minimum set of dimensions for supply chain analysis (Beier, 1989; Bask, 2001).

2.5 Linking supply chain uncertainty to the environmental performance of freight transport operations

Recently, the link between the supply chain and the environmental performance of transport operations has been established at a macro level. McKinnon (2007) developed a framework where six sustainability ratios link the supply chain processes with CO₂ emissions generated by freight transport operations (Figure 2.3). However, these ratios can also be influenced by uncertainty in freight transport at operational level. In the specific case of road freight transport, as can be seen in Figure 2.3, there are six ratios that can impact on the level of CO₂ emissions of transport operations. These ratios are handling factor (the number of links in the supply chain), average length of haul, modal split, average load on laden trips, average empty running and fuel efficiency (McKinnon, 2007). Transport uncertainty can have a negative impact on these key ratios.

- Handling factor: this is affected by supply chain structure. At an operational level, inappropriate sourcing (Christopher and Lee, 2004; Giunipero and Eltantawy, 2004), problems in supplier capacity (Cavinato, 2004) and location and storage uncertainty (Van der Vorst and Beulens, 2002; Fowkes et al., 2004) can have a negative impact on supply chain structure. These can make the information flow and communication between supply chain partners less transparent and reliable.
- Average length of haul: the efficiency of vehicle routing influences this ratio. A rigid routing plan can lead to inefficiencies in the transport routing process (Naim et al., 2006). This can cause diversions due to unplanned road congestion. Also, insufficient fleet capacity can be a cause of disruption of

strategic component of the supply chain or a specific source of supply chain uncertainty.

The recent body of work on supply risk and vulnerability has added an important new dimension of exogenous events to the Uncertainty Circle (Peck et al, 2003). Examples of such events might include terrorism, industrial action, disease epidemics and severe weather conditions. Transport operations may be seriously affected either directly through such events or more indirectly through government regulations and controls aimed at preventing their occurrence or minimising their impact. Furthermore, businesses may decide to change their strategies, including their supply chain strategies, to minimise the future impact of government interventions such as taxation changes or new regulations that may be looming on the horizon but whose shape is not yet known for certain. Whilst the work of Peck et al (2003) has added value to the supply chain uncertainty literature, external uncertainty needs to be more fully defined and integrated with the other sources of uncertainty initially proposed by Mason-Jones and Towill (1999).

Other supply chain uncertainty frameworks such as Wilding 1998a, Peck (2003) and Prater (2005) could have been used to develop the conceptual model, however they are more suitable to measure very high impact events which occur very infrequently. These frameworks are more suitable for studying uncertainty affecting supply chains at strategic levels. On the other hand, the combination of the Uncertainty Circles (Mason-Jones and Towill 1999) and the logistics triad (Bask 2003) enables the research to achieve one of the main objectives of this PhD, which is to measure uncertainty that affects day-to-day road freight operations most of the time affected by low-to-medium impact events that occur very frequently.

The first objective of this thesis is:

To determine the uncertainty causes affecting freight transport operations by adapting and translating existing manufacturing-focused uncertainty frameworks to make them suitable for the analysis of uncertainties affecting transport operations.

This objective will be achieved by developing a transport-focused uncertainty model from a supply chain perspective. The foundation stone of this model is the concept of

3.0 Methodology

This chapter aims to present and justify the methodological path selected for this PhD and provide detailed information on the application of the research methods used by the author, which are focus groups, survey and case studies. Firstly, two epistemological perspectives, positivism and critical realism, are presented, discussing how these have influenced logistics research and the topic explored in this thesis. Following that, the existent methodological issues of logistics research and evidence of the application of methodological triangulation in logistics are discussed. Subsequently, a section on the research methods used in the PhD and their application in the logistics discipline is introduced. Also, at the end of the chapter, the author concludes with a synthesis of the methodological path applied.

The discipline of research in this PhD is logistics. Logistics plans, implements, and controls the flow and storage of products, services, and related information from suppliers to end consumers in order to meet customers' needs (Stock and Lambert, 2001). Arlbjorn and Halldorsson (2002) have defined the hard core of logistics as the physical and demand information flows. However, they have stated that the logistics discipline has a protection belt, which are the areas of logistics research that do not explicitly relate to the hard core of the discipline. This presents considerable confusion, since a proportion of researchers within the logistics discipline have tended to undertake research by borrowing theories from other fields. This will be discussed following presentation of the three epistemological perspectives that best reflect research methodology in logistics. Subsequently, the methodological issues of the logistics discipline are discussed and the methodological path of the PhD is introduced. Finally, the applications of the methods used in the thesis, focus groups, survey and case study in logistics are discussed.

3.1 Epistemological perspectives

In this section of the chapter, three epistemological perspectives, positivism, interpretivism and critical realism are discussed, emphasising the main differences between them and the implications and limitations that are involved in their

The second objective of this thesis is:

To evaluate the causes of supply chain uncertainty that impact on the environmental and economic performance of the road freight transport sector.

Also, the third research objective of this PhD is:

To clarify how transport operations mitigate uncertainty.

This will be explored in the deductive stage of the PhD, Chapters 4 to 6, but explained in-depth in the case studies presented in Chapters 7 to 9.

2.6 Concluding remarks

So far, the existent literature on supply chain uncertainty and transport has been examined. Three research objectives have been derived from this literature review. The first is to determine the causes of uncertainty that impact on freight transport operations and the second is to evaluate them by applying a methodological triangulation strategy. In this thesis, the literature review does not include the development of the conceptual model of thesis, due to the fact that it can be argued that a conceptual model can be part of the research path of the thesis.

In the next chapter, the methodology applied in this thesis will be discussed. Then, a transport-focused conceptual model is developed by categorising the existing literature on supply chain and transport uncertainty. After that, in the two following chapters, the conceptual model is refined by applying focus groups and confirmed by applying a questionnaire-based survey. Thus, the first two objectives of the thesis will be largely answered in the Chapters 4, 5 and 6. The third research objective derived in this chapter will be addressed initially in the survey (Chapter 6) and after in more detail in the case study chapters (Chapters 7, 8 and 9). Jointly, the results from these three chapters will help to generalise the finding of the thesis as a whole. Subsequently, the model will be tested at a micro level by the application of the case study method to quantitatively evaluate all the uncertainty causes impacting on road transport operations in terms of the consequences that they have on the cost and CO₂ emissions of road transport operations.

Moreover, unpredictability in arrival times and reduction of efficiency of multimodal hubs (Fowkes et al., 2004) can inhibit the split from road to rail.

- Average load on laden trips: this ratio can be affected by two factors: vehicle utilisation on laden trips and vehicle carrying capacity by weight and volume. If carriers have single vehicle configuration carriers are forced to choose a type of vehicle that may not always match the customer requirements in terms of volume and commodity type (Naim et al., 2006),. Also, transport delays due to inefficiency at the supplier and/or carrier can have a negative effect on the average load on laden trips (McKinnon & Ge, 2004), since, due to delays, a potential full load in a single vehicle can become two half-full vehicles.
- Average empty running: the level of back haulage can affect this ratio. If demand for transport is not managed in a holistic way, empty miles between destination of inbound shipments and origin of outbound shipments can increase (Esper and Williams, 2003), and as a result, the overall vehicle utilisation can decrease. The level of back haulage is a key factor in achieving high levels of fleet utilisation. Difficult and non-standard orders (Boughton, 2003; Fowkes et al., 2004; Vickery et al., 2004) in terms of location of destinations can have a negative effect on the level of back haulage.
- Fuel efficiency: the degree of exposure to traffic congestion can affect this ratio. Road congestion is increasingly affecting transport operations (McKinnon and Ge, 2004). If traffic congestion levels are predictable, then this can be planned for, but in many cases congestion results in variable and less predictable travel times and hence a less reliable service (Van Schijndel and Dinwoodie, 2000; Golob and Regan, 2001). However, when a lorry is running at low speed because of high levels of traffic congestion, its fuel efficiency can be negatively affected.

Supply chain uncertainty can significantly impact on the efficiency of transport operations. Inefficiencies in road freight transport operations can have a knock-on effect on the level of CO₂ emissions in supply chains. Therefore, the mitigation of supply chain uncertainty within transport operations can minimise the risk of disruptions in the delivery process, so transport resources can be utilised in the most efficient and least polluting manner.

- “Science must be conducted in a way that is value-free”. Therefore, research should be undertaken in an objective manner, so a researcher should not accept that his values and beliefs can sometimes bias his research.

3.1.2 Interpretivism

Interpretivism offers a holistic perspective on a given issue and allows complex social situations to be explored and explained. This supports the researcher in coping with the existent complexities of the real world (Remenyi et al., 2005). Interpretivists “have the view that a strategy is required that respects the differences between people and the objects of the natural sciences and therefore requires the social scientist to grasp the subjective meaning of social action” (Bryman and Bell, 2007). They believe that the subjectivity of the actors needs to be considered. The principles of Interpretivism are:

- Reality is made by a combination of multiple constructs and is influenced by the person who holds them (Guba, 1990)
- Meaning is imposed on the object by the researcher and an interaction between the researcher and the object from which meaning is obtained (Crotty, 1998)
- In order to understand what is happening and why it is happening, there is a need to focus social research on the meanings and values of actors (Crotty, 1998)
- The researchers are an active part of the research process and lack a neutral point of observation (Mentzer and Kahn, 1995)
- The interpretive approach focuses on understanding a phenomenon rather than on measuring, explaining or predicting it (Mentzer and Kahn, 1995; Bryman and Bell, 2007).

3.1.3 Critical Realism

Regarding epistemology, critical realism is a philosophical perspective that can be positioned in the middle of the spectrum between positivism and interpretivism. From an ontological position, both positivism and critical realism seek for objectivity in

2002). In logistics, there has been a predominance of positivist research based on quantitative methods (Frankle et al, 2005). However, a discipline might underscore if its academic works are not conducted based on a wide methodological approach (Dunn et al, 1993).

3.1.5 Positivist research in logistics

In logistics, two quantitative methods that can set their roots from the positivist perspective are analytical modelling and survey (Frankle et al., 2005). Analytical modelling is applied to simulate material and information flows of simplified supply chains and to explore what-if scenarios that are difficult to investigate in a real supply chain. Due to the fact that logistics networks are extremely complex, systems need to be simplified to a large extent. An example of a study that has followed this approach is Lee and Tang (1997). These types of academic works have attempted to model logistics flows defining quantitative logistics parameters. Between them there is a common feature, they have developed their models from basic assumptions, e.g. a single-product system, constant demand, a single supplier and customer, and so on, and meanwhile the real-world systems are multi-variable networks composed of many combinations of products, suppliers and customers. On the one hand, these authors have oversimplified real-world scenarios to simulate them. On the other hand, there have been other academic research works where the researcher(s) have embedded more detail into the models. From some of these works supply chains have implemented new strategies to improve their performance. An example of this type of analytical modelling is the work that Disney et al. (2003) undertook to determine the impact of Vendor Management Inventory (VMI) in transport. This particular work has had a considerable impact on the UK grocery industry.

Other logistics researchers have based their works mainly on quantitative surveys applying assumptions that are largely from a positivist perspective (Stock et al, 2000; Li et al, 2005). They have tended to link independent variables, such as best practices or facility location, with performance. In their studies, they tested the association between variables that often have a vague or subjective definition and

- “Human factors need to be considered to disentangle structures beyond superficial social events” (Bryman and Bell, 2007).

Positivism seeks for the simplification of systems through the isolation of variables or system closure. However, the impossibility of achieving experimental closure is a barrier to a scientific approach in studying social science (Collier, 1994). Researchers should explore and analyse research problems as an open system, but “although closure of the system is tricky and not all critical realists think that can be overcome, Baskhar’s response is to look for analogues or substitutes in social science for the role of scientific experiments” (Benton and Craib).

In critical realism, the application of grounded theory is recommended for the development conceptual models (Glasser and Strauss, 1967). Recently, there have been contradicting views regarding the application of grounded theory. Grounded theory is one of the main methodologies which critical realists applied. Glasser and Strauss (1967) emphasise that ‘grounded theory is an inductive research methodology which consists of a set of research stages resulting in the development of conceptual categories/concepts’. They also said that ‘these categories/concepts are interlinked to each other as a theoretical explanation of actions/decisions/behaviour of the actors participating in a research project’. As Allan (2003) stated, ‘this view of grounded theory contradicts the traditional way of developing theoretical models, where researchers derive their models from the literature’. However, according to Strauss and Corbin (1990), ‘researchers require being aware of the vast body of theoretical codes to improve their sensitivity during the data collection process and starting from zero theoretical knowledge may cause researchers to be immerse in the more difficult challenges of grounded theory’.

3.1.4 Influence of positivism and critical realism on logistics research

Positivism and critical realism are the two main approaches applied to explore logistics phenomena, since hardly any research in logistics has applied interpretivism as a sole perspective. It is very difficult to establish the boundaries of the logistics discipline, as “its protection belt is very broad” (Arlborn and Halldorsson,

social science research (Bryman and Bell, 2007). However, positivists believe that neutrality on the researcher's part is perfectly achievable; whereas, critical realists acknowledge that their values and beliefs could bias their research, but they apply methods to mitigate this effect.

Critical realism was "pioneered by a number of works in the UK during the 1970s, such as Harre's realist philosophy and Hesse's models and metaphors in scientific thinking" (Benton and Craib, 2001). A number of UK authors influenced its development (Keat, 1971; Keat and Urry, 1975; Benton, 1977; Baskhar, 1998). However, "Baskhar's work has provided the most systematically developed and influential version of the approach, especially in its account of social science" (Benton and Craib, 2001).

Critical realists advocate the need for disentangling the structures that generate events in the real world. These structures are not observable at the superficial level, so researchers need to apply the practical and theoretical work of social science to identify them (Baskhar, 1989). Therefore, social science requires the application of different methods and procedures more capable of addressing the fact that human beings are the main actors in social systems, contrasting this with natural sciences" (Bryman and Bell, 2007). Hence, the assumption that positivists make that the same methods applied in natural sciences can be applied in social sciences is rejected.

Benton and Craib (2001) discussed the principles of critical realism:

- Critical realism shares with positivism the principle that "the external world is independent of our knowledge of it"
- However, critical realists believe that "the external world is knowable and open to change" (Benton and Craib, 2001), so it differs from the positivist principle in that only theory developed from directly observable phenomena are valid
- For critical realism, "the structures of the real world need to be explored in detail, since the surface that usually positivist research covers can be misleading" (Benton and Craib, 2001)

are difficult to measure. They describe the surface of what is happening in logistics operations by applying structured questionnaires to a large sample.

These two approaches have many positivist features in common. First, they require oversimplification and system closure to apply the deductive approaches of natural sciences. Secondly, they only regard as knowledge theories developed from observable phenomena. Thirdly, they do not consider actors' perceptions about these phenomena. Therefore, their studies mainly describe the real world at a superficial level. They have influenced logistics theory in the early stage of their research topics by describing the whole, but after that more detailed research was needed.

3.1.6 Critical realist research in logistics

Recently, critical realism has gained the interest of an important number of logistics researchers. In logistics research, there is a trade-off between theoretical rigour and industrial relevance (New and Payne, 1995). It is important to apply both quantitative and qualitative research to develop and improve logistics research (Naslund, 2002, cited by Magan et al, 2004). A considerable number of logistics authors have applied different kind of triangulation to achieve depth and industrial relevance in their studies, and meanwhile, achieving high standards of theoretical rigour.

According to Easterby-Smith et al (1991), there are four sorts of triangulation, data triangulation, investigator triangulation, methodological triangulation, and triangulation of theories. Methodological triangulation has been applied to consult actors about results of quantitative studies. New and Payne (1995) developed a logistics performance model applying initially a quantitative survey, after which they consulted 53 logistics practitioners in a series of panels. Mangan et al (2004) developed a decision-making model of ports management. They applied first an inductive approach to clarify the overall features of the UK port industry, and then ran in-depth case studies to determine cause-and-effect relationships. Subsequently, they developed a decision-making model to forecast the impact of management decisions of a panel of 10 logistics practitioners. These two studies

The research topic also needed a great deal of verification at the micro levels (e.g. company- and employee- levels) to develop diagnostic tools that could inform future decision making in companies, supply chains and industry. In achieving this, the researcher needed to explore what occurs in real-world scenarios, thus mixing qualitative and quantitative techniques in the application of the case study method, such as the work of Van der Vorst and Beulens (2002).

3.1.8 Research methodology and the thesis topic

Due to the lack of intensive research developed in the logistics discipline and the unexplored stage at which the research topic was at the beginning of the PhD, the topic needed first to be clarified at a superficial level, before being explained at a company level to truly develop cause-and-effect models that reflect the real world and achieve an acceptable level of rigour. It is necessary to consider the perception of practitioners, but to triangulate their qualitative opinions with other sources of data (e.g. hard company data and simulation models). Therefore, critical realism is the most adequate perspective in this case, although positivist researchers can still contribute by developing research works to add theoretical rigour to the topic.

The author needed to address the deductive objectives of the thesis in order to identify and evaluate the sources and causes of uncertainty that impact on the environmental and economic performance of transport operations and to clarify how transport operations mitigate uncertainty. Subsequently, the inductive objectives of the thesis needed to be addressed, firstly to define how these uncertainties can be measured at the micro level, and secondly, to evaluate their impact on the economic and environmental performance of transport operations. Therefore, methodological triangulation was required and the critical realism principles were applied to complete this research project.

3.2 Methodological issues in logistics research

In comparison with other fields and/or disciplines such as psychology, strategic management and human resources, relatively little attention has been given to methodological issues in the logistics literature. As New and Payne (1995) observe,

have considered the social interactions that can exist in the real world, while applying quantitative methods to achieve rigour in their studies. Also, they have taken account of the overall picture, subsequently disentangled the structures beyond the superficial level to develop valid models.

Other logistics researchers have used data triangulation in the application of case studies. Van der Vorst and Beulens (2002) have applied the case study method using different means of data collection. They ran three detailed case studies to observe how supply chain uncertainty has an impact on logistics performance. In these case studies, qualitative methods such as participant observation and semi-structured interviews were used, after which quantitative methods such as hard-data statistical analysis and value chain mapping were applied. Subsequently, they developed a quantitative business simulation model to generalise their results. Firstly they started consulting practitioners at a very disaggregate level to disentangle their social structures and secondly they generalised the results of the case studies they ran by developing a quantitative model.

Overall, critical realists have influenced this field by applying methodological and data triangulation. They have included in their research projects logistics practitioners who manage real-world operations. They have developed valid and reliable cause-and-effect models without oversimplifying the very often complex real-world scenarios. However, they have also applied the survey method to define the overall picture at a superficial level at the beginning of their studies, or in other cases at the end of their research projects, applied business process simulations to quantitatively generalise the outcomes of their case studies.

3.1.7 Author's own research perspective

The author's academic career has developed from a scientific engineering background at an early stage to a more qualitative background focusing on clarifying logistics practices. In this PhD, the author has continuously considered the perceptions of practitioners regarding the research topic. The literature on the topic of this thesis is at a conceptual stage, since little empirical research has been developed so far. The author starts the thesis by taking a deductive approach, but

3.3 Methodological path of this thesis

The methodological path of this PhD can be described as iterative and multi-methodological. As proposed by van der Zwaan and Engelen (1994), in order to develop new theories, researchers need to follow a research path that is often characterised by three stages: exploration, explanation and validation. Kerssens-van Drongelen (2001) has applied a combined deductive and inductive methodological path in his PhD research. In this PhD, the author has followed a similar methodological route: exploration, verification and explanation.

Figure 3.1 shows the methodological path of this PhD. Initially, the researcher took a deductive approach by consulting the existing literature on supply chain uncertainty. First, at a conceptual stage, a critical literature review was undertaken to categorise the uncertainties identified by previous research works in the topic of supply chain uncertainty. The outcome of this stage was a transport-focussed uncertainty model. After that, in order to refine the conceptual model, the opinions of UK logistics practitioners were consulted through the application of seven focus groups, following which the results of the focus groups were verified by designing and running an online structured questionnaire. Subsequently, the researcher applied an inductive approach to develop a new and innovative tool to link uncertainty with the economic and environmental performance of road transport operations. An initial pilot case study was undertaken of a logistics provider from the UK FMCG sector. The 'extra distance' measure was developed to evaluate the relative importance of different uncertainties in terms of cost and CO₂ emissions. In developing this tool, the literature was consulted, but such a measurement tool was not yet developed. Therefore, as in the case of Kerssen-van Drongelen (2001), an inductive approach was taken. Subsequently, two case studies were run to improve the validity of the tool developed in the first case study and to improve the findings of the overall thesis.

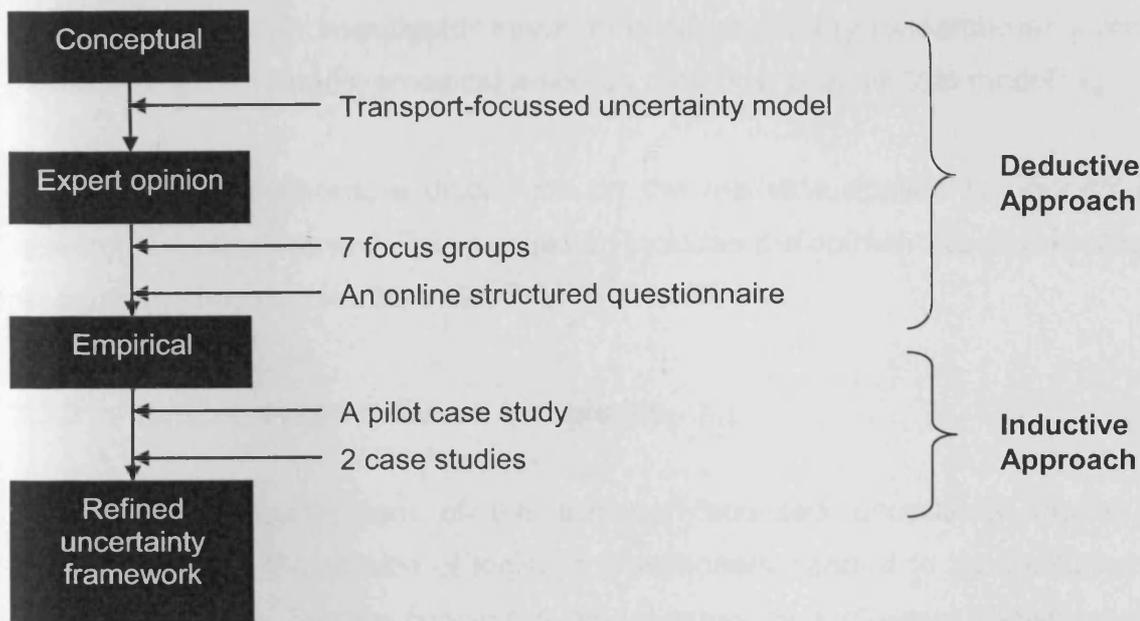


Figure 3.1 Methodological path of this PhD

3.3.1 Conceptual-based research in logistics

As Figure 3.1 depicts, the first stage of this thesis was to conceptually develop a model that would extend the existent literature on supply chain uncertainty to freight transport. This conceptual model provides guidance to the research undertaken in the focus groups. Logistics researchers develop conceptual models in order to:

- Explore the existent gaps in the literature and set future research agenda
- Integrate different and complementary literature into a model
- Have a framework that can support learning and knowledge creation of academics and practitioners in the logistics discipline.

A considerable number of logistics researchers have developed conceptual models in the past. An example of this is the conceptual framework developed by Mason-Jones-Towill (1999). They developed a model on the information decoupling point to improve supply chain performance. Furthermore, Yang et al (2004) integrated all the previous literature on postponement into a conceptual framework. Moreover, Yang et al (2005) extended this conceptual model to determine the impact of postponement on transport to add the environment as a key factor of performance. All this research has set the future agenda on their topics of research. However, after developing a

conceptual model an investigator needs to conduct primary research using opinion-based research methods, empirical research methods, or analytical modelling.

In the following sections, a discussion on the methods applied to undertake the research will be presented. This discussion includes the opinion-based and empirical research method used in the thesis.

3.3.2 Opinion-based research in logistics

Following the development of the transport-focussed uncertainty model at a conceptual level, the opinion of logistics practitioners needed to be consulted. The reason for this was that the conceptual model categorised different uncertainties into five uncertainty sources found in the literature; however, the literature does not clarify how important these uncertainties were. As Figure 3.2 shows, two opinion-based research methods were applied to refine the conceptual model, first by applying the focus group method interrogating UK logistics experts from industry and the government in seven discussion panels, and secondly undertaking a survey in which 56 UK logistics practitioners participated.

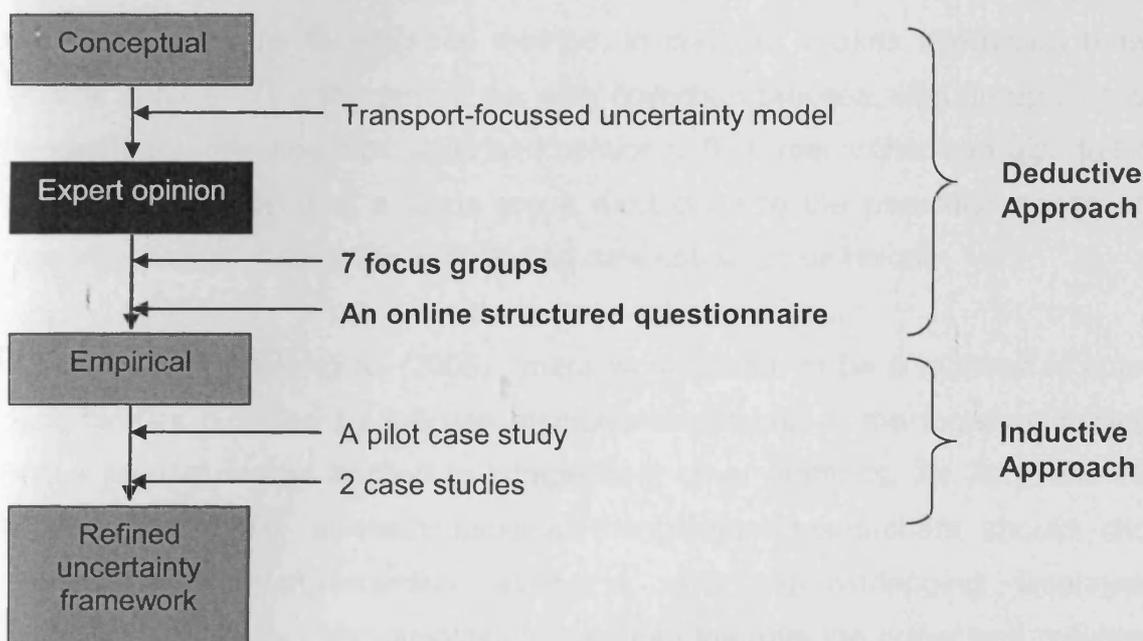


Figure 3.2 Opinion-based research methods applied to refined the conceptual model

The following two sections present a discussion on how to apply focus groups and the survey method, together with examples of the application of these two methods in operations management, supply chain management and logistics and the potential limitations of these two research methods.

3.3.2.1 Focus group method

Focus groups can be defined as group interviews. They have not been extensively used within logistics and are still less popular as a research method (Larsen and Halldorsson, 2004) compared, for example, to case studies (Dinwoodie and Xu, 2008). The focus group method is a group dynamic that aims to control the direction of the research (Krueger 1998a). It can also be defined as a qualitative method that explores the perceptions of the participants. The focus group method is an interpretivist method.

Qualitative research is based on the assumption that 'the world can only be understood from a point of view of the individuals who are directly involved in the activities which are to be studied' (Denzin and Lincoln, 2003). However, 'many regard qualitative researchers as soft scientists or even journalists' (Denzin and Lincoln, 2003). The focus group method, in contrast, makes interaction between several participants a key part of the data collection process, with group discussion generating and testing new ideas and opinions. The researcher can also tailor the structure and content of a focus group discussion to the particular needs of the research project, making it a very flexible data collection technique.

According to Frankle et al. (2005), "there would seem to be a number of potential opportunities provided by the use of multiple methods in the logistics discipline". Focus groups can be applied to complement other methods. As Jack and Raturi (2006) recommend, in methodological triangulation researchers should choose methods with complementary strengths and non-overlapping weaknesses. Combining qualitative and quantitative data can improve the rigour and reliability of research findings. When the research topic has not been studied in the literature, focus groups can be used as a means to refine a conceptual model, so the

researcher can have a better idea of associations between variables before designing a survey. Focus groups can also provide further validation of a conceptual model that has already been tested against statistical data. Furthermore, They can be used to guide the research of a series of case studies, because through the group sessions the researcher is able to confirm the design of the case studies in terms of research themes, scale and scope (Krueger, 1998a).

Before discussing the advantages and disadvantages of the focus group method, it is important to introduce the main characteristics. Krueger (1998a) has established the main features of this method:

- It is a focussed discussion that starts open and ends by focusing on the specific aspects that the researcher is particularly interested in investigating
- It involves experts in a specific field and the level of group members' knowledge on the topic is one of the factors influencing the optimum group size
- The group composition should be designed to maintain a balance of similarities and differences between participants, so the facilitator can ensure an interactive group discussion
- Focus groups are conducted in series, so that when a point of theory saturation is reached the researcher can stop the data collection.

Its application has advantages and drawbacks. The focus group literature highlights the advantages of this method:

- It is an innovative way to solve business problems (Bryman, 2004)
- The researcher has a high degree of flexibility regarding the research plan (Krueger 1998a)
- Focus group discussions are formed by a small group that can represent a large population (Krueger, 1998a)
- Data collection is cost-effective (Patton, 2002)
- Interaction among participants enhances data quality (Patton, 2002).

However, it has certain limitations that need to be considered during the planning stage:

- The researcher has less control over proceedings than in individual semi-structured interviews (Bryman and Bell, 2007)
- The analysis process is a rather time-consuming activity (Bryman and Bell, 2007)
- Focus group facilitation requires flexibility and a set of specific skills on the part of the researcher (Bryman and Bell, 2007; Patton, 2002)
- The divergent views of individual members can be inhibited by dominant views from the rest of the group (Bryman and Bell, 2007; Patton, 2002)
- A focus group strategy is beneficial for identification of major themes but not so much for the micro-analysis of subtle differences (Krueger, 1998a)
- Compared with most qualitative methods, focus groups typically have the disadvantage of taking place outside the natural settings where social interactions normally occur (Madriz, 2000)
- The available response time for any particular individual is restrained in order to hear from everyone (Patton, 2002).

The role of focus groups in multi-methodological path in logistics research

Due to the fact that in this PhD methodological triangulation has been applied and the focus group method is an important aspect of the methodological path of the thesis, a literature review on the contribution of focus groups to multi-methodological research projects in logistics and supply chain management has been undertaken. Through a comprehensive search of the logistics literature, it is possible to identify a number of papers where the research design includes focus groups. In particular, the search focused upon journal articles and targeted databases such as Science Direct, Emerald Insight and EBSCO Business Source Premier. The main search term was 'focus group' and either 'logistics' or 'supply chain'. Both terms are used to reflect the different perspectives people have on the relationship between logistics and supply chains (Larsen and Halldorsson, 2004). The term 'workshop' is also substituted for 'focus group', and papers containing the term consulted to see whether the research was, in effect, using focus groups.

As depicted in Appendix 1, the focus group method has contributed in different ways to multi-methodological path in logistics research projects. The papers found in the literature search were then classified into a number of distinct categories, reflecting the main types of research identified by Saunders et al. (2007):

- Descriptive – one example of such an application exists in the literature, where the focus group method was used to examine the current state of automotive supply chains (Holweg and Miemczyk, 2002)
- Exploratory – these papers used focus groups to investigate a particular issue. This category can be further sub-divided into three:
 - Sole method – these papers directly use the findings of the focus groups to draw conclusions about the issue being investigated. Cullen and Webster (2007) use no other method, while Mangan and Christopher (2005) and Manuj and Mentzer (2008) complement their focus groups with other methods (a survey and interviews respectively). In this case, the methodological path applied did only include focus groups, which does not reflect the approach that logistics researchers have applied most of the time in the past
 - Construct development (Sink et al. 1996; Mentzer et al. 1997;, Dinwoodie 2001; Lancioni et al. 2001; Golicic et al. 2003; Guinipero et al. 2005; Evangelista and Sweeney, 2006 and Tian et al. 2008) – this is the largest grouping and uses the focus group to identify the main constructs for a wider scale survey. Similarly to the papers under this category, in the particular case of this PhD, focus groups were applied as an exploratory method and their findings were used to design a structured questionnaire
 - Other – two other papers applied focus groups in an exploratory manner. Christopher and Jüttner (2005) used the focus group findings to influence their choice of case studies while Rae-Smith and Ellinger (2002) assess the impact of an action research study. The latter is the only example found of exploratory focus groups being used after other empirical research methods.

- Explanatory – in this category, the focus groups are used to assess in more detail causal relationships observed by the use of other methods. Two distinct groupings exist:
 - Survey results – these papers use focus groups to provide more depth to survey findings. In the examples from New and Payne (1995) and Jüttner (2005), a number of focus groups are used because of low survey response rates. Rinehart et al. (2004) and Bernon and Cullen (2007) use fewer focus groups as their response rates are higher
 - Other opinion based methods – here, the focus groups provide more depth as well as the potential to further generalise the findings. Methods used prior to the focus group discussions include interviews (Dainty et al. 2001; Blackhurst et al. 2005), a workshop (Jüttner et al. 2007) and a Delphi study (Melnik et al. 2008).

More details on the contribution of focus groups in multi-methodological path in logistics research can be found in Appendix 1. They have been analysed on the basis of the following factors: research approach, role of focus group within the research strategy, research design, format of the focus group and the analytical process. These are key stages in the focus group method and are discussed in more detail shortly.

The focus group process

Figure 3.3 depicts the different stages in the application of the focus group method and the factors that influence each stage. First of all, the research problem needs to be defined. This decision is reflected in the categorisation of logistics research in the previous section. After defining the research problem, the focus group procedure needs to be designed. The literature suggests that two factors determine the controllability of the group discussion and the quality of the data gathered: group size and composition.

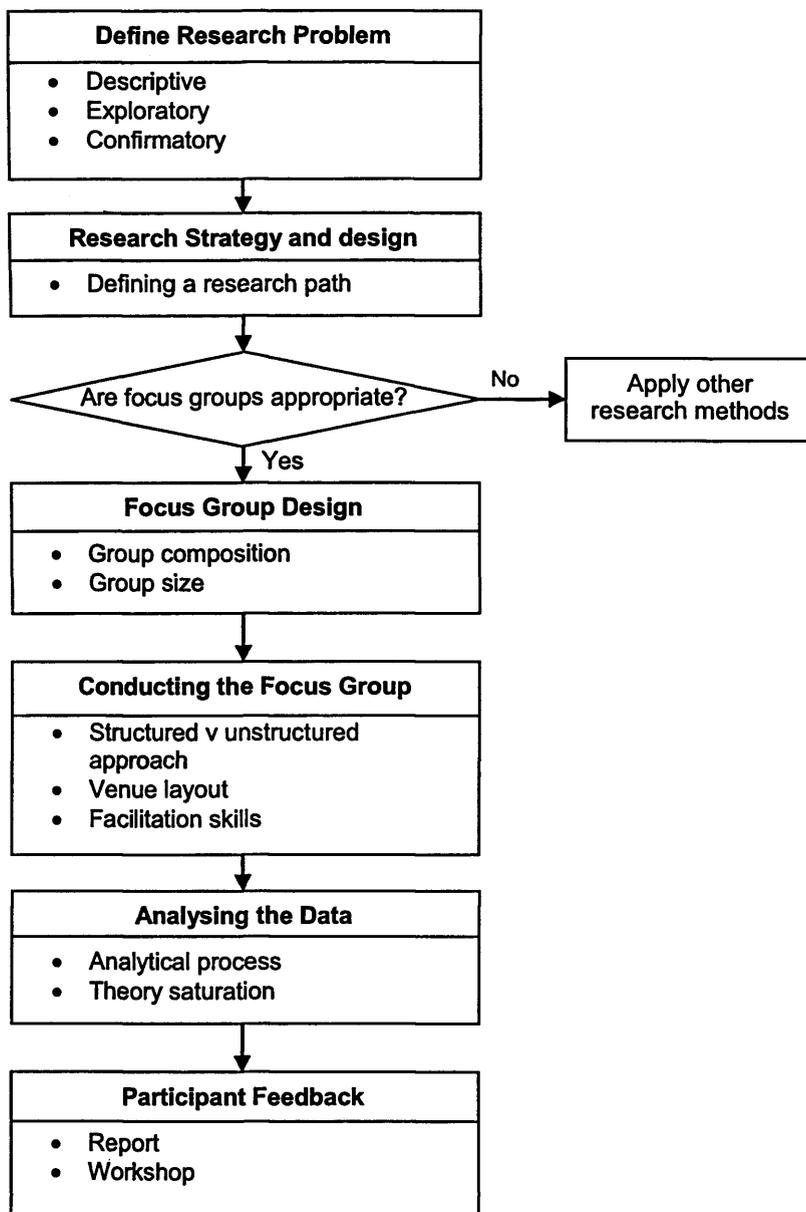


Figure 3.3 Adapted generic focus group process (Krueger 1998a, Morgan 1998)

Figure 3.4 depicts how group size can influence the group discussion controllability and the quality of the data. According to Krueger (1998a), as Figure 3.4 shows, in order to achieve ideal levels of data richness and group control, a focus group session should have between 6 and 10 members. If a focus group session has more than 10 members, the facilitator needs to apply alternative strategies to manage the group effectively, such as splitting it into smaller groups. If the facilitator has enough assistants, the group can be divided into two. Otherwise, the facilitator needs to extend the time arranged for the session. On the other hand, if there are fewer than 6 members, the group discussion can be poor. However, if the group members are

experts from a particular field, the minimum acceptable number of members is 4, since each participant has a greater contribution to make in terms of knowledge and insight (Morgan, 1998). Referring to Appendix 1, it seems that in logistics, focus group size has tended to be at the larger end of the scale. Further, it appears that the focus groups conducted in Europe tend to be smaller in size than those in North America. Only two examples from the latter region had 10 or fewer participants in their focus groups (Lancioni et al., 2001; Golicic et al., 2003).

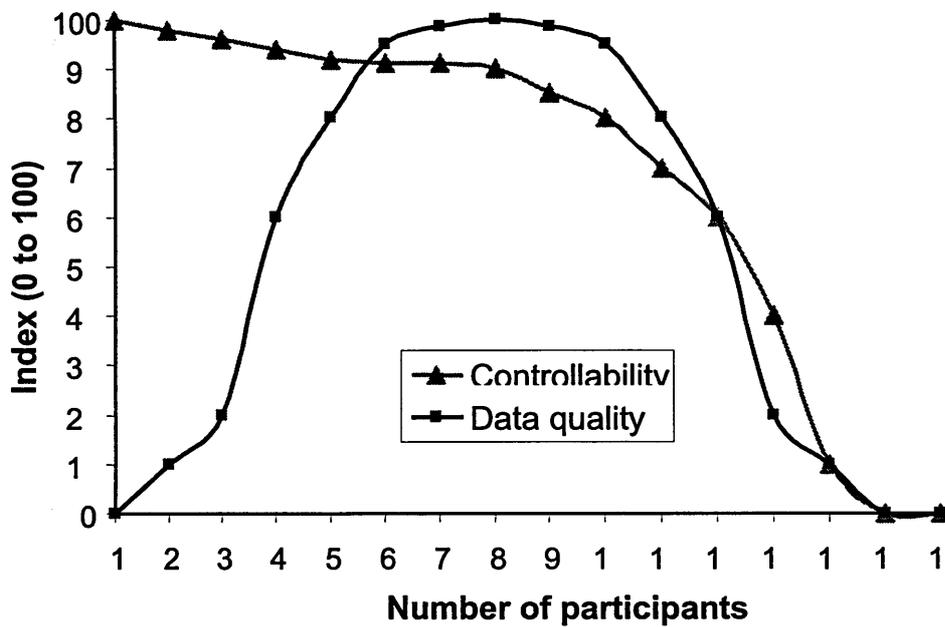


Figure 3.4 Effect of group size on quality and controllability (Krueger, 1998a)

In terms of group composition, the mix of interests and expertise must clearly reflect the purpose of the research. Some diversity of background and knowledge is, nevertheless, required to build new ideas and make group participants ‘think outside of the box’. On the other hand, it has been suggested that group discussions work best if conducted with like minded people (Eggins et al., 2008). Therefore, in the design stage, the research team needs to find the right balance between similarities and differences within group members (Krueger, 1998a). If participants are too similar, the group discussion may not be sufficiently holistic, open and innovative. However, if they are too different and there are no evident synergies between them, group discussions can become diffuse and unproductive.

The literature also considers how focus group discussions should be conducted. It is important to decide on whether a structured or unstructured approach is taken. A structured approach presents the participant with a number of potential topics related to the issue being discussed. In contrast, the unstructured approach poses a few prompting questions to initiate a free discussion between participants. The evidence from the papers in Appendix 1 suggests that, for logistics, an unstructured approach is more popular for exploratory studies and a structured approach for explanatory studies.

The facilitator should have certain skills to reach the standard required in terms of data quality and controllability. According to Krueger (1998a) and Morgan (1998), the facilitator should play different roles to ensure a rich and interactive discussion:

- Expert consultant in the topic discussed, having a similar level of knowledge of the subject to that of the group as a whole
- Challenger, questioning the opinions of participants, making the group rethink their assumptions and not allowing dominant members to divert the discussion onto less relevant topics
- Referee, intervening when there is conflict between participants
- Discussion leader, actively facilitating and guiding the group
- Effective interrogator, capable of asking probing questions
- Mentally alert and free from distractions
- Listening and taking notes at the same time, keeping a written record of the discussion.

The approach taken to facilitate focus groups should be directly linked to the initial research objectives. However, the approach can be modified to take account of the specific circumstances of each new group and the level of theory saturation achieved previously.

In order to achieve a high level of data quality in the analysis stage, it is good practice to employ an assistant facilitator to ensure that group discussions are appropriately recorded and notes taken (Krueger, 1998a). Their facilitation skills can complement those of the main facilitator.

Venue layout and equipment are other important success factors in the organisation of focus group sessions. The venue layout needs to ensure that all the participants are able to listen to the facilitator and fellow participants and they can easily see the presentation used to support the facilitation. The venue layout needs to be a room that offers a considerable amount of flexibility in terms of chairs and tables, so that it can be possible to re-arrange the layout depending on the number of attendees that turn up.

The other two stages in the application of the focus group method are data analysis and participant feedback. The literature briefly describes three factors that the researcher should consider when analysing focus group data, namely frequency, extensiveness and intensity of participants' opinions (Krueger, 1998b). The majority of papers in Appendix 1 adopt some form of clustering exercise, either manually or with the help of software. However, the literature does not consider further the quantitative approaches that can be used in the analysis stage to improve objectivity and rigour. It is also important to test for theory saturation to ensure that the findings are as complete as possible. According to Krueger (1998a), theory saturation is reached when an additional focus group does not add any new theme to the data collected, but adds more cost to the data collection process. In effect, the opinions expressed within a focus group are the same as those identified through previous focus groups. Generally speaking, theory saturation tends to be reached after the fifth session (Krueger, 1998a; Morgan, 1998). Only one paper in Appendix 1 explicitly tests for theory saturation (Cullen and Webster, 2007). This could raise concerns in the other cases as to the credibility of the findings, although they do all deploy methodological triangulation which reduces the risk of bias.

The process culminates in the writing of a final report and dissemination of feedback to participants (Krueger, 1998a).

3.3.2.2 Survey method

Quantitative research is considered more rigorous since validity and reliability can be statistically proven (Bryman and Bell, 2007; Patton, 2002; Saunders et al., 2007). This statistical validity is often gained, however, at the expense of a deeper

understanding of attitudes, behaviour and processes, much of which requires the collection and interpretation of qualitative data. A survey can be applied to interrogate practitioners or customers by using mailed questionnaires, telephone calls, personal interview about themselves or about the social units in which they live or work (Rossi et al., 1983). The survey method is based on the assumption that the sampling process of a survey obtains information about a large population with a known degree of accuracy (Rea and Parker, 1992).

In operations management, work on the survey method has derived three types of survey research (Pinsonneault and Kraemer, 1993; Filippini, 1997; Malhotra and Grover, 1998). Forza (2002) has defined these three types of survey research:

- Exploratory - this type of survey research is applied when the aim is to gain insights about the topic. Usually a conceptual model has not been developed and the topic needs to be better understood. Also, it can help the researcher to find initial evidence of associations between variables and define the boundaries of the model. As can be seen in Appendix 1, Rinehart et al. (2004) and New and Payne (1995) have applied the survey method as an exploratory tool.
- Confirmatory - this type of survey research is used when well-defined concepts and models on the research topic are available in the literature. It has the aim of testing the validity of existing theories and explaining these theories much more. In this type of survey research, the investigator needs to develop hypotheses that serve as linkages between concepts. Evangelista and Sweeney (2006) and Tian et al. (2008) applied the survey method after developing a conceptual model from the literature and refining that model by using focus groups (see Appendix 1). When they designed, piloted and ran their surveys, the conceptual model was based on a sufficiently robust body of theory
- Descriptive - this type of survey research has the objective of understanding the relevance of a research topic. Its main objective is not theory development, although it can guide both theory building and theory refinement (Dubin, 1978; Malhotra and Grover, 1998; Wacker, 1998). An example of the

application of descriptive survey research in logistics is the model of supply chain practices and performance developed by Li et al. (2005).

The survey research process

Forza (2002) developed a framework to guide researchers on how to undertake survey-type research in the field of operations management. He developed the theory-testing survey research process, which consists of the following six stages:

1. Link to the theory level - at this stage, the researcher needs to conduct a search of secondary sources including the literature, databases and government reports. This stage has the objective of:
 - Defining boundaries of the survey in terms of the unit of analysis and population, and
 - Developing the constructs of the survey and linkages between them based on the initial hypothesis of the survey.
2. Design – At this stage of the survey, the research needs to consider the existent external constraints to clarify the data needed in the survey. According to Zikmund (2002), samples are defined as subsets or parts of a larger population. According to Saunders et al (2007), there are two sorts of sampling strategies: probabilistic and non-probabilistic. Also, the sample of a survey needs to be defined and researchers use probabilistic samples that most of the times are selected randomly to reduce the risk of bias. Moreover, the profile of the survey invitees needs to be selected at this stage. According to Kotzab (2005), over three quarters of invitees from surveys run in logistics hold senior management positions. However, the decision of how senior the respondent should be is made based on how strategic is the topic investigated in the survey. Furthermore, the investigator needs to select the data collection technique and develop the measurement instrument for the survey. Saunders et al (2007) defined two types of questionnaires, self-administered and interviewer-administered. Nevertheless, according to Kotzab (2005), about 60% of samples of survey papers published in the Journal of Business Logistics between 1993 and 2003 applied a non-probabilistic sampling strategy. In the case of this PhD, the researcher has

selected a self-administered questionnaire to avoid influencing the responses of the survey participants.

3. Pilot testing - At this stage, the researcher needs to select a smaller sample to test the validity of the survey constructs and the initial hypothesis and also to check the appropriateness of the questions. This pilot sample can be selected randomly or purposively, since it is important to know that the pilot participants who will assess the validity of the survey are willing and able to do so.
4. Collect data for theory testing - At this stage, the investigator administers the data that is returned by the survey invitees and identifies the clusters of samples with low response rate, and in the follow-up process, focuses attention on these clusters. In addition, at the end of this stage, the researcher should estimate the degree of non-response bias and take an informed decision regarding when to stop the data collection.
5. Analyse data: In operations management and logistics, usually this stage involves testing the significance of the relationship between the survey variables and determining the degree of strength of the correlation between independent and dependent variables. Other researchers have applied cluster analysis without focusing on the correlation between variables. In this PhD, the aim of the survey was to determine the degree of importance of the uncertainty clusters found in the focus groups, rather than concentrating on clarifying the relationship between variables. Also, it is important to notice that any data analysis process depends highly on which type of data is collected. According to Saunders et al (2007), two types of data can be gathered through the application of a survey: categorical data- nominal and ordinal, and quantifiable data- discrete and continuous. The former is data that cannot be quantified but can be ranked, such as in the case of the data obtained from the early questions of the survey in this PhD; and the latter is data that can be quantified from the perception of respondents, such as the data gathered in the second part of the survey in this PhD, or from hard measurements.
6. Generate report - In the survey report, the investigator needs to draw both theoretical conclusions and managerial implications for the survey respondents. Additionally, the researcher needs to provide information about the further opportunities derived from the survey.

It is important to mention that from the survey process developed by Forza (2002) the steps that influence the quality of research more are steps No. 1 to 4. According to Frohlich (1998) and Forza (2002), at the stage of linking to the theory level (Step No. 1), the researcher has the opportunity to select an industrially relevant topic, so they can find central government institutions such as the Department for Transport to sponsor the survey. At the design and pilot testing stages, the investigator can ensure the validity and appropriateness of the questionnaire and select respondents who are highly interested in the topic. Also, identifying respondents from multiple mailing lists can assist the researcher in securing a high response rate. At the pilot stage, the survey can be pre-tested and the researcher also assesses the formatting of the questionnaire. When the researcher is conducting the survey, Frohlich (1998) recommended a pre-notice letter and a polite appeal in the actual invitation letter to encourage practitioners to contribute to the survey. In addition, Frohlich (1998) suggests that survey respondents should be offered a report based on the survey findings. In the case of postal mail surveys, the researcher should include a pre-paid postage envelope to allow respondents to reply to the survey without incurring any additional cost for themselves. Furthermore, Frohlich (1998) emphasised the importance of a persistent follow-up process. According to Kotzab (2005), 37% of survey papers published in the Journal of Business Logistics between 1993 and 2003 applied one round of follow-up reminders and 12% applied two rounds of follow-up reminders. This means that according to Kotzab (2005) 51% of these papers did not apply Frohlich's (1998) recommendation of undertaking a follow-up after an invitation is sent to the potential survey participants.

The survey method applied on its own can have a number of limitations:

- It is only capable of describing and/or explaining the surface of a topic (Bryman and Bell, 2007; Saunders et al, 2007).
- Low response rate has always been an ongoing concern in conducting mail surveys (Greer et al., 2002). Nowadays, access to the opinion of logistics practitioners is very restricted by confidentiality and productivity rules set by companies.
- Measuring a construct from the perception of practitioners based on a Likert-type scale can carry a considerable degree of subjectivity.

According to Forza (2002), only about 10% of operations management papers published in recognised academic journals (JOM, MS, IIE, DS, IJPR, IJOPM and POM) have triangulated the survey method with another research method. On the other hand, in the recent literature search undertaken in this PhD to explore the contribution of the focus group method to the multi-methodological path of research undertaken in logistics and supply chain management, 14 out of 22 papers applied focus groups to complement the survey method.

3.3.3 Empirical research

Following the focus groups and the survey, the relationship between uncertainty causes and the economic and environmental performance of transport operations needed to be measured. Therefore, three case studies were designed and run, two from the UK and one from South Africa (Figure 3.5). In order to measure the frequency and impact of uncertainty on the performance of transport operations, it was necessary to design and run a pilot case study in an initially selected primary distribution network from the UK FMCG sector. In this pilot case study, a measurement assessment tool called 'extra distance' was developed and tested. Subsequently, two additional case studies were selected, designed and run in two secondary distribution networks from FMCG sector in the UK and South Africa.

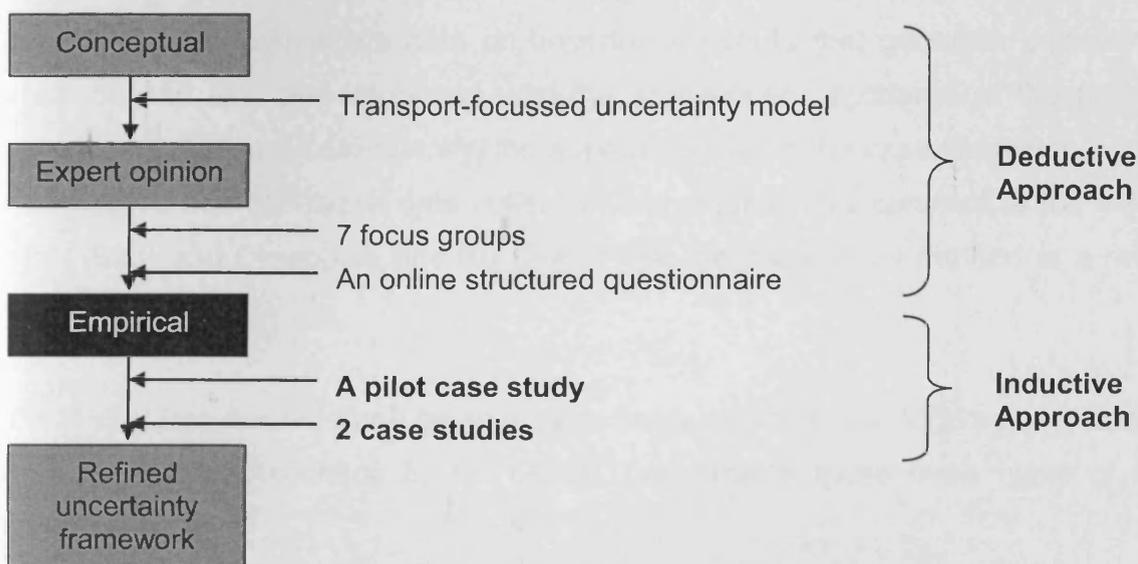


Figure 3.5 Empirical research methods applied as an explanatory tool

The next section includes background information about the case study method and its application in logistics and supply chain management.

3.3.3.1 Case study method

“A case study is an empirical enquiry that (1) investigates a contemporary phenomenon within its real life context, especially when (2) the boundaries between phenomenon and context are not clearly evident” (Yin, 2003, pg. 13). A case study is one which explores a real-world situation to answer specific research questions and which seeks a range of evidence, and which has to be abstracted to obtain the best possible answers to the research questions (Gillham, 2000).

According to Aastrup and Halldorsson (2008), the application of the case study method in logistics and supply chain management research can derive its origins from the critical realist perspective, since its aim is to clarify generative mechanisms that underlie practice and performance. The case study method is inductive and qualitative in nature, in contrast to strategies which apply experimental designs seeking to establish universally applicable statements, associated with deductive and quantitative research (Dinwoodie and Xu, 2008). In the case of this PhD, an inductive approach was applied in the first case study and tested in the other two case studies. Also, the case studies applied in this thesis are based on the triangulation of quantitative data on uncertainty events that generate unnecessary distance and time and interviews with the practitioners in charge of the transport operations studied. Consequently, the approach used in the case studies is a mix of quantitative and qualitative data collection techniques. This contradicts the view of Yin (1993) and Dinwoodie and Xu (2008) that the case study method is a merely qualitative method.

Yin (1993) has defined three types of case study research: exploratory, explanatory, and descriptive. According to Yin (2003), the aims of these three types of case studies are:

- Exploratory - to define the questions and hypotheses of a future research project or determine the feasibility of the desired research or data collection

approach. The first case study in this PhD project aimed to develop and test a new measure to link uncertainty with the economic and environmental performance of road transport operations, thus having a similar objective as the latter aim proposed by Yin (2003). According to Dinwoodie and Xu (2008), this type of case study research has been applied in logistics to:

1. understand a process better,
 2. derive tentative hypotheses for future research, or
 3. prototype a proportion of a novel context
- Descriptive - to present a comprehensive description of a research topic within its context
 - Explanatory - to collect data to explain cause-and-effect relationships between variables and explain how events occur. Following the pilot case study, the two subsequent cases have in broad terms a similar objective; however, they also have the aim of ensuring the development of a robust measurement system designed to evaluate the link between uncertainty and transport performance. This type of case study research has been categorised by Dinwoodie and Xu (2008) in three sub-categories: validation studies, theory refinement and theory extension. Validation studies have been used in logistics: (1) from a positivist perspective, often via application of a procedure, to differentiate between items, (2) to illustrate the benefits of an approach, or (3) from a qualitative viewpoint, to further case study selection to identify further cases of interest (Dinwoodie and Xu, 2008). On the other hand, theory refinement studies has been applied in logistics: (1) to refocus previous studies, (2) to analyse the dynamics of change, (3) to study the impact of intervention (these last two usually described as action research), or (4) to research specific processes (Dinwoodie and Xu, 2008). Furthermore, theory extension studies have been applied in logistics: (1) to explore the generic principles of strategies or characteristics of supply chain management in other contexts or sectors, or (2) to contribute to a non-conclusive theory.

Stake (1995) added three other types of case studies: Intrinsic - when there is an explicit interest in the case on the part of the researcher; Instrumental - when the case study is applied to explain its evidence further to the researcher; Collective -

when a group of cases is studied. Explanatory case studies are usually applied for explaining causal investigations (Tellis, 1997). In the case of this PhD, explanatory case study research has been applied to triangulate the findings of case studies with the research evidence obtained during the initial stages of this PhD.

Scholz and Tietje (2002) have introduced the concept of embedded case study as 'a research method that considers more than one unit of analysis and usually are not limited to qualitative analysis'. Also, they stated that an embedded case study allows a multiplicity of techniques to be applied to the different units of analyses. In logistics and supply chain management research, from a total of 109 journal papers published between 1996 and 2008, 68 papers based their findings on a single case study and 41 of them used multiple case studies (Dinwoodie and Xu, 2008). A total of 15 of these papers have as unit of analysis a network or supply chain and 65 of them have as unit of analysis an organisation (Dinwoodie and Xu, 2008). In addition, 49 of them did not use another method to complement the findings of their case studies (Dinwoodie and Xu, 2008). In this PhD, the unit of analysis of the three case studies is a distribution network formed by three organisations: supplier(s), logistics provider; and customer, since it was important to assess the whole network instead of one organisation. The unit of analysis of the case studies has been selected based on the concept of the logistics triad (Beier, 1989; Bask, 2001). Also, it is believed in this PhD that case study research should be part of a methodological triangulation strategy rather than the methodological path alone.

In terms of the quality factors that need to be considered while designing and running a case study, Mayring (2002) proposed six quality factors: process documentation, safeguarding interpretations by argument (or feedback from the practitioners), research process structured by rules based on an initially agreed and approved data collection protocol by the practitioners, closeness to the study items (defining the boundaries of the data collection), communicative validation (constantly seeking feedback from practitioners), and triangulation by applying interviews and seeking the opinion of different actors. In addition, Yin (2003) stated that the validity of a case study should be initially assessed in terms of its constructs, when collecting the data internally in the organisation, and after finishing the case study, externally by comparing the case study with another from the same sector.

Stuart et al. (2002) have proposed five stages of case study research:

1. Development of the research questions - The research questions are developed depending on the research objective of the case study. At this stage, the type of case study proposed by Dinwoodie and Xu (2008) is selected
2. Instrument development - First the researcher needs to define the unit(s) of analysis for the case study, deciding which stage of the supply chain will be studied. Also, the researcher needs to choose and secure access to the case study or a number of case studies, depending which approach is taken
3. Data gathering - At the beginning of the data collection, the case study is in an exploratory stage where the researcher is identifying the appropriate sources of evidence for the case study. After that, the data gathered is validated by the researcher through the application of semi-structured interviews to appropriate practitioners
4. Data analysis - Usually in operations management, data from case studies is primarily in the form of transcripts from interviews, so a technique to compare data from multiple case studies needs to be selected. However, in the case of this PhD, comparisons are drawn in three dimensions: (1) merely quantitative, the findings from the evaluation of the impact of different supply chain uncertainty on transport performance; (2) depending on the data available, how the assessment tool has been applied; and (3) from interviews, the researcher has determined the uncertainty mitigation approach applied by the three case study companies
5. Case quality- This stage is executed when the researcher disseminates the results of the case study to the company management staff and to other practitioners from other companies but from the same industry. Both recommendations have been applied in this research project, the findings of the first case study have been validated in the other two and the findings from the first two case studies were validated in a workshop where the audience was comprised of practitioners from the UK road transport sector.

A number of authors have identified the weaknesses of case study research in supply chains:

- The investigator did not specify the reason for selecting a single case study (Seuring 2008, Asstrup and Halldorson 2008). The selection of the three case studies was based on the characteristics of the FMCG sector where uncertainty can considerably affect transport performance
- Just one stage of the supply chain is approached, ignoring the network characteristics of supply chains (Seuring 2008, Asstrup and Halldorson 2008). In this research project, a triad perspective was maintained in the three case studies
- Data collection has been undertaken via few interviews and analysis of the company website (Seuring 2008). In this PhD, the findings of the three case studies are based on the triangulation of performance data gathered from the companies and continuous involvement of the logistics managers in charged of the transport operations studied
- The papers did not properly clarify how the data was analysed (Seuring 2008). In this thesis, the data was analysed by applying a quantitative case-and-effect exercise
- Finally, how the rigor of the research was ensured (Seuring 2008). The rigor of the findings from the three case studies has been ensured through the internal dissemination within the three companies and their customers and suppliers, together with external dissemination within the sector to which they belong.

3.4 Concluding remarks

In this PhD, a multi-methodological approach has been applied for a number of reasons. Firstly, the philosophical approach of the PhD candidate can be positioned in the critical realist perspective. Secondly, the topic of research was unexplored at commencement of the PhD, so the surface of the topic needed clarification before explaining the mechanisms of the topic at a micro level. From the literature review a conceptual model was developed and the initial objectives required the interrogation of practitioners at a macro level. To do this, the researcher took a deductive research

approach. Before starting any case study, the literature on how the impact of uncertainty on transport performance can be measured at micro level was searched, and no evidence of any measurement system was found. Therefore, an inductive research approach was taken following the realities and recommendations from the first case study. However, the measurement system developed in the first case study was refined in the two subsequent case studies.

This PhD offers evidence of the advantages of taking a multi-methodological approach. Findings from the initial stages of the research assist the researcher in generalising the results from the case studies. Also, the findings from the conceptual model, focus groups and survey defined the scope of the case study. Furthermore, the combined deductive-inductive approach can be used as an exemplar case when future researchers explore the macro level and subsequently explain the findings from the macro level through the application of case studies.

The research methods applied in this research project can be supported in the future with the application of business simulation methods, so the framework of transport uncertainty can be validated and fully generalised.

3.5 Contribution

To Methodology in logistics research

This chapter highlights the benefits of applying methodological and data triangulation in logistics research. In addition, it demonstrates that there is a lack of balance between academic rigor and industrial relevance in logistics research and a critical realist approach can be used to address this problem. Moreover, it shows when a deductive approach is applied, as well as the benefits of applying an inductive approach when studying a phenomenon at the micro level. Regarding the methods applied in this PhD, specifically in the case of the focus group method, from the generic literature, two frameworks have been developed to guide future applications of this method in logistics. Furthermore, the chapter includes a review that demonstrates how focus groups can complement other research methods. This review can also guide future research in logistics.

To PhD

This chapter justifies the multi-methodological approach applied in the PhD. Additionally, it justifies the application of the research methods used in the four stages of the PhD research methodological path. It highlights the limitations of each method applied in the PhD and how they were addressed in their application.

4.0 Conceptual model

4.1 Introduction

In the literature review chapter, the literature on supply chain uncertainty and risk has been explored. Also, the aim of this chapter is to start answering the first objective of the thesis, which is:

Link the uncertainties originated within the supply chain and externally with the economic and environmental performance of road freight transport operations and also to identify potential mitigation tools and/or approaches to minimise their effects

This aim will be achieved by considering perspectives from wider theories such as system and network theories and process-based orientation. The Uncertainty Circle framework (Mason-Jones and Towill, 1999) has been selected as a starting point for the development of the PhD conceptual model since it takes a supply chain perspective to assess uncertainty affecting manufacturing operations. As it has been mentioned in Chapter 2, transport will be treated as a supply chain process throughout the thesis. The aim of the conceptual model developed in this chapter is to frame the rest of the research undertaken in the thesis. Because, it facilitates the identification and evaluation of uncertainty events which affects transport operation at tactical and operational levels.

4.2 Method

The literature review developed previously in the thesis supports the choice of the logistics triad as the initial concept around which to integrate all the supply chain uncertainty literature (Beier, 1989). Because most attention has been paid in the past to uncertainty research from a manufacturing perspective, a need was identified to undertake a comprehensive search for literature focusing on uncertainty within transport operations, or affecting transport operations. Hence, a thorough search was conducted using databases such as ABI/INFORM, Emerald, ScienceDirect, IngentaConnect, EBSCO Business Source Premier, academic journals, electronic

journals, trade magazines and reports, including information from freight best practice surveys.

The methodological framework formulated in the methodology chapter will be used. This part of the research is undertaken by developing a conceptual model from the existing literature on the topic. This recognises that to date the logistics triad uncertainty model has been developed purely as a conceptual model. In the following chapters, it will be further developed and validated through the application of research methods such as focus groups, surveys and case studies. The data obtained from such empirical research will be used to develop, refine and validate the model, so that it can be used both in the industry and for further academic research.

Before embarking on the literature search, a plan of the potential areas and themes to be interrogated was undertaken. The principal objective was to develop a holistic supply chain uncertainty framework, but focusing on supply chain uncertainty issues that can potentially impact on the economic and environmental performance of transport operations. A series of keyword combinations were selected for the search. The starting point was the phrase 'transport uncertainty' with alternative words for each part also considered. The idea was to find uncertainty causes that can directly impact on transport performance. However, in many cases, the impact was more indirect, so other key words were needed. Due to potential ambiguity between the terms 'uncertainty' and 'risk', both were used. In the literature, there are papers on risk that also relate to supply chain uncertainty. The literature shows that 'flexibility' is a possible response to uncertainty in supply chains (Naim et al, 2006) and was therefore included as an alternative keyword to locate previous works on uncertainty in a less direct manner. 'Uncertainty', 'risk' and 'flexibility' were also used as keywords in combination with keywords that are similar to 'transport', 'supply chain', 'manufacturing', 'demand' and 'external' (Figure 4.1). An additional avenue was to identify key academic journal papers in the topic area and to examine the references cited in these papers.

A systematic approach to synthesising the literature was adopted. Firstly, a spreadsheet was constructed to summarise all the causes of uncertainty found in the

relevant papers identified in the search. Secondly, those causes were categorised into the five main sources of uncertainty of the model which will be discussed in more detail later. After that, in order to define where uncertainty originates from, a series of clusters were developed within each of the five uncertainty sources.

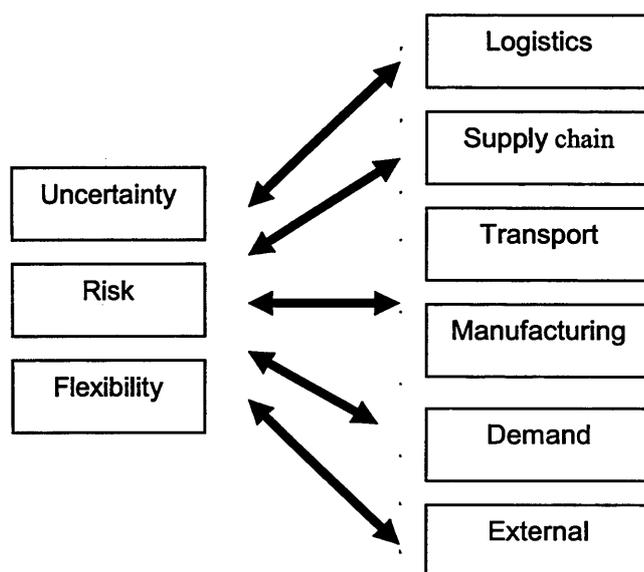


Figure 4.1 Keywords for the literature search

4.3 Transport and supply chain uncertainty

In this section of the paper, the logistics triad uncertainty model will be presented and the logic followed in developing the model will be explained. The starting point for the development of the model was the Uncertainty Circle (Mason-Jones and Towill, 1999). The Uncertainty Circle has been developed from a manufacturing perspective. This model has been refined at this stage of the thesis to identify different sources of uncertainty within the logistics triad taking a transport perspective. This is because, according to the literature review, uncertainty affecting transport operations seems to be under researched. The refined model can be seen in Figure 4.2. The conceptual model considers the carrier as the transport process and adds external uncertainty, reflecting Peck et al.'s (2003) framework, to highlight the fact that logistics operations are open systems. Uncertainty can be initiated from any one source and can potentially affect other members of the logistics triad. In this respect, it is important to bear in mind the point made earlier that responsibility for the transport operation may rest with either the upstream or the downstream partner.

Perfect sharing of information will mean that all triad members have access to full information, which will eliminate such asymmetries, but some triad members may have a vested interest in masking information, especially when things are not going well, and hence perfect sharing of information is unlikely in practice.

Now, the causes of transport uncertainty identified in the literature will be integrated and categorized and the resulting conceptual model presented.

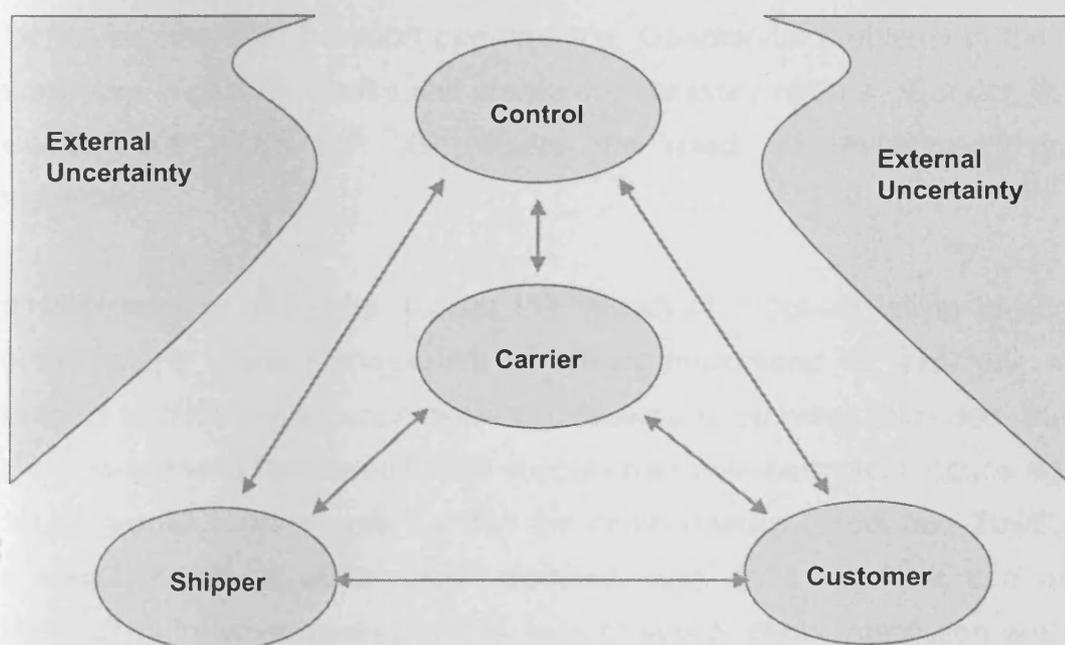


Figure 4.2 Transport-focused uncertainty model

4.3.1 Uncertainty related to suppliers

In this section, the focus is on the sources of uncertainty which can be related to inappropriate management at the source of the goods to be transported. The review of relevant literature, summarised in Table 4.1, highlights the fact that selection of ineffective suppliers or poor supplier performance (reflected perhaps in lack of adequate supply capacity at peak times, poor product quality or other inefficiencies within the manufacturing process at suppliers) can be a significant source of uncertainty within the logistics triad. From the perspective of outbound transport, this

is because there could well be effects on whether loads of product are ready for despatch on time, or on the likelihood of full or part loads being rejected by customers (and hence having to be returned). Similarly, problems in the manufacturing operation itself, such as ineffective scheduling, problems with quality control or operational problems such as machine breakdown, can also delay the loading of products at the supplier's facility or lead to high rates of product return. According to a freight best practice report published by the Department for Transport (2007), 7% of the delays within the delivery process originate at loading bays. A significant number of authors highlight the potential impacts of poor inventory and order management on transport performance. Operational problems in the storage process can impact on quality and create unnecessary returns (Van der Vorst and Beulens, 2002). This can also create the need for unnecessary transport movements.

A smaller number of papers discuss the impact of suppliers failing to engage in effective supply chain management with their customers; for example, not with customers to obtaining accurate demand forecasts for planning purposes. Such poor demand forecasting between different supply chain members can produce significant levels of amplification in orders within the chain (Mason-Jones and Towill, 1999), with knock-on effects on transport demand, and as a result, it can generate inefficiency in transport operations. A lack of supply chain integration and control can also cause duplication and fragmentation in the delivery process (Cavinato, 2004). Furthermore, limited communication in the ordering process can cause suppliers to amplify the demand from customers, so artificial transport demand can be generated. See Potter and Lalwani (2008) for a greater analysis on the impact of demand amplification on transport. Demand amplification can have a serious environmental knock-on effect on transport operations.

The relatively large amount of literature identified and discussed in this section reflects the topicality of management issues such as supplier management, quality management and inventory reduction in recent years, and whilst most of the literature in such fields does not consider transport impacts to any great extent, the potential impacts on the efficiency of transport use are recognised.

Area	Cause of Uncertainty	Authors	Papers
Supplier	Problems in supplier capacity	Cavinato (2004), Giunipero & Eltantawy (2004), Childerhouse & Towill (2003), Mason-Jones & Towill (1999), Van der Vorst & Beulens (2002)	5
	Inefficiency of supplier	Christopher & Lee (2004), Geary et al. (2002), Esper & Williams (2003), Serel (2008), Shah (2009), Huang et al. (2009), Chiang (2008), Avhinder et al (2009)	8
	Inappropriate sourcing	Christopher & Lee (2004), Giunipero & Eltantawy (2004), Tseng (2009), Rossi (2009)	4
Supply Chain Management	Lack of supply chain integration and control	Geary et 2002, Cavinato (2004), Childerhouse & Towill (2003)	2
	Supply chain infrastructure dispersion	Cavinato (2004)	1
	Lack of communication in the ordering process	Geary et al (2002)	1
	Inconsistent demand forecasting by different supply chain members	Mason-Jones & Towill (1999)	1
Marketing	Inappropriate Product Life Cycle Management	Vickery et al (1999), Van der Vorst & Beulens (2002), Geary et al (2002), Childerhouse & Towill (2003), Christopher & Lee (2004), Vickery et al (1999), Lockamy III (2008)	7
	Lack of integration between Marketing and Production	Giunipero & Eltantawy (2004), Vickery et al (1999)	2
	Packaging Uncertainty	Beier (1989)	1
	Promotion Uncertainty	Beier (1989)	1
Manufacturing	Operational Problems	Childerhouse & Towill (2003), Cavinato (2004), Giunipero & Eltantawy (2004), Mason-Jones & Towill (1999), Geary et al (2002), McKinnon & Ge (2004), Van der Vorst & Beulens (2002), Geary et al (2002), Rossi (2009), McKinnon et al (2009), Song (2009)	10
	Problems in Quality Control	Childerhouse & Towill (2003), Mason-Jones & Towill (1999), Van der Vorst & Beulens (2002), Geary et al (2002), Vlajic et al. (2009)	5
	Ineffective Scheduling	Van der Vorst & Beulens (2002), Childerhouse & Towill (2003), McKinnon & Ge (2004)	3
Inventory and Order Management	Inventory and order management uncertainty	Lalwani et al (2006), Schwarz & Wang (1999), Christopher & Lee (2004), Morash & Clinton (1997), Childerhouse & Towill (2003), Mason-Jones & Towill (1999), Galasso et al. (2009), Kaipia (2009)	8
Transport, Shipping and Storage	Shipping uncertainty	Morash & Clinton (1997), Fowkes et al (2004), Department for Transport (2007)	3
	Storage uncertainty	Van der Vorst & Beulens (2002)	1
	Transport management issues	Fowkes et al (2004), Geary et al (2002)	2

Table 4.1 Sources of uncertainty related to suppliers

The amount of literature also reflects the fact that it has been very common for manufacturers to assume responsibility for outbound transport operations. If the supplier of the goods is responsible for outbound distribution activities such as

organization of the downstream transport and warehousing, further important sources of uncertainty are generated. Issues will arise if transport is managed inefficiently, or if transport and distribution networks are not adequately attuned to the needs of the product during marketing and promotional initiatives (which may change pack size and packaging requirements) or to the differing needs at different stages of the product life cycle. If, on the other hand, major customers (such as large multiple retailers) opt to manage the transport function and collect products 'ex-works', uncertainties due to these latter elements are not the responsibility of the supplier, and hence are more appropriately categorized as being related to the customer.

4.3.2 Uncertainty related to customers

In contrast to the previous section, the focus of this section is on the sources of uncertainty which can be related to inappropriate management at the destination of the goods to be transported. Table 4.2 summarises the findings from the literature search of the main causes of transport uncertainty relating to the customer. Rather less literature was identified than for suppliers, but nevertheless it is possible to identify some key themes.

Boughton (2003), Morash and Clinton (1997) and Fowkes et al. (2004) all identify inefficient unloading processes, reflected in differences between the agreed and actual unloading times and in excessive waiting or queuing times as a significant source of uncertainty. This is confirmed by a freight best practice report published by the Department for Transport (2007) for the UK food sector where 26% of the delays within the delivery process are generated in unloading bays. This can generate the need for the deployment of more resources and can also potentially create the need for unnecessary transport movements. Practices such as 'factory gate pricing', where the recipient of the goods assumes responsibility for inbound transport, can offer one way to mitigate such uncertainties. Other literature (Cavinato, 2004; Van der Vorst and Beulens, 2002) points to further potential transport uncertainties caused by poor management of distribution centres or retail outlets. Despatch of inaccurate quantities to retail outlets can lead to stockouts and loss of sales (Vickery et al, 1999), and may call for emergency deliveries or returns which will impact on

overall transport efficiency. This can have both a significant economic and environmental impact on transport performance.

Area	Cause of Uncertainty	Authors	Papers
Supply Chain Management	Lack of integration of all strategic areas within supply chains	Milligan (1999), Geary et al (2002), Naim et al (2006)	3
	Transport not included in purchasing costs	Milligan (1999)	1
	Rigidities in the distribution network, static nodes, the same links	Naim et al (2006)	1
	Wrong location of retail outlets, excessive stock and loss of sales	Vickery et al (1999)	1
Ordering and Inventory Management	Difficult and nonstandard orders, excessive customisation creating excessive variations in the demand for transport	Boughton (2003), Fowkes et al (2004) Vickery et al (1999)	3
	Suboptimal order consolidation	Milligan (1999)	1
	Wrong weekly forecast from customers	Mason-Jones & Towill (1999), Van der Vorst & Beulens (2002), Rojas & Frein (2008), McKinnon et al (2009), Ustundag & Tanyas (2009), Bichescu & Fry (2009)	6
	Wrong operational planning of transport and inventory	Morash & Clinton (1997), Crnkonic et al (2008)	2
	Higher customer expectation, impacting on delivery frequency	Lalwani et (2006), McKinnon et al (2009)	2
	Lack of visibility to the shipper of consolidations and carrier optimisation plans	Esper & Williams (2003)	1
Unloading processes	Unloading time uncertainty, waiting or queue times between delivery appointment and unloading	Boughton (2003), Esper & Williams (2003), McKinnon & Ge (2004), McKinnon et al (2009), Department for Transport (2007)	5
	Unsyncronised transport-congestion, confusion and poor delivery sequencing at the customer receiving docks	Morash & Clinton (1997), McKinnon et al (2009)	2
	Rigid delivery window in customer unloading facilities, more significant in operations more likely to incur late arrivals	Fowkes et al (2004)	1
Store and depot management	Special promotions	Morash & Clinton (1997)	1
	Excessive time-to-market	Cavinato (2004)	1
	Costs and loss opportunities due to wrong innovation	Cavinato (2004)	1
	Inefficiencies in labelling	Van der Vorst & Beulens (2002)	1
	Wrong store layout and shelf capacity too small	Van der Vorst & Beulens (2002)	1

Table 4.2 Sources of uncertainty related to the customer

As with supplier uncertainty, a failure by customers to engage in effective supply chain management with supply chain partners and ineffective order management and inventory management systems are both further contributors to transport-related uncertainty. Poor order and inventory management by customers can put pressure on suppliers and carriers, for example by causing unnecessary variations on freight transport demand (Fowkes et al., 2004), and as a result, unnecessary transport movements can be generated. Inaccurate weekly forecasts from customers can affect transport demand considerably (Van der Vorst and Beulens, 2001) by causing stock-outs, requiring emergency deliveries or by obsolescence, possibly leading to excessive product returns. Esper and Williams (2003) give importance to problems in the effectiveness of the consolidation of consignments, which are generated due poor visibility of information.

If the customers for manufactured products (such as major multiple retailers) choose to take control of the supply chain operations including transport and warehousing, then shortcomings in supply chain management on their part can result in very considerable logistics uncertainty. This may result from poor supply chain planning at a tactical level or rigidities regarding supply chain infrastructure. Lack of integration of all strategic areas, purchasing, sales, and transport, within the logistics triad can cause problems of information visibility, and as a result amplify the demand for products and transport (Naim et al., 2006). If there is not sufficient information visibility, the carrier does not have enough time to generate the most optimal transport plan.

4.3.3 Uncertainty related to carriers

Table 4.3 summarises the main causes of transport uncertainty relating to the carrier. The carrier can internally create uncertainty to the members of the logistics triad, largely due to communication and operational problems regarding information and physical processes of transport.

Area	Cause of Uncertainty	Authors	Papers
Transport Fleet Management	Empty miles between destination of inbound shipments and origin of outbound shipments	Esper & Williams (2003)	1
	Disruption of operations due to insufficient fleet capacity or unreliable carrier service	Fowkes et al (2004), Swan & Tyworth (2001), Closs et al (2003), Ahlert et al (2009), Colicchia & Dallari (2009), McKinnon et al (2009)	5
	Single vehicle configuration	Naim et al (2006)	1
	Lack of flexibility in terms of time, location, item or delivery frequency	Morash & Clinton (1997)	1
Transport Process (Physical and Information Flows)	Transport delays due to internal reasons, e.g. defective vehicle and lack of driver	Mason et al (2003), McKinnon & Ge (2004), Vljajic et al. (2009), McKinnon et al (2009), Department for Transport (2007)	5
	Narrow scope to change to other distribution channel, different goods	Naim et al (2006)	1
	Insufficient information visibility regarding location of trucks and drivers	Mason et al (2003), Rossi (2009)	2
Transport network management	Lack of communication between different carriers and different transport modes	Choy et al (2007), Naim et al (2006), McKinnon et al (2009)	3
	Collaboration between two hauliers or two transport operations, let arrivals impact in the whole system, in series	Fowkes et al (2004)	1
	Demand for transport is not managed in a holistic and collaborative way	Naim et al (2006)	1
Scheduling and routing	Unpredictability in arrival times, reduction of efficiency of transport hubs	Fowkes et al (2004)	1
	Lack of flexibility of transport shipment and scheduling	Christopher & Lee (2004), Rossi (2009)	2
	Rigid plan of routing	Naim et al (2006)	1
	Logistics providers safety slacks, extra lead times to build in safety times, extra unnecessary capacity	Christopher & Lee (2004)	1
	Delays leading to implications with respect to drivers' hours regulations	Fowkes et al (2004)	1
Cost and profitability	Low margins	Hoffman (2006)	1

Table 4.3 Sources of uncertainty from the carrier

A UK study by Fowkes et al (2004) identified various sources of delay to freight transport resulting in variability in journey times. Three kinds of delay to freight transport were identified:

- (1) Delay resulting from an increased journey time, with fixed departure time;

- (2) An increase in the spread (or range) of arrival times for a fixed departure time;
- (3) Schedule delay, where the departure time is effectively put back.

The authors argued that a high level of certainty and reliability of journey times is an essential requirement for an effective operation. Reasons for such a requirement are: (1) demand considerations (JIT and Quick Response strategies; port deadlines; 'hub and spoke' operations) and (2) supply-side issues (two-way loading; consolidation of deliveries; implications on driving hours; scope for round-the-clock operation; order management and warehousing regimes). Journey time reliability is also important in the context of rising operating costs, narrow profit margins and attempts to improve the efficiency of transport operations. When a vehicle is late, that vehicle can miss the next load scheduled for it, and as a result, an additional and unnecessary trip can be generated, which has a significant impact on the environmental performance of road transport operations.

Insufficient fleet capacity can be a cause of disruption of transport operations, delaying the delivery process to customers (Fowkes et al 2004). Uncertainty can also be originated because of lack of carrier flexibility in terms of time, location, delivery frequency or vehicle configuration (Naim et al., 2006). This can limit the opportunities to perform load consolidation within the distribution network. Inefficient fleet management, reflected in poor vehicle utilisation or excess empty running, can negatively impact on transport operations (Esper and Williams, 2003) in terms of extra and unnecessary cost and CO₂ emissions. If demand for transport is not managed in a holistic and collaborative way, issues such as empty running, delivery delays, and low transport capacity utilisation are likely to arise (Naim et al 2006).

Uncertainty can result from transport delays due to internal reasons such as defective vehicles or lack of drivers (Mason et al., 2003; McKinnon and Ge, 2004). In the UK food sector, 26% of the delays within delivery process are generated due to internal inefficiency problems (Department for Transport, 2007). Uncertainty in the form of a lack of information about the location of trucks and drivers can lessen visibility on the customer side and delay the delivery process (Mason et al, 2003). This can generate the need for sourcing a vehicle from a more remote location than

the vehicle that was initially scheduled in the transport plan. Meanwhile, transport network management can be another significant source of carrier uncertainty. There can be integration and collaboration issues because of lack of communication between different carriers, possibly involving different transport modes (Choy et al, 2007). When hauliers attempt to integrate their transport work for different clients in sequence, major delays can be compounded, leading to significant impact on clients towards the end of the work schedule (Fowkes et al, 2004). The way that transport demand is managed can affect the flow and utilisation of the transport network.

Carrier uncertainty can also originate in the scheduling and routing processes. Lack of flexibility of shipment and transport schedules (Christopher and Lee, 2004) can cause operational problems at customer facilities and result in delays in the delivery process. Inefficient transport scheduling can make arrival times more unpredictable, hence having a detrimental impact on the efficiency of hubs (Fowkes et al, 2004). Very rigid routing plans can require extra unnecessary capacity (Christopher and Lee, 2004), and it may be difficult to source the most suitable vehicles for the work, particularly in highly specialised conditions (Naim et al 2006).

The typically low margins in much of the freight transport industry (Hoffman, 2006) can result in uncertainties as operators struggle to balance costs against their labour resource pressures and legal obligations. Financial exigency may dictate that hauliers bid for work at low rates, and then struggle to meet the required level of performance. Delayed journeys can be highly problematic due to constraints regarding the legal maximum working time of a driver (Fowkes et al, 2004), as vehicles may need to wait for a replacement driver in the middle of the delivery process.

4.3.4 Uncertainties relating to control systems

Uncertainties relating to control systems can be classified into information management uncertainties, ICT systems uncertainties and physical systems uncertainties (Table 4.4). Information uncertainty can result from inaccurate information on inventories, demand (actual and forecast), production plans, capacity, and order status within the supply chain (Christopher and Lee, 2004). This is usually

a consequence of the lack of a systematic means of handling information (Choy et al 2007), preventing the information available in ICT systems from being updated quickly. Any such information uncertainty caused by demand forecast inaccuracy can lead to increased demand amplification backing up the supply chain from customer to suppliers (Mason et al., 2003). Therefore, unnecessary inventory is potentially moved within the supply chain and carriers may be required to perform emergency deliveries, possibly involving poor vehicle utilisation. This can add unnecessary miles to distribution networks, and as a result, extra cost and CO₂ emissions.

Area	Cause of Uncertainty	Authors	Papers
Information Management	Inaccurate information of inventories, actual demand and forecast, production plans, capacity, and order status within the chain	Christopher & Lee (2004), Boughton (2003), Carter & Ferrin (1996), Christopher & Lee (2004) Mason-Jones & Towill (1999), Mason et al (2003)	6
	Insufficient information due to lack of systematic means of handling information	Choy et al (2007)	1
	Forecast inaccuracy throughout the chain, demand amplification	Mason et al (2003), Christopher & Lee (2004)	2
ICT Systems Management	Information flow rigidity, not adapting while the journey happens	Corry & Kozan (2006), Carter & Ferrin (1996)	2
	Inventory control systems, that does not allow horizontal collaboration between carriers	Tyan et al (2003)	1
	Transport is not included in the inventory control systems	Mason et al (2003)	1
	Incorrect information input on ITC systems	Geary et al (2002), Christopher & Lee (2004)	2
Physical Systems Management	Poor stock auditing	Geary et al (2002), Van der Vorst & Beulens (2002)	2
	No synchronisation and poor visibility among adjacent processes	Geary et al (2002)	1
	Wrong location at DCs	Van der Vorst & Beulens (2002)	1

Table 4.4 Sources of control systems uncertainty

Regarding ICT, rigidity in the information flow, such as the lack of real updated data during a journey (Corry and Kozan, 2006), can create a significant degree of uncertainty in the delivery process. In many cases, inventory control systems do not allow horizontal collaboration between 3PLs (Tyan et al, 2003), so transport management is fragmented and transport movements from carriers cannot be optimised. This produces duplications between carriers with distribution networks.

This can be an outcome of the use of suboptimal inventory systems that do not include transport (Mason et al, 2003). Moreover, there could be problems in the set-up and operation of key ICT systems (e.g. MRP, EDI) (Christopher and Lee, 2004). This issue can generate considerable information distortion within the logistics triad, so the wrong product mix may be delivered to the customer and consequently the customer may return part of the load. In turn, this can produce the need for unnecessary trips and increase the overall cost and carbon footprint of the transport function of supply chain. However, information control is not the only source of control uncertainty in transport operations. Physical control systems can be another significant source of uncertainty for the logistics triad. Poor stock auditing and poor quality control systems can equally produce confusion (Geary et al., 2002).

4.3.5 External uncertainty

In this section, the impact of uncertainties emanating from external sources that are not under the control of the logistics triad will be discussed, such as variations in key transport macroeconomics, demand unpredictability and congestion (Table 4.5). Uncertainty in transport macroeconomics has been highlighted as a significant issue that affects transport operations; a number of authors (including practitioners, Boughton, 2003) have highlighted variations in fuel prices and HGV driver shortages as important macroeconomic issues that have recently affected freight transport operations in the UK.

In recent years, there has been considerable uncertainty over the price and availability of fuel, both in the short term and in terms of the future resource cost of fuel, (particularly conventional diesel) and the future availability of such fuel. In the short term, the UK fuel crisis of Autumn 2000 caused severe short term shortages, resulting in major uncertainties for many road hauliers (Whiteing et al, 2002). Prices have been quite volatile in recent years and whilst larger users, such as major rail freight companies, can minimize the impact of short term volatility through forward buying and hedging, small operators are not able to do this. Further uncertainty is caused by lack of knowledge of future changes in fuel taxation. In the face of rising oil commodity prices on world markets, some previously announced increases in UK fuel duty have been postponed or cancelled, but others have not.

These uncertainties related to the price of fuel (including the effects of future changes to fuel taxation) are not likely to have a significant physical impact on companies in the triad in the short term, although there is some danger of disruption if a carrier is made bankrupt as a result and ceases operations at short notice.

Area	Uncertainty Cause	Authors	Papers
Transport Macroeconomics	Variations in fuel prices	Schulz (2002), Boughton (2003), Hoffman (2006), Screeton (2009)	4
	Driver shortages and the cost of provision of training and skills development in the logistics sector	Boughton (2003), Hoffman (2006), Skills for Logistics (2005a), Skills for Logistics (2005b), McKinnon et al (2009)	5
Market	Product and transport demand fluctuations	Mason et al (2003), Bailey (2009), Galasso et al. (2009), McKinnon et al (2009)	4
Road conditions	Traffic congestion	Boughton (2003), Fowkes et al (2004), McKinnon and Ge (2004) McKinnon et al (2009), Department for Transport (2007)	5
	Preferred route unavailable	Fowkes et al (2004)	1
	Delays and unreliable travel times	Van Schijndel & Dinwoodie (2000), Golob and Regan (2001)	2
Severe or sudden external disruptions	External events that disrupt the SC	Christopher & Lee (2004), Giunipero & Eltantawy (2004), Watanabe (2006), Garger (2002), LaGrange (2006), McKinnon (2006), Saldanha et al (2006)	7

Table 4.5 External sources of uncertainty

Another group of external uncertainties relates to labour shortages and the cost of provision of training and skills development in the logistics sector. Skills for Logistics, the official UK Sector-specific Skills Council for the freight transport industry, recognises the shortage of large goods vehicle (LGV) drivers as a problem which is having wider cost implications for the logistics industry. Lack of time and facilities for training, the substantial costs involved in sending a trainee to a driving school, recruitment costs in excess of £1,000 and difficulties in retaining staff are quoted as factors contributing to this shortage (Skills for Logistics, 2005a). Labour shortages cause delays in the delivery process and result in the provision of inferior customer service. Whether or not the sector will be successful in meeting its future training and skills needs will depend largely on its rapport with government (Skills for Logistics, 2005b).

Road congestion is increasingly affecting transport operations (McKinnon and Ge, 2004). In the UK food sector, 19% of the delays within delivery process are generated due to traffic congestion (Department for Transport 2007). If congestion levels are predictable, then this can be planned for, but in many cases congestion results in variable and less predictable travel times and hence a less reliable service (Van Schijndel and Dinwoodie, 2000; Golob and Regan, 2001). Delays can lead to delivery refusals at depots. Preferred transport routes may not always be available. Serious accidents or the need for unplanned repairs can lead to lengthy and unannounced road and rail closures, resulting in long detours away from preferred routes (Fowkes et al 2004). Congestion and delays may also have a detrimental effect on staff morale (and consequently retention of staff in the transport sector) compounding the driver shortages discussed above (Golob and Regan, 2001).

Other external causes of uncertainty affecting transport operations cannot be predicted in any way. These can be categorised as chaotic uncertainty since they tend to happen in a totally random and sudden manner, and can cause unavoidable disruption to supply chain operations. (Christopher and Lee, 2004; Giunipero and Eltantawy, 2004). Natural disasters are one example. The Kobe earthquake, for instance, caused damage to the transport infrastructure which very quickly disrupted the just-in-time supply of materials to Japanese factories (Watanabe, 2006). Bad weather can be disruptive, for example causing unreliability in ocean shipping transit times, although vessel routing may mitigate this (Saldana et al, 2006). More severe weather events, such as hurricanes, can be extremely disruptive (LaGrange, 2006). McKinnon (2006) presents a macroeconomic assessment of the potential impact of massive disruption to road freight transport due to catastrophic failure of a country's road transport system. In similar vein, although perhaps less random and sudden, it is difficult to predict the likelihood or the potential severity of industrial action, or to take effective action to ameliorate its effects. A good example of this is the uncertainty which resulted from port congestion on the US west coast in 2002, sparked by industrial action. Some supply chains had to make recourse to the emergency use of air freight (Garger, 2002).

Demand for products (and hence the requirement for transport) fluctuates (Mason et al., 2003) although demand variability varies from sector to sector. In general,

members of the triad should be able to mitigate the impact of demand volatility through the use of better demand forecasting techniques or by improving the visibility of information within the supply chain. Some demand fluctuation will always remain, however, due to inherent randomness or the impact of unpredictable factors, such as the weather.

4.4 Discussion and Conclusions

This chapter presents research which has investigated supply chain uncertainty from a transport perspective. The chapter intends to categorise the literature to develop a conceptual foundation for the rest of the thesis and has developed definitions and classifications of different types of uncertainty. In doing so, a wide and diverse literature on uncertainty in supply chains has been synthesised with many causes of uncertainty that affect transport derived from this. No previous literature has attempted to codify this in a systematic manner or to explicitly examine transport uncertainty within the context of supply chain uncertainty. The findings are summarised in Figure 4.3, which identifies the five main areas for transport uncertainty and also some of the main themes that emerge from the literature.

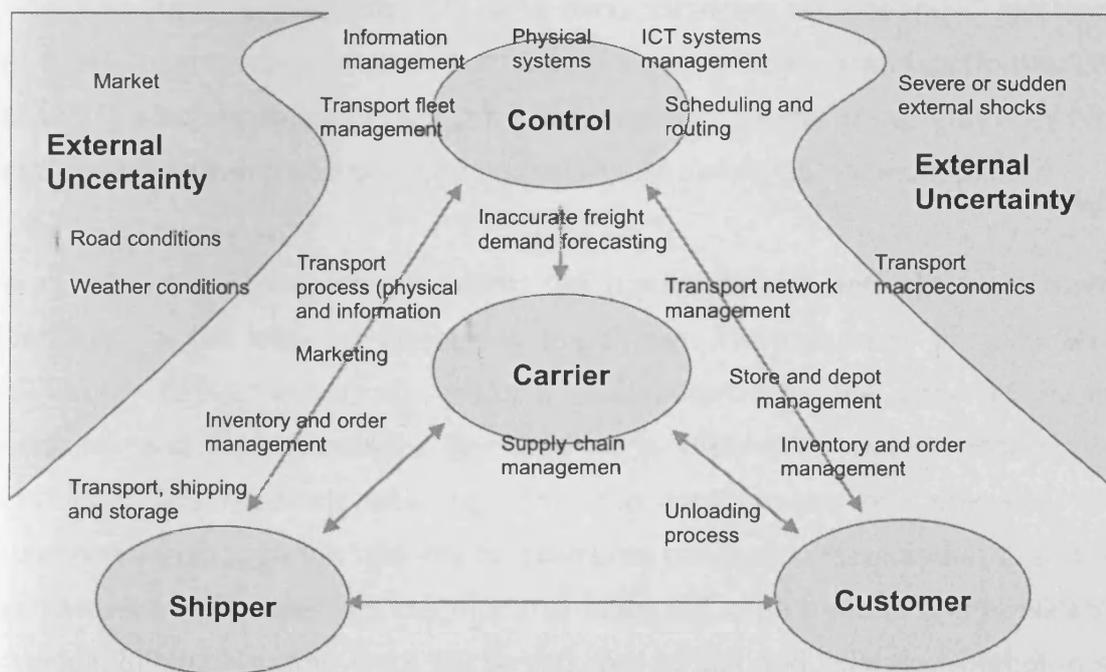


Figure 4.3 Transport-focused uncertainty model – location of key uncertainties

The model developed acts as a template by which organisations may develop a supply chain strategy vis-à-vis their uncertainties. By categorising uncertainty into the five types described, organisations may determine where the greatest uncertainties lie and hence develop a prioritised plan for supply chain re-engineering by initially targeting those uncertainties that result in the greatest risks to the successful operation of the supply chain. The model will also determine to what extent the uncertainties can be tackled by a single organisation alone, or in collaboration with other partners in the supply chain, the wider industry and government. Not only will this enable the performance of the transport operations to be improved, but the whole supply chain should perform better (Tracey, 2004).

One important outcome of this work is that, whilst many of the causes of uncertainty and their impacts can be linked primarily to one particular member of the logistics triad, in other cases the location of uncertainty depends on which triad member is responsible for planning, organising, procuring and managing the freight transport operation. In principle, the impact of any uncertainty can be reduced through the creation of excellent supply chain control mechanisms and by complete sharing of all information relevant to the supply chain. Such information sharing will not always be possible, however, and there will be circumstances when triad members will be reluctant to share all information. In such circumstances, the continued existence of information asymmetries implies that supply chain efficiency and performance will depend on which organisation assumes responsibility for transport. This may be one reason for the growing use of 'factory gate pricing' initiatives, for example.

The results of this chapter will inform the opinion-based and empirical research undertaken for the following chapter in this thesis. The results of this chapter can also inform further empirical research undertaken into the area of transport uncertainty and hence logistics flexibility as a means for accommodating such uncertainty. The research also highlights the root causes of inefficiency within transport. Even though the majority of examples cited and discussed in this chapter refer to road freight transport, the model is intended to be generic and applicable to all modes, although further work will be required to test and validate whether this will be possible. Transport inefficiency – and most especially inefficiency in the use of

road transport – is closely related to environmental performance, but this relationship has not been tested in this chapter, and much research is needed to investigate the impact of transport uncertainty on supply chain environmental performance. This will be addressed in the case study chapters of this thesis.

4.5 Contribution

To methodology in logistics research

The categorisation undertaken to populate the logistics triad uncertainty model can be used as a guide in future developments of a conceptual model in logistics, particularly when researchers are interested in categorising a topic into clusters. In this case, the researcher counted the number of times each uncertainty cause was highlighted in the literature. Other dimensions could be included in the categorisation, e.g. frequency and impact, quantity, quality and time, but there was insufficient empirical evidence to do that.

To the PhD

The chapter has achieved the first objective derived from the literature review. The different uncertainties found in the literature were categorised into five uncertainty sources. This will guide the research in the following two chapters. However, the model still needs to be refined in terms of scope and also the second objective of this PhD still needs to be achieved.

To the topic

In this chapter, the logistics triad uncertainty model has been developed. This model can be used to guide future research on uncertainty impacting on freight transport operation. Also, this model can be used as a diagnostic tool in industry.

5.0 Evaluating the causes of uncertainty in logistics operations

5.1 Introduction

In the previous chapter, a model of transport uncertainty was developed from published literature. This model categorised the sources and causes of supply chain uncertainty in transport operations. However, the model needed to be refined by logistics practitioners before its validity could be tested by an industry survey. In order to achieve this, focus groups were chosen over other methods for two main reasons. Firstly, they provide an efficient way to gather data from a large number of participants in a shorter time than would be possible with individual interviews. Secondly, it allowed different perspectives on the subject to be assembled and compared during an interactive session.

The transport-focused uncertainty model (see Figure 4.2 in Chapter 4) was developed in the previous chapter. This model needed to be refined by practitioners by applying an exploratory research method. Therefore, focus groups were selected to achieve that goal. The objectives of the focus groups were first to identify the main causes of supply chain uncertainty within current UK logistics operations and, secondly, to identify the root causes of these uncertainties. The aim of this chapter is to evaluate the impact of uncertainty on the performance of transport operations. At this stage, uncertainty causes will be evaluated in a qualitative manner.

The chapter proceeds by discussing the method applied in the data collection. Before presenting the findings, a framework to guide the application of the focus group method in logistics research is discussed. After that, an analysis of the findings is presented based on both the supply chain role and industrial sector of the focus group participants. Subsequently, the four uncertainty clusters found in the data collections are drawn into the conceptual model developed in the previous chapter. Then, a discussion based on the lessons learnt through the application of the focus group method is presented. Furthermore, the managerial implications, research implications and limitations of the findings are presented in the following

two sections. In addition, the contributions of the findings, to logistics methodology, to the PhD and to the topic are highlighted in the final section of this chapter.

5.2 Method

In the planning stage, seven potential venues were chosen, taking into account major logistics flows and business locations within the UK. As mentioned in Chapter 3, venue location is not considered to be a key issue in the generic literature of focus groups (see Figure 3.3). By taking account of the geographical location of potential participants, their journey time and inconvenience can be reduced, and as a result, their attendance can be increased. A similar approach is adopted by New and Payne (1995), Dainty et al. (2001), Guinipero et al. (2003) and Evangelista and Sweeney (2006). Locations were selected as a pilot session in Birmingham, two sessions in London, two in Nottingham, and one each in Cardiff and Edinburgh. When selecting the sample for the focus groups, in order to ensure a high attendance rate and the required participants' profile, it was necessary to have participants with previous research involvement with the academic partners in the Green Logistics project. Therefore, as recommended by Saunders et al. (2007), a purposive sampling strategy was applied to identify the potential focus group participants, since it was important to ensure that the participants' profile fitted with the research. Postal invitations were sent to 156 potential participants from logistic-related companies (manufacturers, retailers, 3PLs, and technology providers), trade associations, government bodies and logistics consultancy companies. The postal invitations included information about the Green Logistics projects, a personal invitation letter and a response form to confirm attendance. Participants were allocated to a focus group depending on their workplace location. In order to encourage attendance at the focus groups, as recommended in the generic focus group literature (see Figure 3.3), participants were offered a written feedback report and a potential invitation to a dissemination workshop. Evangelista and Sweeney (2006) also offered an incentive to attendees, but in the form of a free magazine subscription.

From the initial mailing, 26 positive responses were received. A follow-up process was undertaken combined with the addition of 21 more invitees. This involved e-mail and telephone contact with the invitees to encourage them to attend. As a result, the

final number of participants was 58, giving an attendance rate from 171 invitees of 34%. As shown in Figure 3.3 in Chapter 3, group size is one of the key factors to be considered when designing focus groups. The aim was to have 8 participants per focus group, as this represents the optimum size according to Krueger (1998). In reality, the size of focus group varied between 5 and 12 (Morgan, 1998).

The size and composition of the seven focus groups varied widely (Table 5.1). First, regarding group size, there were three focus groups that did not have the between 6 and 10 participants recommended by Krueger (1998a). Two had more than 10 participants. In the first of these (London 1), the group was divided in two for discussions. However, this reduced the quality of data recorded. In some groups the diversity of sectors represented also impaired the quality of discussion. The Cardiff focus group had only five participants, but they were from large enterprises and had a wide knowledge in the topic area. Morgan (1998) suggests a minimum of 4 for such a group, and depth in the discussions was possible. Golicic et al. (2003) and Cullen and Webster (2007) both had similar sized groups. The most important point regarding size and composition is that all the focus groups followed the recommendations found in the literature shown in Figure 3.3 in Chapter 3, and in those instances where these two factors were slightly out of range, the facilitator adapted the discussion to mitigate this problem.

Focus group session	Group size	Type of organisation represented						No. of industrial sectors
		Shipper	Carrier	Customer	Enabler	Trade Association	Policy Maker	
Birmingham	6	1	2	1	1	1	0	5
London 1	11	2	2	1	2	2	2	7
London 2	7	1	2	0	2	2	0	5
Nottingham 1	9	3	2	1	1	1	1	7
Nottingham 2	7	1	2	1	2	1	0	5
Cardiff	5	2	0	1	0	1	1	4
Edinburgh	13	6	1	0	1	4	1	7
Total	58	16	11	5	9	12	5	

Table 5.1 Group size and composition of the 7 sessions

The focus groups were designed to last for half a day for their session. Each session lasted around 120 minutes and had a refreshment break in the middle. However, there was a short initial presentation that gave some background to the overall research project.

In each focus group, the question posed was:

'Which are the most important causes of uncertainty that inhibit effectiveness of your transport operations?'

When this question was asked, each participant wrote their suggestions on Post-It notes, one comment per note. After that, each participant presented and discussed their notes individually, while the other group members were encouraged to intervene in the discussion so ideas might be developed further. In this discussion, participants stated why their selected uncertainty causes have a significant impact on their operations. The group as a whole then categorised the individual Post-It notes into clusters. The researcher advised the participants that, given the phrasing of the question posed, it was assumed that the number of Post-It notes reflected each issue's relative importance. Although no one objected to this assumption, the facilitator ran a discussion asking participants to confirm that the largest cluster represents the biggest challenge for their operations and/or industrial sectors. The session ended with a cause-and-effect exercise to determine the main root causes of these clusters. The clusters form the main unit of analysis of this paper. Notes were taken by the research team and complemented by audio recordings, to which all participants agreed prior to the focus group commencing.

After the focus groups, scripts for each session were produced from the notes and recordings. The Post-It notes recorded by participants were triangulated with the scripts and the cause-and-effect exercises. The data was synthesised using two-way tables to compare individual issues with top-level clusters, uncertainty types and sectors. Also, clusters were compared with the type of participants to see to what extent the participants' background may influence their perceptions. The classification is based on that developed by the European Logistics Users, Providers and Enablers Group (ELUPEG). However, to avoid clusters becoming too large, as Table 5.2 shows, this categorisation was disaggregated into the following:

- Shipper – an organisation which ships products to a wide range of external customers
- Customer – a business that receives products from a wide range of shippers. They may also have a distribution network internal to the company
- Provider – companies where the main business is the provision of transport and logistics services
- Enabler – a company that provides technology or consultancy to facilitate the movements of goods
- Trade Body – an organisation that represents a number of businesses from a particular sector
- Policy maker/influencer – government and other bodies that affect the external environment within which transport operates.

Supply Chain Role	Number of participants	Percentage of participants
Shipper	16	27
Customer	5	9
Provider	11	19
Enabler	9	15
Trade body	12	21
Policy maker/influencer	5	9
Total	58	100

Table 5.2 Breakdown of focus group participants

As stated in Figure 3.3 in Chapter 3, theory saturation is one of the main factors to be considered in the process of analysing the data gathered in a series of focus groups. Generally, when the focus group method is applied, theory saturation is reached after the fifth session (Morgan and Krueger, 1997). To confirm theory saturation, the Post-It exercise was analysed. Figure 5.1.a shows that the number of new issues raised (on individual Post-It notes) per participant does appear to tail off. However, when looking at clusters (Figure 5.1.b), there are no new clusters between the fourth and sixth focus groups. Nevertheless, the seventh focus group represents a slight exception as new sectors were involved that had not previously contributed to the focus groups from the drink industry. They identified issues unique to their

sectors. Overall, however, there is sufficient confidence as to the reliability of the findings. Focus groups are conducted in series, so when a point of theory saturation is reached the researcher can stop the data collection (Krueger, 1998b), since the researcher does not obtain new input from additional participants, there is no need to deploy further resources in conducting any additional focus group.

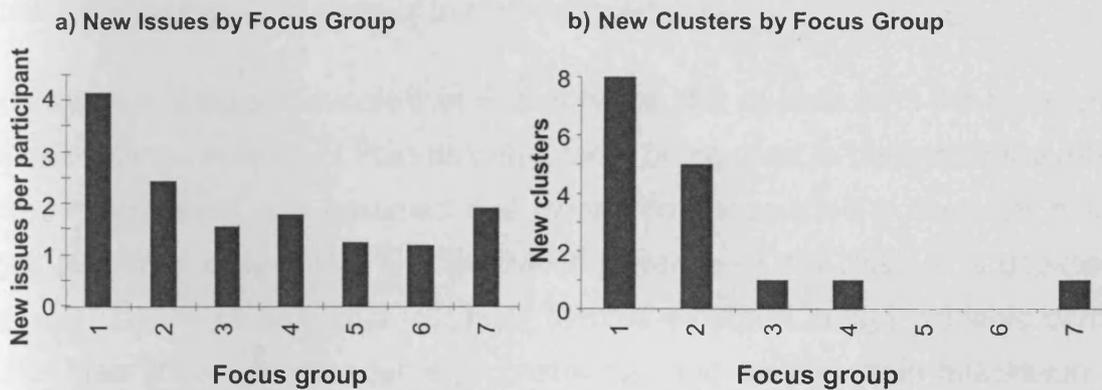


Figure 5.1 Theory saturation of the focus group sessions

5.3 Uncertainty within logistics triads

The first part of the analysis considers the results as a whole. Table 5.3 shows the relative importance of the 5 sources of uncertainty, which are depicted in Figure 4.2 shown in Chapter 4, within transport operations. The scores are based on the total number of Post-It notes for each generic source of uncertainty. Post-Its are counted multiple times if the type of uncertainty can arise from more than one cause. Overall, most sources of uncertainty are equally represented, with the exception of control systems. The bias of attendees towards shippers accounts for this source receiving a slightly lower number of Post-it notes. The rating of control systems may reflect the level of usage of technology within freight transport, which can often be quite low (for example, see Davies et al., 2007). Alternatively, it may be that the perception of attendees reflects more general views on freight transport that it is there to react to the demands of the supply chain (Potter and Lalwani, 2007), and that the information systems that generate these requirements are beyond the scope of the logistics triad.

Source of uncertainty	Number of Post-It notes
Shipper	50
Carrier	73
Customer	74
Control System	22
External	65

Table 5.3 The original sources of transport uncertainty

Rather than looking at the individual Post-It notes, the clusters form the basic unit of analysis with the number of Post-Its within them being used to determine the relative importance of each. It is assumed that more Post-its equates to a cluster being a larger cluster of uncertainty. The relative importance of the clusters is depicted in Figure 5.2. It can be seen that four main themes emerge - delays, variable demand and/or inaccurate forecast, delivery constraints, and supply chain integration and coordination - and represent about 65% of total Post-It notes gathered in the focus groups. Participants commented that the lack of supply-chain integration within the logistics triad can cause serious issues with coordination and communication between partners, ultimately impacting upon delays. The terminology for the clusters is based on the views of the focus group participants.

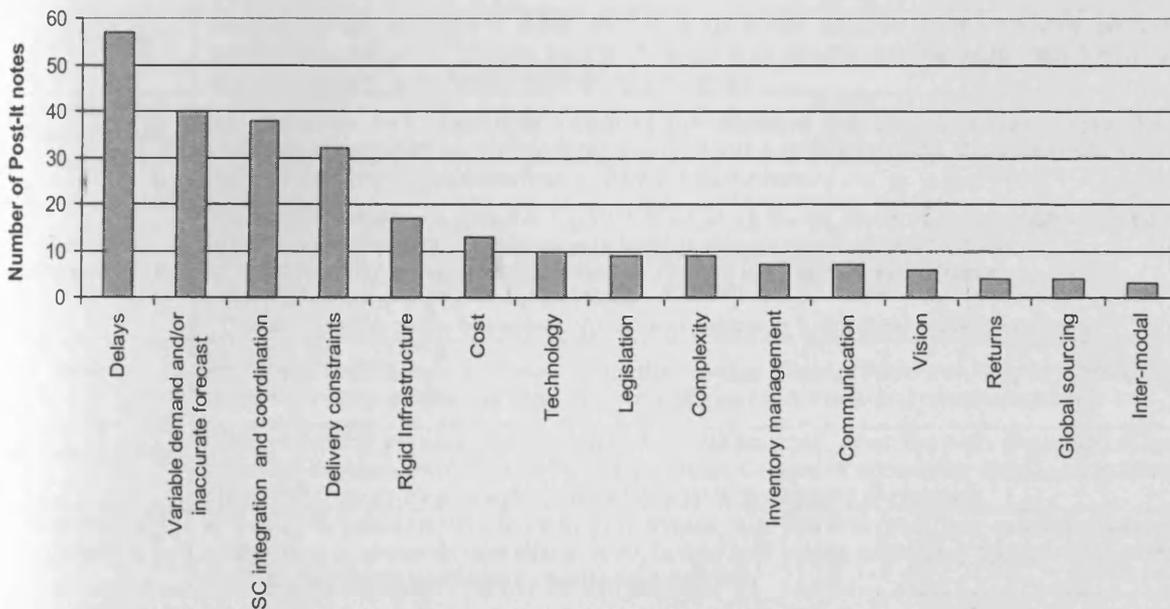


Figure 5.2 Issues causing uncertainty in transport operations

Definition of these terms can be found in Table 5.4. The individual issues behind these main clusters will be discussed in more detail later in the chapter.

Cluster	Definition
Delays	Delays occur when a delivery process takes place later than scheduled. Delays are mostly caused by three factors: road network congestion, supply disruptions, and operational problems in unloading and loading.
Variable demand and/or inaccurate forecast	The demand from customers may be highly volatile and sudden changes may occur due to seasonality and unexpected promotions. The main causes of this include demand volatility; poor demand forecast accuracy and lack of information visibility.
Delivery constraints	Delivery constraints are restrictions in the delivery process that can limit normal transport operations. Delivery constraints are a result of three main factors: delivery curfews at the customer facilities, restricted delivery windows imposed by the customer, and limited storage capacity at the customer depots.
Lack of coordination	Uncertainty occurs when the logistics triad processes are not properly synchronised, the communication and information flow is not effective. The main factors that cause a lack of coordination within the triad are high customer demand for transport flexibility, disconnections between sales and logistics departments at the company level and lack of integration between carriers and customers.
Rigid infrastructure	The infrastructure of the road and rail network is not flexible in the short term and so inhibits the performance of transport. Rigid infrastructure can occur at company, supply-chain and macro-level.
Supply chain integration	Integration within the logistics triad allows a holistic planning and execution of all the logistics triad activities in the transfer of information and materials flow. Insufficient supply chain integration lessens the visibility and transparency of information within the triad.
Cost	Cost uncertainty relates to staff and asset utilisation. Macro problems like driver shortages, volatility of fuel prices and congestion charges can considerably affect cost. Internally, companies have operational issues that negatively impact on cost as well.
Technology	The logistics triad members can have different levels of technology capability causing unavoidable operational distortions in the information and communication flow and problems in the delivery process.
Legislation	Legislation determines the basic rules of the transport sector in the UK. It must be sufficiently flexible so companies do not have constraints in terms of staff and assets. However, legislation can impose restrictions on logistics companies that can affect as usual trends.
Complexity	Complexity can increase if there are many variables involved in the delivery process, leading to uncertainty. Causes include different and diverse requirements from customers and drop deliveries to diverse portfolio of customers.
Inventory management issues	An ineffective and fragmented inventory management approach can cause operational problems in transport originating from a lack of stock available within the supply chain, and sub-optimal inventory policies imposed by the customers.
Lack of communication	Poor communication within the logistics triad at all levels leads to information uncertainty within the logistics triad. Serious operational problems can originate through: <ul style="list-style-type: none"> - Lack of communication regarding delivery failure from carrier to customer. - Insufficient driver-carrier communication. - Communication errors between shipper and customer that cause delivery refusals.
Returns	Any operational issues originating from the reverse supply chain, including processes like recycling, return of defective products and logistics equipment, and remanufacturing.
Global-sourcing	Global sourcing imposes a challenge to the logistics triad, since the high dispersion of raw materials increase the length of the supply chain. Causes of uncertainty include operational problems of information visibility, insufficient stock and quality of products.
Inter-modal operations	A lack of fit between different transport modes, e.g. rail and road, can cause operational problems in inter-modal operations. Also, operational issues originating by rigid inter-modal facilities can cause problems in the delivery process.

Table 5.4 Definitions of clusters according to focus groups

Of the other clusters, rigid infrastructure, cost and technology together represent around 16% of the total number of issues. The lack of flexibility of both road and rail infrastructure is considered a major barrier in achieving journey time reliability. Meanwhile, the transport costs of the supply chain are primarily affected by labour and asset utilisation and how close are the actual volumes to the transport plan. Most participants stated that there is an evident gap between the technological capabilities within the logistics triad. This can be expected because carriers cannot possibly keep the same pace of technological changes as their partners, since they often have financial pressures impeding new technology acquisitions.

The other clusters found have fewer than 10 occurrences. Legislation is considered a source of external uncertainty for the logistics triad, but participants usually focus on the issues that can be changed internally instead. On the other hand, the issues under complexity, inventory management and communication were implicitly related with the other themes that have more occurrences. Complexity increases if the level of supply chain coordination is low, and if there are significant constraints in the delivery process. Furthermore, a fragmented inventory management policy can have a negative impact on the demand and information processes. However, a lack of communication and supply chain integration can negatively influence the logistics triad coordination.

5.3.1 Uncertainty clusters per supply chain role

As well as considering the population as a whole, the results are also classified according to the role of the participant within the supply chain. The results from this can be found in Table 5.5. Considering the core members of the logistics triad first, it can be seen that all three members place a strong emphasis on delays as a cause of uncertainty. This reflects the direct impact that these have on transport operations. Both shippers and customers identify variable demand and/or inaccurate forecast as important. These are the members of the triad that would be affected more by these types of issues. By contrast, shippers and carriers also identify delivery constraints as another important factor. It may be that, because the constraints are often imposed by the customer, they do not perceive them to impact upon their operations.

Themes	Delays	Variable demand and/or inaccurate forecast	Insufficient supply chain integration and coordination	Delivery constraints	Rigid Infrastructure	Cost	Technology	Legislation	Complexity	Inventory management	Communication	Vision	Returns	Global sourcing	Inter-modal	Total number of Post-It notes
Shipper	19	22	9	14	2	5	2	3	3	4	3	1	2	3	3	95
Customer	8	10	2	1	1	2	2	1	1	1	0	0	0	0	0	29
Provider	8	2	6	7	1	1	4	1	2	1	0	0	0	0	0	33
Enabler	4	2	18	4	2	2	1	0	2	0	2	4	1	0	0	42
Trade body	15	3	2	5	10	2	1	3	0	1	2	1	1	0	0	47
Policy maker/influencer	3	1	1	1	1	1	0	1	1	0	0	0	0	1	0	10
Total number of Post-It notes	57	40	38	32	17	13	10	9	9	7	7	6	4	4	3	256

Table 5.5 Comparison of clusters based on supply chain role

From the remaining classifications, enablers particularly identify coordination as an issue. This reflects the fact that many of the companies within this cluster provide software and other services linked to the coordination of supply chains. Therefore, they are perhaps more likely to identify issues in this area. However, it could also be that, because they sit outside the supply chain but have a view of all operations, they can identify issues that those more involved in the operations cannot see. Many of the trade bodies represent the freight transport industry, and therefore identify delays as a significant cause of uncertainty. As with enablers, they can also take a broader view of transport operations and therefore see infrastructure issues that do not affect individual supply chains but do impact on the freight transport system as a whole. Finally, policy makers show a slight bias towards delays but there is insufficient data to draw meaningful conclusions.

5.3.2 Uncertainty Clusters per Industrial Sector

The final part of the analysis sought to compare between the findings based on industrial sectors of the participants. This reflects the fact that different sectors are

subject to different pressures, which may then have an impact on transport uncertainty. Companies were clustered according to their main business areas, and the smaller sectors (with 3 or fewer representatives) were then grouped to form an “Other” category. The results can be found in Table 5.6.

Themes	Delays	Variable demand and/or inaccurate forecast	Insufficient supply chain integration and coordination	Delivery constraints	Rigid Infrastructure	Cost	Technology	Legislation	Complexity	Inventory management	Communication	Vision	Returns	Global sourcing	Inter-modal	Total number of Post-It notes
3PL	11	4	3	5	3	3	2	3	2	1	2	0	0	0	0	39
IT provider	3	5	7	4	2	0	2	1	0	0	2	1	2	1	0	30
Grocery	7	7	3	5	1	1	0	0	0	1	1	1	0	0	0	27
Drinks	4	13	2	4	1	0	0	0	0	2	0	0	0	2	2	30
Primary	2	2	5	2	0	0	2	1	4	0	0	1	0	0	1	20
Rail and Inter-modal	4	0	1	3	5	3	0	0	1	0	0	1	0	0	0	18
Transport Trade Bodies	5	2	4	1	1	1	0	1	0	2	1	0	0	0	0	18
Policy Makers and Influencers	5	1	2	0	1	1	0	1	0	0	0	0	0	1	0	12
Retailer	9	2	2	1	1	0	2	0	1	0	0	2	0	0	0	20
Consultant	2	0	6	2	1	1	0	0	1	0	1	0	0	0	0	14
Waste and Reverse Logistics	3	0	0	4	0	0	1	0	0	0	0	0	2	0	0	10
Construction	2	1	1	1	1	3	1	2	0	0	0	0	0	0	0	12
Health	0	3	2	0	0	0	0	0	0	1	0	0	0	0	0	6
Total number of Post-It notes	57	40	38	32	17	13	10	9	9	7	7	6	4	4	3	256

Table 5.6 Comparison of clusters based on industrial sectors

Most of the sectors that took part in the focus groups have a similar distribution of occurrences within the themes discussed as the overall findings. However, a few sectors do not follow this pattern. Third party logistics providers, policy makers and retailers all have a larger share of Post-It notes from delays. Transport operators

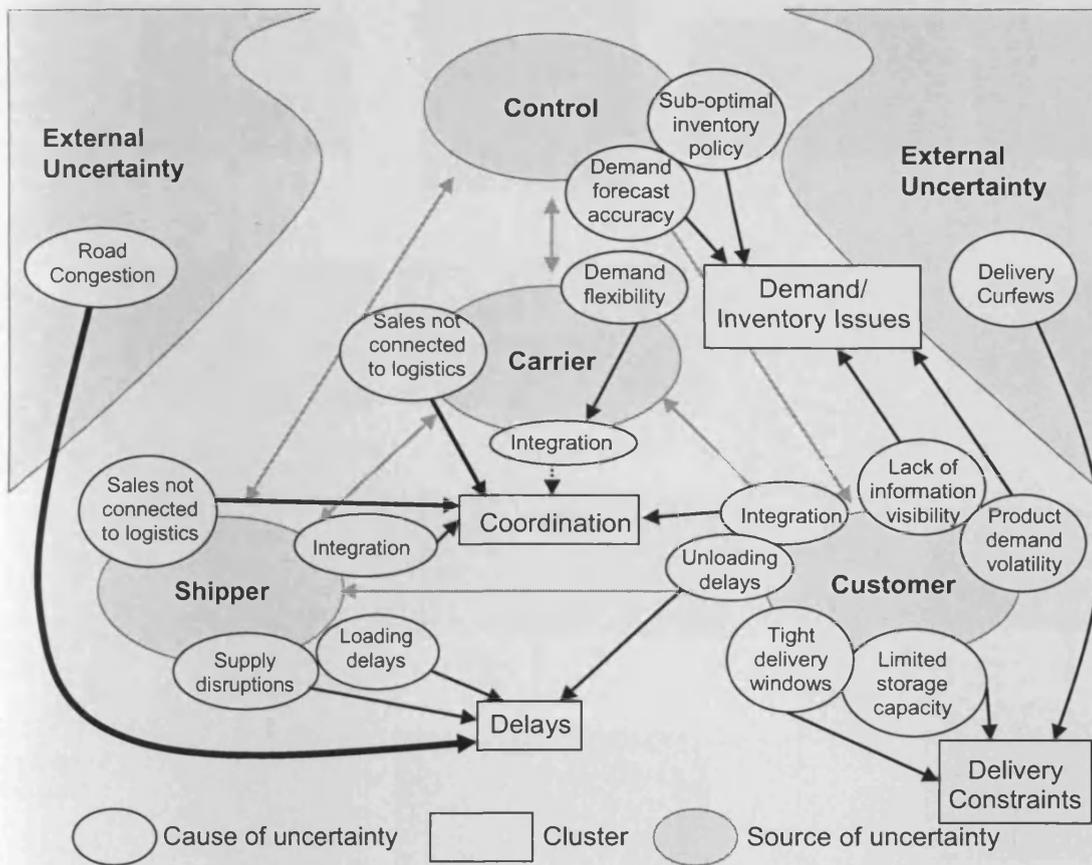
often have to deal with the impact of uncertainty from delays. This can reduce their efficiency. Policy makers see the wider economic impact of late deliveries on the economy of a region or country. Retailers are affected by diverse delays issues, such as supplier delays, road network congestion and loading and unloading delays. Delays can stop the operation of retailers, which in turn can have an immediate knock-on effect on their service and cost performance.

Another sector that has a different distribution in comparison to the overall trend is that of drinks. This industry has 13 occurrences out of 30 on issues regarding variable demand and/or inaccurate forecast, such as insufficient demand forecast, short notice changes in the customer orders and sub-scale procurement and orders. These then cause uncertainty for transport operations. The participants from the drinks sector have global operations (also reflected in the global sourcing cluster), so their supply chains are usually lengthier than in other sectors. Therefore, this sector can be greatly affected by variable demand and/or inaccurate forecast.

Finally, it is interesting to note the distribution of issues relating to inter-modal transport. These only emerged for the drinks and primary industry companies, despite there being a cluster of inter-modal transport providers. The nature of operations in the drinks and primary industry sectors makes them well suited to the use of other modes. However, operators are more focussed on operational issues, and particularly the infrastructure with issues such as the lack of flexibility in rail freight operations featuring in 50% of the Post-It notes in this cluster.

5.4 Causes of transport uncertainty

The following analysis reflects the clusters identified as the most important during the focus groups. What is evident is that the sources of uncertainty emerge from throughout the transport uncertainty model. The top three issues from the four largest clusters are mapped onto the model to illustrate the impact of transport uncertainty. This is shown in Figure 5.3, which provides greater depth to the analysis.



Number of Post-It notes

→ Under 5 → 5 to 10 → 10 to 15 → 15 to 20 → 20 to 25

Figure 5.3 Main uncertainty causes, clusters and sources

Overall, the results suggest that suppliers, customers and carriers should work together more closely to identify these sources of uncertainty within their particular supply chain and develop a plan together to address them. However, the largest overall contribution to uncertainty is congestion on the road network, which is beyond the scope of the logistics triad. Now, the analysis will be expanded to further details for these four clusters, using the focus group discussions to provide depth to the commentary. Furthermore, the results from the cause-and-effect exercises undertaken in the focus groups are shown in Figure 5.4. They have been included in the analysis of the four main uncertainty clusters.

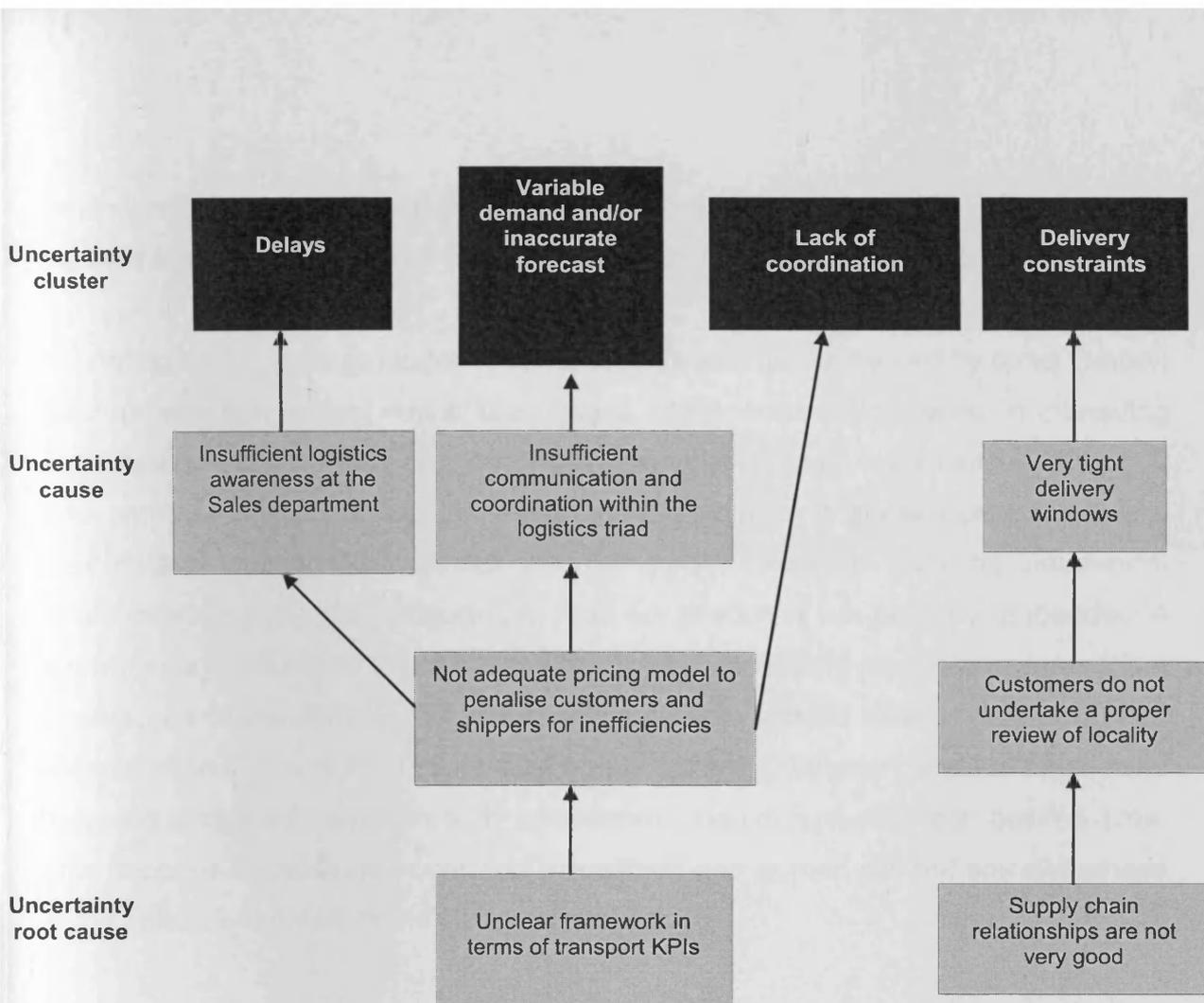


Figure 5.4 Findings from the cause-and-effect exercise

5.4.1 Delays

Delays appear to be particularly important for shippers, customers and providers, and therefore affect all the triad members and most of the sectors that were represented in the focus groups. Delays in the delivery process are caused by disruptions in the different supply-chain processes, production, storage, shipping, and transportation and unloading. Delays are considered the principal barrier in achieving a high level of delivery performance, since disruptions in the supply chain processes have a knock-on effect on transport reliability. Delays can be linked to most of the CO₂ emissions ratios of the McKinnon's (2007) framework. Delays can cause vehicles to miss the next scheduled load available for them, necessitating a second vehicle to replace the delayed vehicle, so the average empty running can increase. Also, delays can cause a load that was originally planned for one trip to be run in two trips, so the average length of haul can rise. Furthermore, the capacity

utilisation of the two trips is lower than the capacity utilisation of the originally planned trip, therefore the average load on laden trips can be reduced.

According to the focus group participants, delays are mainly caused by three factors: road network congestion, supply disruptions, and operational problems in unloading and loading. Road network congestion is an external uncertainty source (Figure 5.3) and participants commented that it can be predictable in some cases but totally random and unexpected in others. According to the findings from the cause-and-effect exercise depicted in Figure 5.4, road congestion is not properly embedded in the transport plan due to the fact that when a new contract is signed and agreed, the targets and responsibilities that the carrier has are decided without having a clear framework in terms of KPIs to monitor and control the delivery process. Thus, road transport congestion is not properly considered when defining the total delivery time. This happens because new contracts are signed and agreed without any awareness at the sales department of the transport process.

Road congestion can be mitigated by applying routeing algorithms, so the carrier can possibly predict the expected congestion within the road transport network and the fastest possible route can be estimated. However, events such as accidents are not predictable at all, although it was commented that their occurrence can be mitigated by the application of GPS systems combined with the development of alternative plans regarding routeing.

Supply disruption in the production and shipping process can also have a negative impact on the delivery process. This type of disruption mostly occurs at the shipper. This is more evident when the supplier is located overseas, so there is less control over quality measures and delivery of overseas operations. Therefore, supply disruption can be mitigated by developing a tight relationship with the shipper. On the other hand, delays can originate in the unloading and loading process at both the shipper and customer. Problems at unloading and loading facilities within the logistics triad can be initiated by, for example, the unavailability of staff or unsuitable facilities for loading and unloading. Furthermore, as shown in Figure 5.4, the root cause of delays at loading and/or unloading facilities is that the carrier does not

or last minute cancellations of previously agreed loads. Meanwhile, insufficient information visibility can reduce the accuracy of demand, increasing the levels of safety stocks at the shipper and the number of unnecessary transport movements. Insufficient demand accuracy can have a knock-on effect on the demand volatility of transport regarding volume. This is also due to, as depicted in Figure 5.4, the fact that there is not a clear framework in terms of transport KPIs, so customers and shippers are not charged for their volume variability, primarily due to insufficient coordination and communication in the process of volume demand forecast within the logistics triad. However, participants agree that this type of problem occurs due to the fact that customers and shippers are not properly penalised or charged for the volume forecast inaccuracy and/or late-notification of extra volumes.

In addition, a sub-optimal inventory policy designed by the customer without including transport operations in the equation can increase the frequency of deliveries. Therefore, the demand for transport artificially rises, adding an extra variable to the complexity involved in the delivery process. This can have a negative impact on transport utilisation and increase costs. This occurs due to the transport KPIs within the logistics triad not being sufficiently clear, so as mentioned before, customers and shippers are not properly charged for the demand that they generate artificially. Although one participant particularly identified just-in-time as a cause of this, a more general view was that transport is often ignored in inventory management. However, participants commented that this uncertainty can potentially be mitigated by the implementation of horizontal integration initiatives, such as inventory and transport consolidation either by the shippers or the carriers.

5.4.3 Delivery constraints

Delivery constraints are restrictions in the delivery process that can limit normal transport operations. They usually occur at the customer facilities, but sometimes happen at the shipper's facilities. Delivery constraints are considered by participants to be the third most significant barrier in transport operations, since they can restrict the unloading processes, causing queues that potentially delay the return of vehicles to other loading points. This uncertainty cluster can be linked to one of McKinnon's

usually have an adequate pricing model to charge the customer and the shipper for inefficiencies, e.g. delays at their facilities.

5.4.2 Variable demand and/or inaccurate forecast

This theme was considered the second most important barrier to achieving a high level of logistics performance. Most group participants affected by this theme are from shippers and customers, with 22 and 10 occurrences respectively (Table 5.5). These numbers are disproportionate to the number of attendees from these triad members in the focus groups. For many of the suppliers that took part in the focus groups, the demand from customers is highly volatile and suddenly changes due to seasonality factors and unexpected promotions. Also, sub-optimal inventory policies that do not include transport can dramatically increase the delivery frequency, and consequently the likelihood of failure within the delivery process. Moreover, participants from the drinks and grocery sectors seem to place more emphasis on this uncertainty cluster. This could be due to the demand volatility in these two sectors.

Variable demand and/or inaccurate forecast impact on three of the factors included in the McKinnon's (2007) framework the average length of haul, the average load on laden trips and the average empty running. This uncertainty cluster causes the carrier to re-plan deliveries and/or collections with a lower capacity utilisation than originally planned and the carrier tends not to find a backload for these trips, so the average load on laden trips decreases and the average empty running rises. Also, sometimes increases in volume come from remote geographical locations where the carrier cannot find the most economical subcontractor to run the extra trip. Therefore, the average length of haul can also rise.

Variable demand and/or inaccurate forecast originate from volatility of customer demand, insufficient demand forecast accuracy, lack of information visibility and sub-optimal inventory policies imposed by the customer (Figure 5.3). Seasonality factors, such as the weather, can have a considerable impact on demand volatility, but unnecessary promotions set by the customer can also produce sudden changes in the demand trend. This can cause unexpected short-notice extra transport deliveries

5.4.4 Insufficient supply chain integration and coordination

A lack of coordination within the logistics triad and at the individual-company level can cause disruptions in the delivery process. However, if there is a high level of coordination within the triad, it can represent the principal enabler in reducing uncertainty. Lack of coordination as a theme represents just over 10 per cent of the total frequency from participants and particularly from enablers.

The main factors that cause a lack of coordination within the triad are high customer demand for transport flexibility, functional barriers between sales and logistics departments at the company level and lack of integration between carriers and customers (Figure 5.3). In many of the industrial sectors represented, customers require a high level of transport flexibility. This adds one more variable to the already complex transport process, so tighter coordination is needed to mitigate the complexity. Moreover, some participants felt that transport is not integrated in strategic processes, and the level of communication within the triad is restricted because the carrier is usually a servant rather than truly a partner. This occurs because within the carrier the sales department is often disconnected from the logistics function, and sales negotiate new contracts without taking account of the logistics consequences. This was confirmed in the cause-and-effect exercise, shown in Figure 5.4. The absence of an appropriate pricing model does not allow more coordination and communication within the logistics triad, since the supply chain relationships between carriers, customers and shippers are not at the necessary level of maturity and trust. An example was given where the sales department agrees loose and unachievable contracts with the customer and raises the customer's expectations regarding the level of transport service, and then the logistics function fails to fulfil expectations. However, a tight contract from the beginning of the partnership can enable high levels of integration and coordination within the logistics triad.

(2007) CO₂ emissions ratios. This uncertainty cluster can generate additional distance onto the planned distance of trips, so the average length of haul rises.

Delivery constraints are a result of three main factors: delivery curfews at the customer facilities, tight delivery windows imposed by the customer and limited storage capacity at the customer depots (Figure 5.3). As with road network congestion, delivery curfews are an external uncertainty source. Examples of the reasons for delivery curfews include security issues with inventory and delivery drivers (particularly with early morning and late night deliveries), or local restrictions imposed to improve the quality of life for local residents. According to the results of the cause-and-effect exercise presented in Figure 5.4, delivery constraints are not mitigated appropriately since generally customers do not undertake a proper review of locality to assess the existent delivery constraints at loading bays located in restricted areas.

Limited storage capacity at the customer distribution centres and stores restricts the volume of the delivery and increases the delivery frequency, and as a consequence, the number of vehicles arriving to storage points. This can encourage increasingly tighter delivery windows. Six participants agreed that the tight delivery windows that the customer imposes on carriers and shippers have a negative effect on the overall transport costs. The only response that customers have to mitigate delivery constraints are very tight delivery windows that cause excessive queues and delays at distribution centres. As shown in Figure 5.4, the focus group participants agreed that this occurs because the supply chain relationships between the customers and their partners, the carrier and the shipper, are not very good. Tight delivery windows increase the transport costs due to the idle time generated when vehicles and drivers are waiting for unloading. Delivery windows can also have a knock-on effect on transport performance, since transport journeys usually occur in series. However, participants felt that the negative effect of delivery windows can be mitigated by tighter coordination from the customer side to increase synchronisation between carriers, and greater levels of feedback information from the carrier to the customer.

5.5 Methodological lessons learnt: Factors that influence the effectiveness of focus groups

In the literature and also throughout the application of focus groups presented in this chapter, it was possible to identify a number of key factors influencing the effectiveness of the focus group, particularly in terms of data quality (Figure 5.5). The aim of this section is to reflect on the lessons learnt during the application of the focus group method.

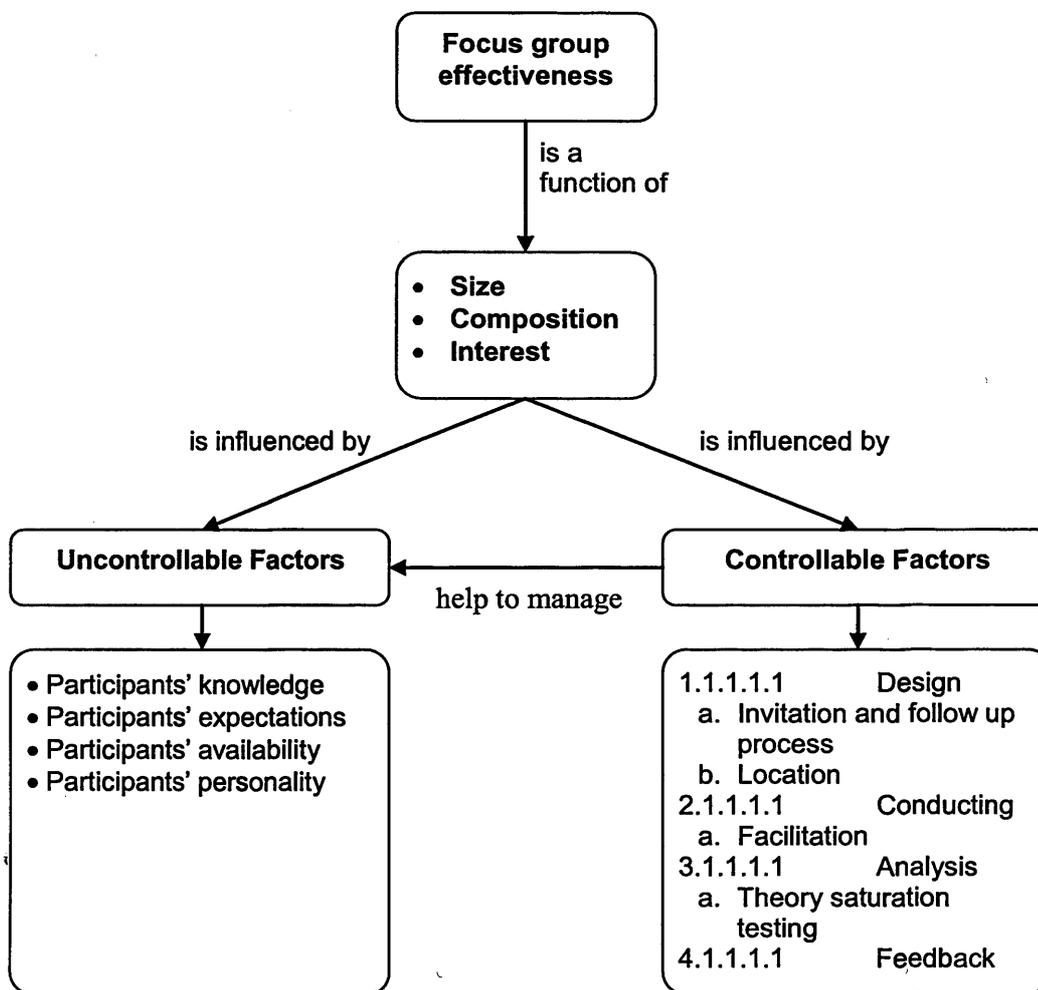


Figure 5.5 Factors influencing focus group effectiveness

In the focus group literature, much emphasis is placed on group size and composition. However, it is also important that the participants are interested in the content of the discussion. The type of company and industrial sector influenced the level of participation in each focus group session. There are also a number of other

factors that need to be considered. They have been categorised as uncontrollable and controllable.

Uncontrollable factors relate specifically to the group participants. There are four attributes that appear to affect the size, composition and interest of the focus groups, namely participants' knowledge, expectations, availability and personality. People are only likely to attend if they feel that they have something to contribute to the topic(s) being discussed within the focus groups. However, it is also important that participants have appropriate expectations as to what the focus group will achieve and the related benefit for them and their organisations. Finally, the personality of participants affects their contribution to the discussion.

Given these uncontrollable factors, it is important to consider the controllable factors that the researcher can influence. The design stage is the point when it is possible to ensure that the appropriate people are selected for the focus group. For example, Mangan and Christopher (2005) targeted executive education students to identify the skills requirements required for supply chain managers. The method of inviting participants is also critical. Personal contact with potential participants is important in generating interest. In the case of this PhD, this happened during the follow up process but it could form part of the initial invitation. Another important aspect is the location of the focus groups. By holding sessions around the UK, participants' travelling time could be minimised.

The nature of the facilitation is important for both stimulating discussion and ensuring that everyone participates. With a group of diverse personalities, there is a danger that those who are more confident dominate the discussion and distort the findings. In the application of focus groups in this thesis, the Post-It note exercise proves an effective means of encouraging contributions from all participants. By asking participants to record their opinions before the discussion starts, it helps the facilitator to bring their opinions into the discussion. Conversely, making the discussion too structured could reduce the level of discussion, and interest in the topic might wane. The most important element, however, is for the researcher to reflect upon each focus group and, if necessary, adjust the facilitation approach to improve the quality of data collected.

In the analysis stage, there is the need to reflect upon any bias in the findings. Testing for theory saturation can help to detect bias and assess the thoroughness with which the subject has been discussed. Previous applications of the focus group method in the field, an exception being Cullen and Webster (2007), appear not have measured the degree of theory saturation.

Finally, a significant number of participants expressed a desire to take back relevant information and insights to their organisations. Maintaining good relations with delegates after the focus group also increases the probability of them participating in future research.

5.6 Managerial Implications

Although the participants in the focus groups were predominantly from the UK, the research has identified a number of issues in relation to uncertainty within transport operations. From this, it is possible to identify some generic managerial implications. Section 5.4 has highlighted the importance of looking at the whole of the logistics triad when dealing with uncertainty, as often there are multiple sources involving the shipper, carrier and customer. Equally, section 5.4 has highlighted the importance of external factors and managers need to consider how to deal with these issues. While the easiest approach is to accommodate them within operational plans, there is scope for engaging with policy makers to identify ways forward. Indeed, the policy makers who did participate in the focus groups commented that they found it beneficial to learn more about the challenges facing the logistics industry.

Another issue that is becoming important for managers today is the issue of the environment. In this chapter, the links between transport efficiency and environmental impact have been drawn by connecting CO₂ emissions ratios from McKinnon's (2007) green logistics framework with the four main uncertainty clusters found in the focus groups. By focussing on the sources of uncertainty within the logistics triad, companies can address the root causes of issues, rather than trying to optimise their response based upon current constraints.

In enabling the above actions, the refined transport-focused uncertainty model is a tool that can be applied to identify issues leading to uncertainty and their sources. As demonstrated through Figure 5.3, issues can be mapped against their original sources and from this an improvement plan targeting the appropriate areas can be developed. Therefore, it can help senior managers and policy makers to identify the main root causes of the barriers that impede economic and environmental sustainability in logistics.

5.7 Concluding remarks

So far, four main clusters of uncertainty in transport operations have been found—delays, variable demand and/or inaccurate forecast, delivery constraints and a lack of coordination. According to the findings, delays are the most important cluster of uncertainty for transport operations, which might be considered an intuitive result, but this research shows its frequency relative to other issues. The consequence of these is to reduce the efficiency of transport operations. Also, in the overall focus group data, road congestion represents the largest individual issue leading to uncertainty. While congestion due to road works and peak traffic flows can be incorporated into transport planning, unplanned road congestion (for example, due to an accident) leads to greater disruption. The challenge for transport providers is to mitigate the impact of this unplanned road congestion without impacting significantly on the efficiency of their operations.

In terms of the sources of uncertainty, most issues arise from the shipper, carrier, customer or external environment. Only a limited number of issues relating to control systems were raised. This is surprising given that control systems are likely to have a major influence in determining the level of transport demand, and perhaps reflects the lack of integration of transport operations with the rest of the supply chain. In looking at individual roles within the supply chain, enablers particularly identify lack of coordination as a major issue, whereas members of the logistics triad were more concerned with operational issues. However, integration within the triad may enable businesses to address these more effectively.

developed, guiding the PhD candidate and future focus group applications in logistics on the relevant factors that influence the effectiveness of a focus group.

To the PhD

The chapter also contributes to the overall methodological path of the PhD by refining the conceptual model developed in the previous chapter. Different causes and clusters of supply chain uncertainty that impact on transport operations has been evaluated. The four most important uncertainty clusters found are: delays, variable demand and/or inaccurate forecast, insufficient supply chain integration, and coordination and delivery constraints.

To the topic

This chapter contributes to the topic of supply chain uncertainty and transport by guiding future research as to which uncertainties impact more on transport operations. As stated in the previous chapter, most of the literature on uncertainty focuses on supply chain and manufacturing, while transport is implicitly and marginally considered. Also, the findings from this chapter can help researchers and practitioners to prioritise between different uncertainties in terms of their relative impact on transport performance. However, these findings need to be verified with more empirical evidence.

The model has been refined based only on participants' perceptions. Further empirical-based research is needed to quantitatively validate it, for each cluster identifying the frequency with which it occurs and the impact on economic and environmental performance. This will further strengthen the understanding of the main uncertainty causes within supply chains in the UK. Those internal to the logistics triad can be addressed while external issues need to be accommodated, so, methods for achieving both of these need to be identified through the research. Furthermore, given the importance industry has attached to road congestion, new and novel approaches enabling transport planning to respond to unpredictable congestion needs to be developed, with minimal impact on both environmental and economic performance.

At this stage of the research, the model has been refined through the application of the focus group method. The main objective of this stage of the research was to explore which are the main causes of supply chain uncertainty that impact on transport operations, rather than provide a comprehensive list of all uncertainties. The model needs to be verified through the application of the survey method, so potential participating companies can give frequency and impact scores to each uncertainty cause found in the focus groups. This will be achieved in the following chapter. The model should also be tested through the investigation of real-world situations, measuring the marginal impact, in terms of unnecessary miles, and probability of the supply chain uncertainty causes derived from the focus groups. This will be addressed in the case study chapters. Moreover, the transport uncertainty model needs to be incorporated within a wider business process re-engineering approach to proactively develop and evaluate solutions to reduce transport uncertainty within supply chains.

5.8 Contribution

To Methodology in logistics research

This chapter has presented an innovative way of applying focus groups to the wider methodology in logistics. Focus groups have been applied as a complementary method within the overall methodological path of this PhD. A framework has been

6.0 The main uncertainty causes impacting on the economic and environmental performance of road transport operations in the UK

6.1 Introduction

At this point in the thesis, the transport-focused uncertainty model has been developed and refined in the two previous chapters. In this chapter, the relative importance of these causes of supply chain uncertainty needs to be determined by measuring the level of risk that they represent for transport operations. The aim of the chapter is to verify the model taking a supply-chain perspective, and assess the risk that different causes and sources of supply chain uncertainty have in terms of the economic and environmental performance of road transport operations in a UK context.

To do this, the chapter proceeds by recapping on what has been completed so far and drawing a link between the conceptual model developed in Chapter 4 and Green Logistics. After that, the method applied to undertake the research is explained. Subsequently, the overall results of the study are presented and analysed. Following that, the findings are analysed at supply chain member level and also at industrial sector level. In the final section of the paper, the main research findings are highlighted together with further research opportunities.

6.2 Refined transport-focused uncertainty model

So far, the transport-focused uncertainty model has been developed and refined. In the previous chapter, four uncertainty clusters and their causes were derived from the application of seven focus groups. According to the focus group participants, the main uncertainty clusters impacting on the performance of UK transport operations are: delays, variable demand and/or inaccurate forecast, delivery constraints and insufficient supply chain integration and coordination.

This findings need to be verified by interrogating other randomly sampled participants from companies that operate in the sector with a higher participation in

the focus groups. The aim of this chapter is to verify the findings from the focus groups by undertaking a ranking and risk assessment exercise of all the uncertainty clusters found in the previous chapter to verify whether or not the four main clusters found in the focus groups are repeatedly the most important ones in a different sample. This will be achieved by undertaking a questionnaire-based survey interrogating participants from shippers, carriers and customers from the UK road freight transport sector.

6.3 Method

A wider scale survey was undertaken to assess the impact that the uncertainty clusters, derived from the focus groups phase, have on the sustainability of road transport operations. In order to achieve an appropriate balance between research rigour and industrial relevance, a methodology triangulation research strategy was applied as recommended by Easterby-Smith et al (1991), New and Payne (1995), Arlbjorn & Halldorsson (2002), Mangan et al (2004). The findings from the focus groups needed verification, since the sampling strategy was purposive sampling. Also, the opinions of each participant of the focus groups could be influenced by other dominant participant(s). Therefore, it was necessary to triangulate the focus group findings with the application of a more quantitative method. This selected method was the survey method.

In the planning stage, an online questionnaire was designed based on the clusters or sources of transport uncertainty derived from the focus groups. An online questionnaire was preferred over a mail questionnaire, since the sample targeted had access to internet and for participants it could be faster to complete an online questionnaire rather than a postal questionnaire. In addition, the cost of the online questionnaire was 60% of the cost of the postal questionnaire. Appendix 2 shows a copy of the questionnaire. In the questionnaire, practitioners were asked to:

- Provide background information about their companies: annual turnover in pounds, percentage of that transport cost represented from the annual turnover, industrial sector and supply chain role (shipper, carrier or customer)

For the full survey, a total of 5000 companies were identified by using the Financial Analysis Made Easy (FAME) database, from all industrial sectors where the companies would be expected to either move goods or be directly involved in the movement of goods. The only constraint imposed was a minimum company size of 250 employees. The initial invitation letter was directed to a person from the company board identified in the FAME database, since company's logistics manager and/or director names and contact details are not available in FAME. However, it was requested that the details be passed to a person responsible for leading the logistics department of the company. The survey was available between December 2007 and February 2008.

After four weeks of low response rate (12 responses), a random sample of 25% of the total population within the sectors that were responding, automotive, grocery, retail and road freight transport was selected. Two emails reminders were sent to the sampled companies as well as contacting them by telephone. As part of this process, the names and contact details of the person in charge of the logistics function of the company was obtained for at least 30% of the companies, and communication was directed to these people instead. In parallel to this, the Charter Institute of Logistics and Transport (CILT) sent an email inviting all their members from these sampled companies to participate in the survey. As a result of the follow-up process including the support of the CILT, 20 further responses were achieved. Also, they sent two reminder emails to the non-respondents from the sample selected, the first one after three weeks and the second one after six weeks of the initial CILT invitation. The overall increase in responses achieved during the follow-up stage was from 12 to 56 responses.

By February 2008, 56 practitioners had completed the survey. As Table 6.1 shows, responses were only received from a limited range of industrial sectors, with four sectors particularly well represented. Based on the sectors that responded, the overall response rate of these sectors was just 3.6 per cent. While this is low, the focus group data added depth to the analysis. Other supply chain researchers also combined focus groups and survey findings where a low response rate had been obtained (for example, New and Payne, 1995). Table 6.1 indicates the four sectors that have used focus group data for extra depth.

- Select and rank the top four clusters of uncertainty that impact more on their businesses, based on the 15 uncertainty clusters found in the focus groups
- Assess the economic and environmental impact that their top four uncertainty clusters selected have on their company's transport operations using a 5 point-Likert scale (1- very low, 2- low, 3- medium, 4- high 5- very high)
- Evaluate the frequency of occurrence for their top four uncertainty clusters. A five-item frequency scale was given – daily, weekly, monthly, quarterly and annually
- List up to five analysis and design tools that their company uses to improve the efficiency of logistics operations. This was not exclusively limited to ICT solutions.

In the third question of the questionnaire, where respondents were asked to assess the economic and environmental impact of the uncertainty clusters they were asked to select in question 2, labels were used to describe the alternatives answers for impact, since generally it can be easy for respondents to relate to labels such as low and high rather than numbers such as 2 or 4. Also, a 5-point Likert scale is used instead of a 3-point Likert scale, since as Matell and Jacoby (1972) demonstrated, as the number of scale steps increases the likelihood that respondents use the mid-point category decreases. However, the pilot participants perceived a 7-point Likert scale to be rather confusing. Furthermore, in the case of the fourth question, generally the pilot participants felt that the frequency labels reflecting how industry works were daily, weekly, monthly, quarterly and annually.

Additionally, a definition of each uncertainty cluster was available in the electronic survey, again based on the focus group findings. These definitions were developed as an outcome of the focus groups (see chapter 5).

Fifteen practitioners were selected from focus group participants to pilot the online survey first. Postal invitation letters were sent, and 8 pilot participants responded to the online pilot questionnaire. As a result of the pilot, a number of changes were made to improve the readability, relevance and practicality of the survey.

Uncertainty cluster	No of Responses	Spearman's Correlation test			t-test		
		T	Critical value	Non-response bias	Sg	Critical value	Non-response bias
Delays	34	0.377	2	No	0.775	0.05	No
Demand and information issues	29	0.692	2	No	0.562	0.05	No
Delivery constraints	23	0.131	2	No	0.119	0.05	No
Rigid infrastructure	6	0.669	2	No	0.725	0.05	No
Supply chain integration	21	0.511	2	No	0.876	0.05	No
Cost	18	0.177	2	No	0.058	0.05	No
Technology	6	0.566	2	No	0.804	0.05	No
Legislation	14	0.06	2	No	0.015	0.05	Yes, due to statistical noise
Complexity	19	0.111	2	No	0.053	0.05	No
Inventory management issues	10	0.662	2	No	0.374	0.05	No
Lack of communication	17	0.654	2	No	0.968	0.05	No
Lack of company vision about logistics	4	0.066	2	No	0.018	0.05	Yes, due to statistical noise
Returns	5	0.779	2	No	0.782	0.05	No
Global-sourcing	9	0.184	2	No	0.080	0.05	No
Inter-modal operations	3	1	2	No	0.624	0.05	No

Table 6.2 Results of the two non-parametric tests to verify the absence of non-response bias

Recently, it has been an emphasis on reducing common method bias in surveys in the field of Psychology (Podsakoff et al. 2003, Conway and Lance 2010). 'Method variance can be defined as the variance linked to the measurement method rather than to the items being measured, which is attributable to the form of measurement at the levels of abstraction (the content of specific items, scale type, response format, and the general context) generating response bias such as halo effects, social desirability, acquiescence and leniency effects' (Fiske, 1982). This is a trend that is expanding rapidly in all the disciplines of business and management. It is important to discuss which strategies were used to mitigate common method bias in

Description	Focus group data	Population	Responses	Response rate (%)
Grocery Manufacturing	Yes	248	10	4.0
Retail	Yes	153	11	7.2
Road freight transport	Yes	291	20	6.9
Automotive	No	161	9	5.6
Office Machinery	No	35	1	2.9
Chemical	No	212	2	0.9
Electrical	No	110	1	0.9
Furniture	No	161	1	0.6
Metal	No	187	1	0.5
Total		1,558	56	3.6

Table 6.1 Survey sample

Furthermore, as recommended by Armstrong and Overton (1977), in order to estimate the degree of non-response bias of the survey, two different non-parametric statistical tests have been run: the independent-samples t-test and Spearman's correction. The results of these two statistical tests are shown in Table 6.2. The independent-samples t-test was used to compare the means between two data samples, the early respondents and the late respondents. The result of this test revealed insignificant differences between the means of the early- and late-respondents groups; hence this indicates an absence of non-response bias. Furthermore, the Spearman's correlation was applied to test the relationship between the rankings of all the uncertainty clusters selected by the 56 participants and the number of days they took to respond to the online questionnaire. This test did not find a significant correction between the means of the rankings and the time participants took to respond to the survey, since the P values are less than the critical value, so the correction between these two variables is not significantly different from 0, and as a result, non-response bias was also not found.

the survey. According to Podsakoff et al. (2003), in questionnaire-based surveys, there can be four clusters of common method bias:

- *Common rater effects*: 'refer to any artifactual covariance between the predictor and criterion variables generated by the fact that the survey respondent assigning scores to these variables is the same'. In the survey, this cluster of common method bias was mitigated by interrogating the opinion of two different samples in the focus groups and survey. Nevertheless, the potential bias of asking the survey respondents to select the clusters of uncertainty generated by their partners affecting them was not mitigated.
- *Item characteristics effects*: 'refer to any artifactual covariance that is caused by the influence or interpretation that a respondent might ascribe to an item solely because of specific properties or characteristics the item possesses'. This source of common method bias was mitigated during the pilot. Through the pilot, the items were assessed to ensure they were neutral, avoiding any positive or negative content on them, and they did not stimulate respondents to score them in any particular way. Also, any overlaps between items or ambiguity on their definitions were corrected by applying the feedback from the pilot participants as well as the Likert scale of the potential responses was revised. According to Podsakoff et al. (2003), there are six possible causes of item characteristics effects:
 1. Item social desirability originates since items may be constructed in such a way as to reflect more socially desirable attitudes, behaviours, or perceptions.
 2. Item demand characteristics can be generated by hidden cues as to how to respond to items.
 3. Item ambiguity can be generated by ambiguity in items that allow respondents to respond to them systematically using their own heuristic or respond to them randomly.
 4. Common scale formats can be defined as the artifactual covariation generated by the use of the same scale format (e.g., Likert scales, semantic differential scales, "faces" scales) on a questionnaire. In particular, the measurement of the items was achieved by different means of measurement. The respondents were asked to rank the

items first and subsequently to score them in terms of their economic and environmental impacts and frequencies. Different scales were used throughout the questionnaire, as recommended by Frohlich (1998) and also the pilot participants.

5. Common scale anchors originates by the repeated use the same scaling points (e.g. extremely, always, sometimes) on a questionnaire. This cause of common method bias was mitigated in the same fashion as common scale formats. The questionnaire did not have repeated scale anchors.
 6. Positive and negative item wording can be caused by the use of positively (negatively) worded items that may generate artifactual relationships on the questionnaire.
- Item context effects: 'Refer to any influence or interpretation that a respondent may have on an item solely because of its relation to the other items making up an instrument' (Wainer & Kiely, 1987). This source of common method bias is related to questionnaires that aim to correlate independent with dependent variables. In the specific case of this survey, the aim of the questionnaire was to identify which clusters of uncertainty were affecting more the respondent's freight transport operations rather than correlating constructs. However, there could have been tradeoffs when participants chosen the four main clusters of uncertainty affecting their company road freight transport operations. This source of common method bias was mitigated during the pilot, particularly when the pilot practitioners refine the definitions of the 15 uncertainty clusters developed in the focus groups. Also, the fact that these clusters were developed by a group of 58 UK logistics practitioners ensures that there were not any overlaps or ambiguity among them. Podsakoff et al. (2003) categorise this cluster of common method bias in the following five causes:
 - Item priming effects are generated 'when the positioning of the predictor (or criterion) variable on the questionnaire can make that variable more prominent to the respondent and induce a causal relationship with other variables'. In the survey, all the alternative items (clusters of uncertainty) were show to the survey respondent at the same time and were defined neutrally based on the inputs from the focus group and pilot participants.

- Item embeddedness 'originates by neutral items embedded in the context of either items worded positively or negatively that take on the assessment properties of those items'. As mention before, the fact that the focus group and pilot participants develop the items and pilot participants revised the survey questions ensures that there were not non-neutral items in the questionnaire.
- Context-induce mood is produced 'when the first question (or set of questions) encountered on the questionnaire influence a mood for responding to the rest of the questionnaire'.
- Scale length effects are 'generated if scales have fewer items, responses to previous items are more likely to be accessible in short-term memory and to be recalled when responding to other items'. This was partially mitigated by using 5-item scales for the respondents to score the frequency and impacts of the four main clusters of uncertainty chosen and ranked in the first question. As it has already been mentioned, even though Matell and Jacoby (1972) recommend using 7-Likert scales to avoid this sort of bias, the pilot participant found 5-Likert scales rather clearer than 7-Likert scales.
- Intermixing of items or constructs on the questionnaire is 'caused by items from different constructs that are grouped jointly may decrease intra-construct correlations and rise inter-construct correlations'. As mention previously, this is not applicable to the particular case of this survey.
- Measurement context effects: 'refer to any artifactual co-variation generated by the context in which the measures are gathered'. According to Podsakoff (2003), this source of common method bias can be generated by the fact that predictor and criterion variables are scored at the same point in time, and/or in the same location, and/or using the same scale. Firstly, as mentioned before the importance of the clusters of uncertainty were measured by respondents by selecting and ranking these clusters and their frequency and impacts were measured by using different scales. However, in the specific case of this survey the items were measured at the same point of time and in the same location, nevertheless the focus group participants measured them at a

different point of time, in a different location and using a different scale to the one applied in the survey.

To analyse the data, the 56 responses were categorised depending on their company logistics cost and industrial sector. The total rankings of the 15 uncertainty clusters were calculated. After that, in order to assess the relative importance of the 15 uncertainty clusters, the economic and environmental risk was calculated from the multiplication of frequency and impact (Pflug and Romisch, 2007). Also, the means and standard deviations of the risk scores were calculated for each of the 15 uncertainty clusters. To calculate each individual risk score, the impact was multiplied by the frequency. The former was already based on a numerical Likert scale while, for the latter, the times were converted into a numerical scale where 'daily' was given a score of 5 and 'annually' a score of 1. These findings were then analysed in more detail based on the sectors of the respondent companies, with a focus on those sectors having both better response rates in the survey (between 4% and 9%) and comprehensive focus group results to provide extra depth to the analysis. As seen in Table 6.1, these sectors are grocery manufacturing, retail and road freight transport. Frequency versus economic and environmental impact matrices were drawn, with the findings broken down by sector. Moreover, a categorisation of the tools that companies applied to mitigate uncertainty was undertaken and an analysis based on the links between the main four uncertainty clusters found and the mitigation tools categories has been carried out.

In the next two sections of the chapter, the overall findings and the results from the risk assessments based on the supply chain role and sector of the survey respondents will be presented.

6.4 Overall Results

In analysing the overall findings, the ranking of the uncertainty clusters is considered first. Figure 6.1 shows a comparison of the results from the focus groups and survey. The results shown in Figure 6.1 are based on the total number of post-it notes from the focus groups and the rank given by the survey participants. The two sets of results have been normalised (scaled to 100 based on the uncertainty cluster with

more post-It notes and total ranking score) to facilitate comparison between them. The uncertainty cluster with more Post-It notes and higher survey ranking was given a normalised frequency of 100; this cluster was delays, and the other 14 uncertainty clusters were calculated taking delays as a reference point.

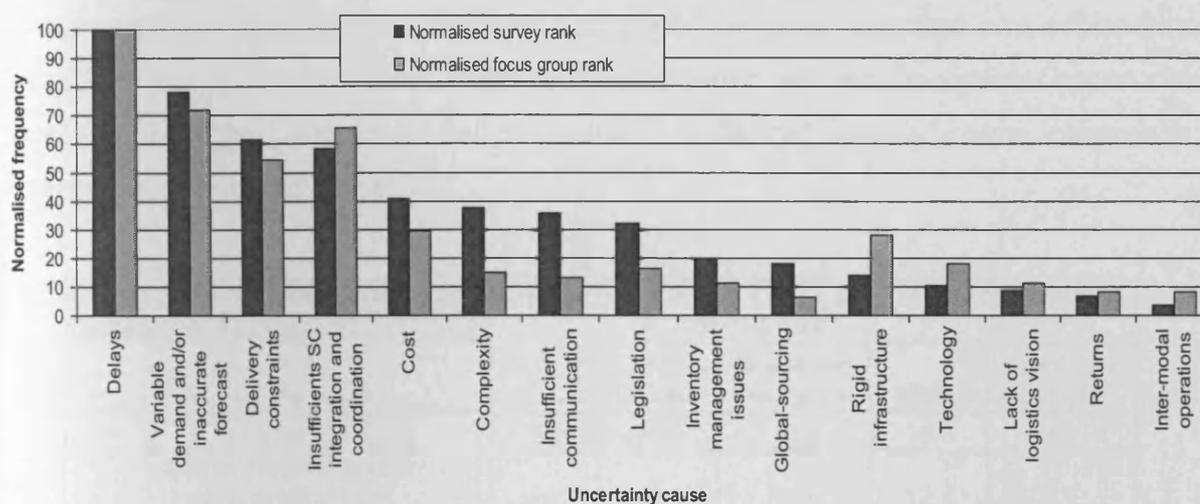


Figure 6.1 Normalised rankings from focus group and survey results

According to the focus group findings, the four main uncertainty clusters are delays, variable demand and/or inaccurate forecast, delivery constraints and insufficient supply chain integration and coordination. The survey confirms these as the main supply chain uncertainty clusters inhibiting the sustainable performance of transport operations in the UK. However, there are some slight differences between the focus group and survey results. In the focus groups, insufficient supply chain integration and coordination is the third most relevant uncertainty cluster, followed by delivery constraints whereas, in the survey, delivery constraints as an uncertainty cluster is the third most important and insufficient supply chain integration is the fourth. Moreover, according to the responses of the survey participants, cost, complexity, insufficient communication and legislation have more weight than in the focus groups.

The results for economic and environmental sustainability are shown in Table 6.3 and are taken from the survey. The economic risk measures have the same pattern as the normalised rankings of the uncertainty clusters shown in Figure 6.1. However, the environmental risk scores are generally lower and their rank is also different.

Delays as an uncertainty cluster have the highest economic and environmental mean scores, but also have the highest standard deviations in the two cases. This means that even if this uncertainty cluster has a high mean, there is more dispersion within its 34 responses. Therefore, there are a number of respondents who perceive delays representing lower economic and environmental risk for their transport operations than the average response. On the other hand, demand and information issues as an uncertainty cluster has lower economic and environmental mean risk scores and higher standard deviation than insufficient supply chain integration, delivery constraints and cost.

Uncertainty source	N	Economic risk		Environmental risk	
		Mean	Standard Deviation	Mean	Standard Deviation
Delays	34	18.4	10.2	16.3	10
Variable demand and/or inaccurate forecast	28	15.4	8.8	12.6	8.1
Insufficient SC integration and coordination	25	16.6	7.4	16.1	7.3
Delivery constraints	22	16.3	9	16.1	9.1
Cost	18	17.1	8.8	13.8	7.7
Complexity	17	14.6	8	13.4	7.3
Lack of communication	15	14.4	8.1	12.6	7.3
Legislation	13	15.7	7.8	13.9	7
Inventory management issues	10	11	4.8	6.3	3
Global-sourcing	9	11.4	4.7	11.7	4.9
Technology	6	16.3	5.4	14.8	5.1
Returns	5	17.6	5.2	18.4	5.4
Rigid infrastructure	5	11.8	4.5	9.5	3.5
Lack of logistics vision	3	10.5	3.2	16.3	5
Inter-modal operations	3	8.3	2.3	10	2.5

Table 6.3 Mean and standard deviation of the economic and environmental risk scores

In terms of environmental sustainability, the risk scores are lower than the economic risk measures. Apart from that, there are other significant differences between the economic and environmental mean risk scores. Variable demand and/or inaccurate forecast as an uncertainty cluster have a lower mean and a higher standard deviation than delivery constraints, cost and complexity. Another relevant trend in the

environmental mean risk score is that technology and returns have substantially high means and low standard deviations. However, these two uncertainty clusters have only 5 and 6 responses respectively. Moreover, global sourcing, rigid infrastructure and inter-modal operations have the lowest economic and environmental mean risk scores and the lowest standard deviations. These three uncertainty clusters do not seem to represent a considerable challenge for the vast majority of the sample.

6.5 Analysis of the findings based on the supply chain role of the survey participants

In this section of the chapter, a comparison of the findings will be undertaken based on the three supply chain roles, shipper, carrier and customer, which took part in both the focus groups and survey. In this section, the survey results of the supply chain roles will be used to evaluate the risk scores for each of the top four uncertainty clusters, while using the focus group findings to provide more depth of understanding to aid the analysis. Frequencies are ranked as high, medium and low, where ranks 4 and 5 are high, rank 3 medium and ranks 1 and 2 are low. As such, the risk analysis is more qualitative in nature.

6.5.1 Delays

Table 6.4 depicts the risk assessment for delays for the three supply chain roles. A high proportion of responses from the three supply chain roles perceive delays as a very frequent uncertainty cluster. When analysing the impact of delays, there are more differences between supply chain roles. In shippers and carriers, about 70 and 80% of the responses perceive delays as having a high economic impact, whereas 50% of customers think that delays have a highly negative effect on cost. On the other hand, the environmental risk assessment shows that a third of carriers perceive delays as having a high environmental impact, and the remainder think that this uncertainty cluster has either a medium or low environmental impact. These results show a lower proportion of carriers perceiving delays as having a high environmental rather than economic impact, a third of responses compared with a 75% of responses in the case of economic impact.

		Frequency		
		Low	Medium	High
Economic Impact	High		Carrier – 7%	Shipper – 75% Carrier – 79% Customer – 50%
	Medium		Shipper – 6%	Shipper – 19% Carrier – 14% Customer – 50%
	Low		Carrier – 7%	Carrier – 7%
Environmental Impact	High			Shipper – 69% Carrier – 36% Customer – 50%
	Medium		Carrier – 7%	Carrier – 29% Customer – 50%
	Low		Shipper – 6% Carrier – 7%	Shipper – 25% Carrier – 21%

Table 6.4 Economic and environmental impact and frequency of delays based on supply chain role

In the previous chapter, loading and unloading delays, unplanned road congestion and supplier delays were presented as the main causes of delays found in the focus groups. A similar trend is observed when analysing the causes of delays at the three supply chain roles. According to the three supply chain roles, road congestion is the main cause of delays. Also, participants from shippers and carriers perceive loading and unloading delays as a considerable cause of delays in the delivery process. However, customers only perceive loading delays as a major cause of delays.

6.5.2 Variable demand and/or inaccurate forecast

A greater number of respondents think that variable demand and/or inaccurate forecast have a high economic impact than the number of respondents perceiving this uncertainty cluster as having a high environmental effect on transport operations in the three supply chain roles assessed in Table 6.5. The differences are greater in the case of carriers, where 77% of respondents perceive this uncertainty cluster to have a high economic impact, whereas 46% of respondents think that this uncertainty cluster generates a highly negative impact on the environment. On the

other hand, in the case of frequency, the three supply chain roles assessed have at least 80% of respondents who perceive that this uncertainty cluster occurs very frequently.

		Frequency		
		Low	Medium	High
Economic Impact	High		Carrier – 8% Customer – 20%	Shipper – 40% Carrier – 69% Customer – 80%
	Medium			Shipper – 30% Carrier – 15%
	Low	Shipper – 10%		Shipper – 20% Carrier – 8%
Environmental Impact	High			Shipper – 30% Carrier – 46% Customer – 40%
	Medium		Carrier – 8% Customer – 20%	Shipper – 20% Carrier – 8% Customer – 20%
	Low	Shipper – 10%		Shipper – 40% Carrier – 38% Customer – 20%

Table 6.5 Economic and environmental impact and frequency of delays based on supply chain role

According to the focus group findings, shippers and carriers think that this cluster is caused by insufficient demand forecast accuracy and volatility of customer demand, whereas customers believe that this uncertainty cluster is originated by the volatility of end customer demand only. This was expected, since shippers and carriers are able to see the consequences of inaccurate demand forecast from customers, whereas, customers are only able to see the volatility in market demand.

6.5.3 Delivery Constraints

According to the survey results, an equally large proportion of respondents perceive delivery constraints as having a high economic and environmental impact on the performance of transport operations. In the case of shippers and carriers, as Table 6.6 shows, between 60 and 75% of respondents think that this uncertainty cluster

can have a very considerable economic and environmental effect on their distribution networks.

		Frequency		
		Low	Medium	High
Economic Impact	High	Carrier – 10%	Carrier – 20%	Shipper – 75% Carrier – 30% Customer – 100%
	Medium			Shipper – 25% Carrier – 20%
	Low			Carrier – 20%
Environmental Impact	High	Carrier – 10%	Carrier – 20%	Shipper – 67% Carrier – 50% Customer – 100%
	Medium			Shipper – 25% Carrier – 10%
	Low			Shipper – 8% Carrier – 10%

Table 6.6 Economic and environmental impact and frequency of delays based on supply chain role

According to focus group participants from these two supply chain roles, delivery constraints are a consequence of tight delivery windows and limited storage capacity, but shippers also believe that this uncertainty cluster is generated by delivery curfews at unloading bays at their customer facilities. Only one survey respondent from a customer selected this uncertainty cluster as one of the four main uncertainty clusters. This is a trend that was also observed in the focus groups, and the reason for that could be that customers do not perceive delivery constraints as a major problem, since they do not have the opportunity to see the knock-on of this uncertainty cluster.

6.5.4 Insufficient supply chain integration and coordination

As Table 6.7 depicts, a very substantial proportion of the survey respondents from shippers and carriers perceive insufficient supply chain integration as having a considerably high economic impact and at the same time a similarly high

environmental effect. Particularly, in the case of shippers, 90% of respondents stated that this uncertainty cluster has a high economic impact and 100% of respondents said that this has a high environmental effect. On the other hand, in the case of carriers, about 91% of respondents score this uncertainty cluster as having high economic impact and 73% of them say that it has a high environmental impact. Another relevant trend that can be seen in Table 6.7 is that across the three supply chain roles, a very high proportion of respondents perceive insufficient supply chain integration occurring very frequently, 100% of respondents in the case of shippers and customers and 73% of respondents in the case of carriers.

		Frequency		
		Low	Medium	High
Economic Impact	High	Carrier – 18%	Carrier – 9%	Shipper – 90% Carrier – 64% Customer – 50%
	Medium			Shipper – 10% Carrier – 9% Customer – 50%
	Low			
Environmental Impact	High		Carrier – 9%	Shipper – 100% Carrier – 64% Customer – 100%
	Medium	Carrier – 9%		
	Low	Carrier – 9%		Carrier – 9%

Table 6.7 Economic and environmental impact and frequency of delays based on supply chain role

Regarding the causes of insufficient supply chain integration found in the focus groups, carriers and shippers perceive that this uncertainty cluster is caused by disconnections between the sales department and logistics section within their companies. This is because contracts are usually arranged and signed between the sales department and the customer without considering the logistics consequences of them. Also, carriers perceived that their customers expect them to be prepared to cope with a high degree of volume demand.

6.6 Analysis of the findings based on the sectors of the survey participants

As noted earlier, in this section, an analysis similar to the one undertaken in the previous section will be conducted, but this analysis will be undertaken at a sectoral level.

6.6.1 Delays

Table 6.8 shows the risk assessment for delays for the three sectors. Generally, delays occur daily or weekly and have a high economic impact. According to the survey participants, delays seem to have a higher economic than environmental impact on transport operations in the grocery and retail sectors. However, the only exception to this is the road freight sector, where delays are perceived as having an equally high economic and environmental impact. This can be explained by the fact that delayed vehicles missed the load allocated to them, initiating the need for extra trips, thereby increasing the total transport cost and CO₂ emissions. Also, delays occur very frequently in the grocery, retail and road freight sectors.

		Frequency		
		Low	Medium	High
Economic Impact	High			Grocery- 66% Retail- 71% Road freight - 69%
	Medium		Road freight - 8%	Grocery- 17% Retail- 29% Road freight - 15%
	Low		Road freight - 8%	Grocery- 17 %
Environmental Impact	High			Grocery- 50% Retail- 57% Road freight - 69%
	Medium			Grocery- 33% Retail- 43%
	Low		Road freight - 16%	Grocery- 17% Road freight - 15%

Table 6.8 Economic and environmental impact and frequency of delays

In the focus groups presented in the previous chapter, participants from these sectors provided the root causes of delays. Overall, participants from these three sectors consider road congestion to be the main cause of delays. However, they also see failures on the supplier side and disruptions in the loading and unloading processes as significant causes of delays. If a vehicle is held at loading and/or unloading points, this has a knock-on effect on the next delivery scheduled for that vehicle and can instigate the need for an extra trip.

6.6.2 Variable demand and/or inaccurate forecast

According to the survey participants, variable demand and/or inaccurate forecast have a higher economic than environmental effect on transport operations in the grocery, retail and road freight sectors (Table 6.9). This can be explained by the fact that product demand uncertainty can affect volume demand in grocery and retail, but through the application of transport consolidation this problem can be mitigated. Since, there is a high degree of variability in these two sectors, the movements of vehicles in the road freight sector are not affected by this. Also, demand uncertainty affects the inventory holding cost more than the transport cost. Moreover, variable demand and/or inaccurate forecast happen very frequently in all these three sectors. Most companies have continuous replenishment or Just-in-Time delivery as a supply chain strategy, while retailers offer very frequent promotions to the end consumers.

The root causes of variable demand and/or inaccurate forecast in transport operations are derived from the focus groups presented in the previous chapter. In the grocery and road freight transport sectors, the factors influencing this uncertainty cluster more are daily volume changes to the customer requirements, because product promotions by the retailer are not properly communicated to the carrier and the grocery manufacturer. In addition, participants from these two sectors perceive demand forecast inaccuracy as one of the main causes of this uncertainty cluster. Furthermore, in the retail sector, this uncertainty cluster occurs since communication between the retailer and their partners is not usually the best.

		Frequency		
		Low	Medium	High
Economic Impact	High		Grocery- 20% Retail- 14%	Grocery- 40% Retail- 44% Road freight - 56%
	Medium			Grocery- 20% Retail- 28% Road freight - 22%
	Low		Grocery- 20%	Retail- 14% Road freight- 22%
Environmental Impact	High		Retail- 14%	Grocery- 40% Retail- 58% Road freight- 11%
	Medium		Grocery- 40%	Retail- 14% Road freight- 22%
	Low			Grocery- 20% Retail- 14% Road freight- 67%

Table 6.9 Economic and environmental impact and frequency of demand and information issues

6.6.3 Delivery Constraints

Table 6.10 shows in more detail a risk assessment of delivery constraints for the three sectors studied. In the three sectors studied, delivery constraints occur daily or weekly and have a high economic impact. According to the survey participants, delivery constraints have an equally high economic and environmental effect on transport operations in these three sectors. Due to delays at unloading bays at stores in these three sectors, vehicles cannot achieve their scheduled backloads, so extra trips are needed in consequence of this issue. This has a direct effect on cost and CO₂ emissions.

Next, the root causes of delivery constraints are briefly explained. In the grocery and road freight transport sectors, the factors impacting more on this uncertainty cluster are delivery curfews at stores located in urban areas and limited storage capacity within secondary distribution channels. This instigates the need for increasingly tighter delivery windows that ultimately have a negative effect on subsequent

scheduled trips. Furthermore, according to the focus group participants, the retailers impose delivery windows on their partners, but they do not have the opportunity to see the knock-on effect that delivery windows have on the overall performance of the logistics triad.

		Frequency		
		Low	Medium	High
Economic Impact	High		Grocery- 25%	Grocery- 50% Retail- 50% Road freight- 88%
	Medium			Grocery- 25% Retail- 50% Road freight- 12%
	Low			Grocery- 25%
Environmental Impact	High		Grocery- 25%	Grocery- 50% Retail- 50% Road freight- 100%
	Medium			Grocery- 25% Retail- 25%
	Low			Retail- 25%

Table 6.10 Economic and environmental impact and frequency of delivery constraints

6.6.4 Insufficient supply chain integration and coordination

As can be seen in Table 6.11, most of the survey participants from the road freight sector perceive insufficient supply chain integration and coordination as having an equally very high economic and environmental effect on their transport operations. The grocery sector presents a different trend in the retail sector, with 87% of the respondents perceiving insufficient supply chain integration to have a high environmental impact, whereas 71% think that this uncertainty issue has a high economic impact. On the other hand, in the retail sector, 50% of respondents think that insufficient supply chain integration has a high economic but low environmental impact on transport (Table 6.10). One explanation to this may be that there is little impact on retailers as consumers have alternative products that they can purchase

and some buffer stock is held at distribution centres to cope with uncertainty. An alternative consideration is the alleged pressure put on suppliers to make deliveries (Blythman, 2004), resulting in a low level of delivery failures even when there are integration issues.

		Frequency		
		Low	Medium	High
Economic Impact	High	Retail- 50%	Road freight- 11%	Grocery- 71% Retail- 50% Road freight- 67%
	Medium	Road freight- 11%		Grocery- 29% Road freight- 11%
	Low			
Environmental Impact	High	Road freight- 11%		Grocery- 87% Retail- 50% Road freight- 67%
	Medium		Road freight- 11%	Grocery- 13% Road freight- 11%
	Low	Retail- 50%		

Table 6.11 Economic and environmental impact and frequency of insufficient supply chain integration

In the retail and road freight sector, the factors affecting this uncertainty source are disconnections between the sales and logistics departments within the supplier and the carrier and horizontal network duplication between third party logistics providers. At the supplier and the carrier, the sales department agree a very loose contract with their customers and the logistics department cannot execute it with the expected level of efficiency. Also, horizontal network duplication between third party logistics providers can affect the level of supply chain integration in the retail sector, since carriers do not usually interact from the planning process. Thus, if they have a sudden increase in volume, they need to subcontract an extra trip at the last minute. Furthermore, in the grocery sector, supply chain integration does not seem to be foremost on the priority list of the focus group participants.

6.7 Tools Applied to Mitigate Logistics Uncertainty

According to the survey findings, a high proportion of respondents applied analysis and design tools that can support their companies to mitigate the effect of the four main uncertainty clusters found. Table 6.12 shows the link between the four main uncertainty clusters found in the focus groups and confirmed in the survey and the mitigation tools applied by companies that responded to the survey. In the four main uncertainty clusters, companies apply tools that help them to mitigate the effect of logistics uncertainty. In addition, the mitigation tools that they apply are directly linked with the problems they face at strategic and operational level.

Uncertainty Cluster	Mitigation tool				% Usage amongst respondents who ranked the cluster as		
	Strategic optimisation	Operational optimisation	Demand forecasting	Quality Management	High Economic Impact	High Environmental Impact	High Frequency
Delays	X	X		X	64%	66%	83%
Variable demand and/or inaccurate forecast			X		90%	90%	50%
Delivery constraints	X	X		X	100%	100%	88%
Insufficient supply chain integration	X		X		80%	80%	80%

Table 6.12 Tools applied to mitigate logistics uncertainty

In the case of delays, about 65% of the respondents who perceived this uncertainty cluster as having high economic and environmental effects and about 83% of respondents who think that this uncertainty is very frequent, stated that their companies applied strategic optimisation; for example, distribution network design software such as Cast and operational optimisation tools such as routing software like Paragon. Furthermore, 100% of respondents who perceive delivery constraints as having a high impact on cost and economic performance said that they also applied strategic and operational optimisation tools. The main objective of strategic optimisation tools is to embed uncertainty into the strategic processes e.g. distribution network design and redesign. A large proportion of that uncertainty is related to achieving journey time reliability in the delivery process, including all the existent constraints in the distribution network. Moreover, operational optimisation such as Paragon helps transport operations to optimise the transport movements within their distribution networks. Additionally, according to the survey findings, delays and delivery constraints are monitored and controlled by applying quality management tools such as TQM and Lean Thinking principles.

Another important trend emerging from the responses of survey participants is that a substantial proportion of the respondents who perceive that demand and information issue have a very considerable effect on economic and environmental performance of their distribution networks, stated that their companies used demand forecasting tools to achieve a better accuracy of the volumes that their customers need to move. Also, 80% of respondents who feel that insufficient supply chain integration has a high economic and environmental impact also said that their companies applied demand forecasting tools to support the information flow within the logistics triad.

6.8 Reflections on the survey

From the planning process up to the follow-up stage, there were a number of actions taken to increase the response rate of the questionnaire as well as mitigating the low response rate obtained in the end. The main strategy used to mitigate the low response rate obtained was to triangulate the survey data with the focus group findings. In that way, the 56 questionnaire responses could be compare with the clusters of uncertainty given by 58 focus group participants and also more depth was

added to the survey data. Furthermore, due to the initial very low response rate, the CILT was involved after four weeks that the questionnaire went live in the internet. That increases the responses from 12 to 56 responses. However, if other strategies that were applied from the beginning of the planning stage, an even higher response rate could have been achieved.

Throughout the planning and execution stages of the survey a number of decisions were taken which seems to be appropriate to stimulate a fairly high response rate at the time they were applied. However, if the research had the opportunity to repeat the exercise, the following strategies to augment the response rate could be taken:

- Changing the database for identifying and selecting potential survey participants: FAME proved to be ineffective in terms of building the invitees' list, when FAME is used as a database, the employees/managers that receive the invitation are not the managers responsible for running the logistics operation of the target companies. Reflecting on this, it would be a better approach to use initially FAME as means of identifying the companies to be surveyed, but after having all the companies identified, sending the invitations through the CILT. If this is done from the planning stage the CILT would presumably be more in the position of sending more invitations than 25% of the companies from the sectors that responded to the first invitation email. Two rounds of email could be sent, the first one with the initial invitation to contribute to the survey and the second one as a follow-up email to further increase the response rate. However, there could be sectors which traditionally have a higher number of practitioners registered in the CILT and others with very low levels of representation. Hence, the response rate in some sectors could still be low. Furthermore, the visibility of the characteristics of respondents could be affected by restrictions related to data protection laws.
- Involving trade/industry associations throughout all target sectors during the follow-up process: Trade/industry-specific association, e.g. the road haulage association, British retail consortium, a number of associations of manufacturers in the food industry, construction industry association and a number of associations of automotive component manufacturer and vehicle

assemblers, could be involved to increase the response rate after three weeks of the CILT the follow-up email is sent. Nevertheless, the willingness of warranting access to their list of members or sending an invitation email to their members can be uncertain and highly unpredictable. Also, due to confidentiality and ethical restrictions enforced by data protection laws, the visibility in terms of the sample characteristics and the process of sending follow-up emails in each of these associations could be rather restricted to the researcher. Furthermore, by applying this strategy the research could run the risk of having overrepresentation from some organisations included in the survey.

- Building a database for the survey with either existent lists of logistics practitioners used in the Green Logistics project and logistics practitioners identified in the internet. The main drawback of this strategy is that it relies on purposive sampling for the selection of invitees.
- Giving the survey invitees the option responding to the questionnaire invitation either by email filling the questionnaire online or by post answering the questionnaire in a Word file: there could be participants who either do not have access to the internet in their offices or do not have the sufficient IT ability to complete the questionnaire online. Hence, it would be appropriate to give the participants the option of completing the questionnaire electronically by using Word.com and send a hard copy of their completed questionnaires by post using a pre-paid envelop. This could cause confusion among most of the invitees regarding what exactly they require to do. Moreover, this strategy could potentially increase the costs of the survey significantly.
- Giving the fact that surveys are increasingly having low response rate in supply chain management and logistics, due perhaps to the fact that practitioners are strongly encouraged by their human resources departments not to respond to questionnaires because of productivity issues, it would be appropriate to consider an alternative method to confirm the findings from the focus groups. As in the study undertaken by Manuj and Mentzer (2008), a series of individual interviews could be undertaken to verify the focus group findings.

As discussed in the 'method' section, a number of strategies were applied in the planning and execution of survey to reduce and mitigate the sources of common method bias. The fact that the clusters used in the survey were derived by a wider sample, including trade associations and policy makers, in the focus groups ensure that the survey findings were appropriately triangulated with the focus group data. Furthermore, the participation of the eight practitioners in the pilot ensures neutrality in the questionnaire questions, items and scales. Moreover, the anonymity of the respondents was protected at all times during the survey. However, there are still a number of strategies that could have been applied to reduce common method bias further. These strategies are:

- The questionnaire could have been completed by the respondent's company and other logistics practitioners in their company's partners. A question asking respondents to forward the questionnaire to their partners could be posed in the end of the questionnaire. Hence, multiple responses from a number of supply chains could be triangulated. However, this could inhibit the initial respondents to participate in the first place. Moreover, this strategy can bring some limitations due to the application of snowballing sampling (Saunders et al., 2007). The calculation of the response rate is much more difficult. Also, the initial invitees are identified randomly, but they purposely pass on the questionnaire to practitioners who are interested in the survey.
- The questionnaire could have been completed by other logistics practitioners of the same companies responding to the survey. In this way, the potential subjectivity of one single person assessing the road freight transport operation of a company could have been reduced. However, the initial respondents could be inhibited to participate as well. Furthermore, this approach brings similar drawbacks due to the application of snowballing sampling.
- The survey respondents could be asked to initially complete the questionnaire and after two month being invited to revise their answers. Therefore, the responses at two separate given times could be compared and triangulated. Even though this strategy could reduce the common method bias, the response rate in the second round could be considerably lower than the one in the first round.

6.9 Concluding remarks

The four main uncertainty clusters identified in the focus groups, delays, variable demand and/or inaccurate forecast, delivery constraints and insufficient supply chain integration and coordination, have been confirmed in the survey. From the focus group findings, the general consensus was that companies concentrate on mitigating and accommodating to external uncertainties and improving their internal operations. This has a negative impact on the efficiency of transport operations. According to the survey findings, delays, variable demand and/or inaccurate forecast, delivery constraints and insufficient supply chain integration and coordination are confirmed as the uncertainty clusters that represent a greater challenge for transport operations within the three supply chain roles and three sectors that took part in the survey and focus groups.

In addition, these top four uncertainty clusters represent a high degree of risk for the economic performance of transport operations. However, with the exception of the road freight transport industry, respondents from the other two sectors perceive delays and variable demand and/or inaccurate forecast as having a lower environmental than economic impact on transport operations. This is also the case when the analysis is undertaken based on the supply chain role of respondents. This may be because managers within the three supply chain roles and three sectors do not have the same level of awareness of the environmental consequence of uncertainty as of the economic repercussions of uncertainty. Increases in transport cost can affect the environmental performance of transport operations only if the rise in cost is generated by an increase in fuel consumption due to unnecessary miles run caused by logistics uncertainty. In other cases, logistics uncertainty can generate time delays without increasing the miles run and the fuel consumption of vehicles. At an aggregated level, the three supply chain roles and sectors that participated in the focus groups perceived road congestion as the principal cause of delays. Time delays increases the labour cost of transport operations but not the CO₂ emissions.

The chapter has also highlighted the causes of the four uncertainty clusters at sectoral and supply chain role levels. From the sectoral analysis, in the grocery, retail and road freight transport sectors, unplanned road congestion represents the

largest individual issue leading to uncertainty. This uncertainty cause is also the major issue for shippers, carriers and customers. While congestion due to road works and peak traffic flows can be incorporated into transport planning, unplanned congestion (for example, due to an accident) leads to greater disruption. The challenge for transport providers is to mitigate the impact of this unplanned congestion without impacting significantly on the efficiency of their operations. Also, the analyses based on sectors and supply chain role, disconnection between the sales and logistics departments has a considerable impact on the logistics triad integration, and as a result, on the sustainability of transport operations within the supply chain.

In addition, regarding mitigation tools applied by UK companies to lessen the effect of delays and delivery constraints, companies that seem to be more affected by these two uncertainty clusters applied strategic optimisation tools when designing the network, operational optimisation tools at the setting stage of the transport plan and quality management tools to monitor the execution of the transport plan. Moreover, respondents stated that demand forecasting tools are applied to lessen the effect of variable demand and/or inaccurate forecast, and at the same time, to achieve better supply chain integration within the logistics triad.

In this chapter, the conceptual model developed in Chapter 4 and refined in chapter 5 has been confirmed based only on participants' perceptions. As mentioned in Chapter 3, methodological triangulation has been applied to achieve this objective. The results from the focus groups increase the depth of the findings, whereas the survey validates and confirms the focus group findings. This further strengthens the understanding of the main uncertainty clusters within supply chains in the UK. The internal root causes of uncertainty can be mitigated while external issues have to be accommodated; therefore, mitigation approaches for reducing external and internal supply chain uncertainty in transport operations need to be identified through the research. This will be explored in the three case study chapters.

In the next three chapters, the findings are verified through the investigation of real-world situations, measuring the marginal impact, in economic and environmental

terms, of logistics disruptions from the loading process at shipper facilities up to the unloading process at distribution centres and stores.

6.10 Contribution

To methodology in logistics research

This chapter shows how the findings from focus groups and a survey can be triangulated. It demonstrates that these two research methods complement each other. Also, it has used a novel risk assessment tool to evaluate uncertainty clusters within three different sectors and three supply chain roles. This assessment tool can be used in other sectors and also in other types of transport operations, e.g. inter-modal transport operations.

To the PhD

The findings obtained in this chapter confirmed the results of the focus groups. The first two research objectives of the PhD have been achieved. In addition, two analyses were undertaken in this chapter at a sectoral and a supply chain role level; the findings from this chapter complement the focus group findings. Furthermore, this chapter links the uncertainty clusters found with the mitigation tools companies used to respond to uncertainty. Thus, the third objective of the PhD has been partly achieved. Moreover, this chapter also guides the selection of the sectors for the case studies.

To the topic

This chapter has established an explicit link between uncertainty and the economic and environmental performance of transport operation. This link was not previously clarified in the literature. However, due to the fact, that the findings are based on the opinion of practitioners, they need to be explained and validated at the micro level.

7.0 Diagnosis of 'extra distance' in a UK FMGC primary distribution network

7.1 Introduction

So far, the research has focused upon gathering evidence of the causes of uncertainty that impact on transport operations by applying opinion-based research methods. In this chapter, a case study undertaken to link uncertainty with road freight transport performance will be presented. In logistics research, there has been a focus on measuring the absolute and/or average performance of road transport operations (Fowkes et al, 2004; McKinnon and Ge, 2004). There is scope for extending the above research further by quantifying the consequences of these uncertainty causes within transport operations. Sector level surveys in the UK do highlight the frequency of occurrence of different events and their impact in terms of time (for example, Department for Transport, 2007). However, this may not translate into a financial cost if there is flexibility in the delivery network to absorb the delays. There is a need to understand more fully the marginal distance, 'extra distance', that occurs due to uncertainty, as this will have a direct financial and environmental cost.

One aspect of performance measurement that appears to be under-researched is the impact of unexpected events upon transport performance. In effect, the marginal impact of supply chain uncertainty on freight transport performance at an operational level has not yet been explored. There is evidence of performance measures detailing the number of incidents that occur, and also macro-level measures of planned versus actual distance travelled (Department for Transport, 2007). However, there have been no studies that have assessed the impact of supply chain disturbances and disruptions in terms of the extra movements required within the transport network. Starting with the assumption that any unnecessary distance run creates a proportional additional cost and output of carbon dioxide, the fourth objective of this thesis is to:

Introduce the concept of 'extra distance' as a means of assessing the marginal impact that deviations from the transport plan have on the economic and environmental performance of road freight transport operations.

In addition, there is a need to evaluate the economic and environmental impact and frequency that these causes have on road freight transport operations. In order to achieve this, an 'extra distance' measure has been developed in this chapter to link the uncertainty causes found in the case study with freight transport performance. Therefore, the fifth objective of this PhD is to:

Evaluate these uncertainty causes in terms of their impact on the environmental and economic performance of road freight transport operation and identify potential mitigation tools and/or approaches to minimise their effect

The chapter proceeds by explaining the method applied to undertake the research. Subsequently, the initial definition of 'extra distance' is presented and linked back to the literature. After that, the findings are outlined. Also, the existent connections between uncertainty and risk and 'extra distance' are explicitly drawn. Finally, we conclude the chapter by highlighting the managerial implications and limitations of the research and stating the contribution to knowledge of the chapter.

7.2 Case study context

In this case study, the 'extra distance' measure has been applied to the primary distribution network of a UK FMCG supply chain, shown schematically in Figure 7.1. Products are moved within a distribution network that consists of a number of distribution centres located throughout the UK. The primary distribution network runs transport movements from suppliers to distribution centres. During the data collection, the author was based in the central planning office of this primary distribution network.

In terms of transport planning, the planners receive an estimate of the volumes to be moved early in the evening the day before the transport plan is executed. The transport planners generate a rough estimate of the resources required for the next day. The deliveries for the most remote suppliers are scheduled late in the evening on the day that the rough transport plan is generated. The following day, suppliers send a confirmation of their volume requirements by mid morning. If there are any

changes after that, extra trips may be added to the transport plan or 'extra distance' added to existent trips.

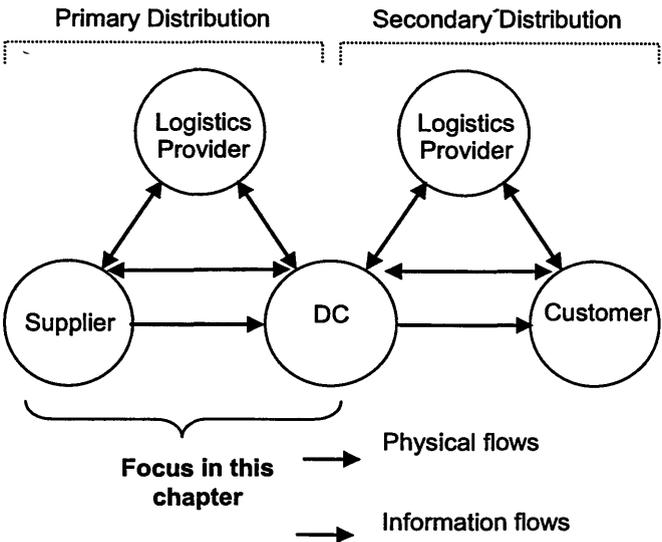


Figure 7.1 Logistics provider position within UK FMCG primary distribution network

There are a number of reasons why this particular case was chosen:

- The 'extra distance' measure was perceived to be important, but before undertaking the case study, there were no previous attempts to measure 'extra distance' within this primary distribution network. Also, the operation needs to link uncertainty to transport performance, which was the same objective of this PhD
- The FMCG sector in the UK is very vulnerable to uncertainty, so it represents a good starting point in the case study stage of the PhD
- The communication from customers and suppliers to logistics providers in primary distribution operations tends to be complex, so there was a particular interest in exploring such an operation.

7.3 Method

In order to undertake the 'extra distance' assessment in this logistics provider, the principles of the case study method recommended by Yin (2003) have been applied,

since the tool needed to be tested in a business setting. The unit of analysis for this assessment is a FMCG retail primary distribution operation.

Due to the lack of research into the marginal impact of transport uncertainty, an inductive research approach has been adopted. The reason for this is that before undertaking the first case study, the boundaries of the transport-focussed uncertainty model needed to be redefined, since it was necessary to develop an appropriate and clear measure in order to clarify the impact uncertainty has on the economic and environmental performance of transport operations, and such a measure was not available in the literature. At the beginning of this case study, the objective was to make a direct link between miles run, output of carbon dioxide (environmental performance) and cost, and from this, the concept of 'extra distance' was developed in a brainstorming session that involved the case study company champion. Consideration was then given as to the different ways in which additional transport may be required in response to the clusters of uncertainty identified and verified in the conceptual and opinion-based stages of the research.

According to the findings from the focus groups and survey, the main clusters of uncertainty that affect transport operations are: delays, variable demand and/or inaccurate forecast, delivery restriction, and insufficient supply chain coordination and integration. However, these needed to be linked with the performance of transport operations in terms of unnecessary deviations from the transport plan. In the brainstorming exercise, five types of 'extra distance' were identified. Following that, the concept of 'extra distance' as a measure was presented in a discussion panel to transport planners and logistics managers from the primary distribution section of the first case study company. They gave feedback about whether or not each of the initial five 'extra distance' types occur in the primary distribution network studied and the potential causes were also verified in the discussion panel. This discussion panel with the practitioners in charge of the operation was run before data collection began, primarily for two reasons. Firstly, the feedback from the practitioners was required to evaluate the validity of the measure. Secondly, the data collection approach to gathering data on 'extra distance' needed to be defined.

In the discussion panel, it was agreed that the author of this thesis would observe the execution of the transport plan from 30th June until 6th July 2008. Archival data on the causes of 'extra distance' was not available as the transport planners did not record the causes of changes to the transport plan. Also, a confidentiality agreement was developed and signed before commencing the case study, so the results shown in this chapter include information that retains the case study company's confidentiality. Generic terms will be used throughout the chapter and exact locations are not mentioned either. In addition, in order to avoid disclosing sensitive commercial information, only percentages are used in the analysis.

Data was collected on the nature of unexpected events and their impact on the total number of miles run in the network. This information was obtained through observation of the 'live' transport planning process. When a supply chain disruption or disturbance occurred, four transport planners informed the researcher and the researcher and they decided whether or not that incident generated 'extra distance'. The main principle was that any inefficiency generated during the execution of the transport plan was 'extra distance'. However, in terms of increases in the volume to be moved, only short-notice volume changes that caused the planner to sub-optimally execute the transport movement were classified as causing 'extra distance'. For the purposes of this analysis, only changes in volume to be moved that were notified or detected after the mid morning cut-off time were classified as eligible for consideration as causing 'extra distance', even though in certain situations, if volumes had been notified earlier, the loads could have been moved more efficiently and with less distance run. After that, the extra kilometres generated by each of the incidents identified were estimated by using the route planning software package called AutoRoute. This software package calculates kilometres with a similar accuracy to Google.com and Paragon. As Table 7:1 shows, before starting the data collection, the accuracy of AutoRoute was verified by comparing the measure of distance of a number of routes in the UK. Subsequently, the visible causes of each of the 'extra distance' incidents were also identified. Apart from the researcher and the four transport planners, a number of managers from the primary distribution operation were constantly validating the data collected and confirming that the interpretations of the researcher and planners reflected the reality of the operation.

Origin	Destination	Round trip?	Kilometres		
			Paragon	Google	AutoRoute
North London	London Central	Round trip	72.5	72.8	72.6
North London	South East Midlands	Round trip	252.8	246.3	250.4
North West London	North East London	One way	115.9	117.2	115.1
South East England	North West London	Round trip	276.9	276.9	277.9
North England	South East England	One way	561.9	561.9	562.2

Table 7.1 Cross-checking the accuracy of AutoRoute

The week when the data was to be collected was selected by using kilometre data over a twelve month period available for the case study. This week was selected due to the fact that it was considered by the company staff as a typical or average period that fairly represents what happens over a 12-month period. Thus, typical case sampling was applied as purposive sampling strategy (Saunders et al, 2007), since the objective was to assess the causes of 'extra distance' in a week that was representative of what happens over a twelve month period. Furthermore, during the data collection, the main objective was to find incidents with a common attribute, namely, that the incidents collected should generate 'extra distance'. In this way, it was not necessary to monitor every single trip run in the network to measure the effect of route diversion due to unplanned road congestion, in terms of 'extra distance'. Moreover, that was not possible, due to the fact that Telematics data on planned and actual kilometres was not available to the researcher during the week when the data was collected. However, the company stakeholders felt that an element of expected road congestion was included within the transport plan.

During the data collection, detailed information about the trips that caused 'extra distance' was recorded in a data collection pro-forma (see Appendix 3); this information includes:

- Incident detail: date, incident number, identified and departure times, planned and actual kilometres.
- Consignment details: supplier name, unit load, whether vehicle was own or subcontracted, customer location, kilometres run, 'extra distance' source, visible cause and root cause,

Subsequently, the results of the data collection were used to estimate the risk that each cause of 'extra distance', in terms of its probability and impact, represents to the operation. Supply chain risk has previously been estimated in a qualitative way by investigating the perception of practitioners about the risk that different events could have on the whole supply network. Geijron (2009) undertook a case study to assess the risk of supply disruptions within the global Ericsson supply chain. Geijron (2009) used a matrix for risk evaluation to estimate the probability and the consequence of each potential event that can disrupt the supply chain. In topic areas like that, accurate quantitative data is not available and the researcher needs to rely on practitioners' perception. However, in other academic fields, when historical data has been available, other researchers have undertaken quantitative risk assessment, e.g Pratt and Magiera (1972). However, when historical data is available, quantitative risk assessment can be undertaken. Operational risk is defined as the risk of loss resulting from inadequate or failed internal processes, people, and systems, or from external events (www.riskglossary.com). Errors and failures within the supply chain can be monitored and recorded, so their probability and impact can be estimated based on quantitative data. As stated by Silver (1997), risk is a function of the probability that an event occurs and the impact of that event. The risk of each cause of 'extra distance' has been estimated as a function of one probability of their occurrence and their impact.

Due to insufficient live information concerning the route selected by drivers while the vehicle is on the road, during the data collection, in this case study, it was not possible to estimate the probability and impact of route diversion due to unplanned road congestion. This is because, in order to collect data on route diversion, it is necessary to monitor every trip that is run within the distribution network. Also, the logistics providers were particularly interested in assessing the risk of the causes of 'extra distance' that could possibly be controlled by them and their supply chain partners. They perceived unplanned road congestion as an uncontrollable cause of 'extra distance', so it did not represent a high priority for them.

In addition, the 'extra distance' generated by every incident was calculated. It was important to record sufficient detail of each incident of 'extra distance', because the practitioners in charge of the operation could validate the data in a more rigorous manner. An Excel spreadsheet was used to undertake an evaluation exercise that could link each cause of uncertainty with the 'extra distance' generated. Appendix 4 shows this Excel spreadsheet. From the spreadsheet, the extra distance' generated by each cause of 'extra distance' was calculated. For each cause of 'extra distance', in order to inform future 'extra distance' reduction programmes, frequency and impact were also calculated.

The data of 'extra distance' was collected most of the time when the planners received the extra load requirements, before the movements were executed. However, when suppliers loaded less than they advised after the trips were run, the logistics provider realised that there was unexpected space in the vehicles. The logistics provider management team identified two suppliers as the two main culprits of this type of 'extra distance' and the researcher and planners together re-planned the trips for the whole week and calculated the miles of these trips. Subsequently, the actual miles were compared with the better optimised miles to quantify 'extra miles'.

The cost of every incident of 'extra distance' was calculated by multiplying the cost per kilometre by the extra kilometres run. Also, the Kg of CO₂ emitted due to every incident of 'extra distance' was calculated by multiplying the average fuel consumption in the network by the extra kilometres per incident of 'extra distance' and by the road freight transport conversion factor for diesel recommended by Defra (2007), 2.63 Kg of CO₂ per litre of fuel.

After completing the analysis of the data, a feedback presentation was delivered to the management team of the primary distribution operation. In that meeting, all the managers involved validated the findings. From their perspective, this presentation represented a starting point towards identifying the potential mitigation strategies and tactics to reduce 'extra distance'.

7.4 Initial definition of ‘extra distance’

From the initial brainstorming session, the following definition of ‘extra distance’ was developed:

Any additional transport movements that are a consequence of unforeseen changes in the delivery process e.g. due to congestion and/or late changes in customer requirements.

With this definition, it was assumed that the original transport plan produced is an optimum given the constraints imposed. From this, five types of ‘extra distance’ were identified, in response to uncertain events within the delivery operations. These are described in the following sections and summarised in Table 7.2.

Type of 'extra distance'	Description	Example of uncertainty cause from literature
Extra distance due to optimal route diversion	Extra distance needs to be run to minimise the delay to the trip.	Unplanned road congestion (Boughton 2003)
Extra trips due to delays	Extra trips are required due to the fact that the vehicle original assigned to the trip could not arrive on time.	Loading delays at shippers or at customers (Geary et al 2003)
		Unload time uncertainty (Esper and Williams 2003)
Extra trips due to load more than advised	Extra trips are caused because there is not enough time to find the most economical way to move the extra volume.	Demand variability and forecast inaccuracy (Mason-Jones and Towill 1998)
Extra trips due to load less than advised	There is unexpected extra space in the vehicles, so the transport plan is suboptimal and unnecessary trips are operated.	Inaccurate demand forecast (Mason-Jones and Towill, 1998); Warehouse inefficiencies (van der Vorst and Beulens 2002)
Extra trips due to inappropriate vehicle size	A smaller vehicle than planned is provided, requiring additional trips to deliver all products.	Transport delays due to internal reasons e.g. defective vehicle or lack of driver (Mason et al., 2003)

Table 7.2 Types of ‘extra distance’ and potential causes

7.4.1 Extra distance due to optimal route diversion

This type of ‘extra distance’ can occur when there is unplanned road congestion along the optimal route initially planned for the trip, so the vehicle needs to be diverted. When the driver is informed of a traffic jam that will delay the vehicle, a

decision may be taken to use an alternative route so as to minimise the delay. If that occurs, the vehicle runs a greater distance within the trip due to the use of a non-optimal route.

7.4.2 Extra trips due to delays

Occasionally delays can occur within the delivery process, such as production and/or loading delays at shippers (Esper and Williams, 2003), unloading delays at customers (Geary et al, 2003) and unplanned road congestion (Boughton, 2003). The consequence of each is that the vehicle will be late for the next load in its schedule, so a different vehicle may be needed to operate that movement, either as an additional trip, or a diversion of an existing trip. In either case it is likely to be less efficient and involve more kilometres being run as a consequence of the earlier delay.

7.4.3 Extra trips due to load more than advised

Inaccurate and/or variable volume forecasts can lead to the short notice requirement to move additional product volumes. Whilst there may be spare capacity to absorb small increases, there may be a need for additional trips that are not moved in the most optimal way due to insufficient time to move the extra load. These result in 'extra distance'. From a carrier perspective, this type of 'extra distance' is difficult to control since it is generated by the carrier's supply chain partners. Also, if the carrier can charge its customer for the 'extra distance' run, there is less commercial incentive for the carrier to mitigate it. However, from a supply chain perspective, volume forecast inaccuracy and/or variability can have a negative environmental impact in terms of extra cost and carbon dioxide emissions.

7.4.4 Extra distance/trips due to load less than advised

Equally, inaccurate forecasts can mean the load to be moved is smaller than originally planned. This would result in unexpected space in the vehicle but insufficient time to re-plan the network to utilise or remove this empty space. From a different perspective, this means that the actual volume to be moved could have

been moved more efficiently, either on fewer trips or truncated trips, which in turn means that 'extra distance' has been run.

7.4.5 Extra distance/ trips due to inappropriate vehicle size

Planning of transport movements is based on specified vehicle capacities within the transport planning system. If the correct vehicle is not available when required for loading, due to a planning failure or technical issue with the vehicle, additional trips can be required in order to complete the delivery of the load.

7.5 'Extra distance' and value-added transport

It is necessary to link the 'extra distance' concept back to the literature. Through the feedback process, it became apparent that the approach adopted is similar to the identification of waste within lean production systems. Therefore, a literature search was carried out to see how the two concepts relate.

The concept of value adding activities has its origins in the Toyota Production System, in particular the principles of identification and elimination of waste. According to Shingo (1989), waste is any activity that does not contribute to an operation. Also, Taiichi Ohno defined seven common forms of waste activities that add cost but no value to the operation: production of goods not yet ordered; waiting; rectification of mistakes; excess processing; excess movement; excess transport; and excess stock (Japan Management Association, 1985).

A number of authors have tried to apply the seven wastes defined by Ohno to logistics. At a conceptual level, Sutherland and Bennett (2007) developed a framework for logistics operations, with seven wastes:

- Overproduction due to inaccurate demand forecast
- Delays and waiting in loading and unloading bays
- Unnecessary transport movements due to lack of backhaul consolidation
- Unnecessary motions within a warehouse because of unsuitable warehouse design

- Warehouse space available inefficiently utilised due to non-standardised pallet sizes
- Excessive inventory
- Manufacturing errors that caused product rework.

Simons et al. (2004) developed a new measure called Overall Vehicle Effectiveness (OVE). OVE is the result of combining three attributes: availability, performance and quality. OVE is affected by four transport wastes: driver breaks, excess load time, fill losses and speed losses. These four transport wastes have an impact on the performance of transport operations in terms of time. However, the OVE measure does not include the distance dimension of transport performance, which can have a direct transport cost.

The concept of 'extra distance' can thus be seen to link directly into that of 'excess transport' proposed by Taiichi Ohno, and more specifically into that of 'unnecessary transport due to lack of backhaul consolidation' proposed by Sutherland and Bennett (2007). However, the latter appear to propose the 'lack of backhaul consolidation', for which it can be read 'lack of schedule optimization', as a direct cause of waste in itself; this research develops the concept by demonstrating situations where the lack of consolidation is actually an effect, with a series of root causes related to uncertainty creating it. In particular, the other six supply chain wastes can create extra trips at the operational level. For example, delays at shippers and/or customers can lead to a vehicle arriving late back at a distribution centre, so the consignment fails to make a scheduled transshipment, leading to an unplanned additional trip being generated within the transport network. Alternatively, warehouse problems can lead to excessive queues at distribution centres, generating delays that later result in 'extra distance'.

7.6 Results and analysis

In this section of the chapter, the overall results of the data collection will be presented first. After that, the impact of the causes of 'extra distance' will be

discussed, highlighting their potential root causes. Subsequently, a risk assessment of all the causes of 'extra distance' found will be shown.

During the week of data collection, 2.4% of the kilometres run within the primary distribution network studied were 'extra distance'. This generates a proportionate amount of extra cost and extra Kg of CO₂. A total of 68 incidents of 'extra distance' were recorded during that week, which represents approximately 3.1% of the total number of trips run in that period. Even though the total 'extra distance' found is 2.4%, it still represents a substantial monetary value for the logistics provider studied.

7.6.1 Main causes of 'extra distance'

As shown in Table 7.3, seven causes of 'extra distance' were identified while gathering data. They were late notification of extra volume to be moved, physical load smaller than advised, loading delays at suppliers, planning failures, unplanned road congestion, product not loaded and product mis-loaded. Table 7.3 shows the 'extra distance', extra cost, extra CO₂ emissions and frequency in terms of percentages. The cost and the Kg of CO₂ emissions of the seven 'extra distance' causes has been calculated by multiplying the extra kilometres of each cause by the cost per kilometre and by the average fuel consumption per kilometres and the Defra conversion factor mentioned in the method section. Given the fact that the logistics provider only allowed the researcher to show percentages in this chapter and the percentages of extra kilometres, extra cost and extra Kg of CO₂ emissions are the same for each cause of 'extra distance', in this section, the author will only refer to the percentages of extra kilometres and of 'extra distance' incidents.

'Late notification of extra volume to be moved' was the main cause of 'extra distance' identified. This cause of 'extra distance' represents 39% of the total 'extra distance' found. Also, this cause of 'extra distance' represents 55% of the total number of 'extra distance' incidents observed in the data collection. This cause of 'extra distance' generates the need for extra trips and/or the need for extending existent trips. Thus, in order to reduce the level of unnecessary 'extra distance' run, a key

priority is to improve the accuracy of volume forecast provided to the logistics providers.

'Extra distance' type	'Extra distance' Cause	Extra Distance (%)	Cost (%)	Kg of CO ₂ (%)	Frequency (%)
Extra distance due to route diversion	Unplanned road congestion	Not measured			
Extra distance/trips due to delays	Loading delays at shippers	7	7	7	6
	Unplanned road congestion	4	4	4	5
Extra distance/trips due to load more than advised	Late notification of extra volume to be moved	39	39	39	55
Extra distance/trips due to load less than advised	Physical load smaller than advised	36	36	36	20
Extra distance/trips due inappropriate vehicle size	Technical vehicle failure	No incidents found			
Not considered	Planning failure	8	8	8	12
	Product not loaded	3	3	3	1
	Product mis-loaded	3	3	3	1

Table 7.3 Overall impact of 'extra kilometres' on the primary distribution network studied

Another very significant cause of 'extra distance' found in the data collection was 'physical load smaller than advised', which represents 36% of the 'extra distance' identified in the primary distribution network studied. This cause of 'extra distance' is originated at the suppliers. The number of incidents of 'load smaller than advised' represents 20% of the total number of 'extra distance' incidents found in the data collection. This cause of 'extra distance' occurs since two particular suppliers usually plan for more volume than they actually need. Thus, this generates unexpected space in the vehicles run for the trips, and as a result, the trips are run in a sub-optimal manner and 'extra distance' is generated because of that. Hence, the logistics provider needs to revise the forecast of volumes generated by these two suppliers.

Consequently, if the delay is more than an hour, it can generate the necessity for an additional trip.

The other two causes of 'extra distance' were identified during the data collection. They are 'product not loaded at distribution centres' and 'product mis-loaded' or loaded to the wrong destination (distribution centre) by suppliers. As in the case of planning failures, these two causes of 'extra distance' were not identified in the discussion panel run before starting the case study. Each of these two 'extra distance' causes generates only 3% of the total 'extra distance' recorded and is 1% of the total number of incidents observed in the data collection. Therefore, they should be at the bottom in terms of priority of any 'extra distance' reduction programme implemented by the logistics provider and its supply chain partners.

After finishing the analysis of the data, the initial definition of 'extra distance' was slightly modified, reflecting the findings from the case study. This definition is:

'Extra distance as a measure is non value-added or unnecessary distance run within a distribution network due to supply chain uncertainty, and defined as the difference between the distance vehicles actually ran, and the distance they would have needed to have run if:

- *the transport operation had received accurate and timely information on the volumes to be moved, and/or*
- *there had been no unexpected delays at loading or unloading points and/or*
- *there had been no operational failures within the distribution network and/or*
- *there had been no congestion on the journey that could not have been foreseen*

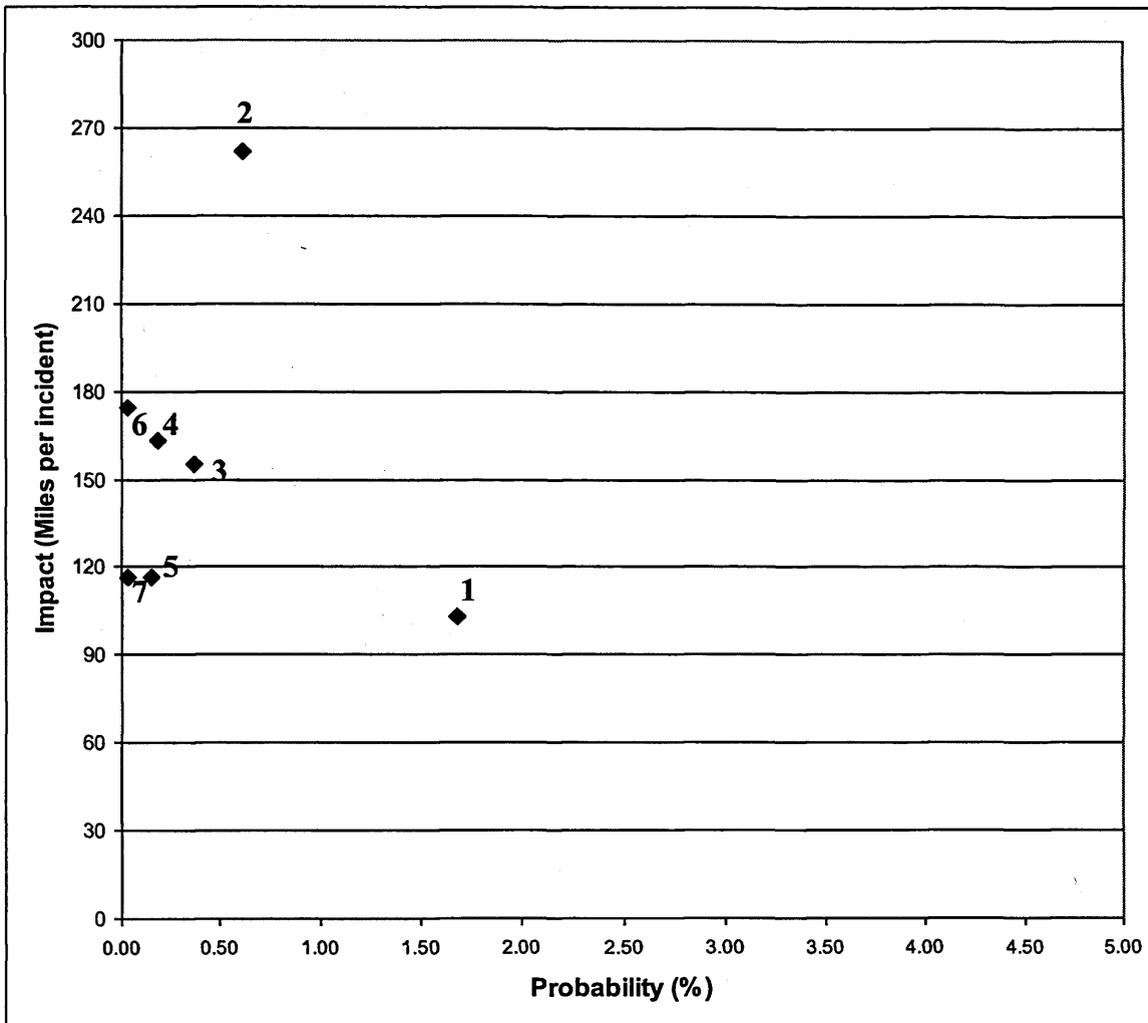
7.6.2 Risk assessment of 'extra distance' causes

In order to evaluate the relative importance of all of the 'extra distance' causes, as has been mentioned in the method section, the risk that they represent has been calculated as a function of impact and probability. Figure 7.2 shows the impact and probability of the seven 'extra distance' causes found in the data collection.

'Planning failure' represents the third most significant 'extra distance' cause, but has an overall impact of only approximately one eighth of the 'extra distance' caused by inaccurate volume notification from suppliers as already discussed. It is important to highlight that this cause of 'extra distance' was not considered while developing the initial definition of 'extra distance'. In total, 8% of the 'extra distance' found and 12% of the 'extra distance' incidents are caused by planning failure. In most of the cases, 'planning failure' occurs when the communication and coordination within the distribution network is insufficient. Also, in a few cases, planning errors were found where planners had committed resources where they were not needed. In mitigating this 'extra distance' cause, the information flow and allocation of resources within the network required attention. However, in the short term, the logistics provider should focus much more on finding alternative solutions for achieving more accurate suppliers' volumes from the transport planning to the execution of the suppliers' collections.

'Loading delays at suppliers' represent a smaller proportion of the total 'extra distance' found. A small minority of the suppliers tend to hold the vehicles at their loading bays, but when the delay is more than two hours it could affect the next trip allocated to the vehicle held. Therefore, the decision is made at the logistics provider to send the vehicle back to the distribution centre where the product is required and another vehicle is allocated to collect the rest of the load. This represents 7% of the total 'extra distance' found and 6% of the total number of incidents. Extra trips caused by 'loading delays at the supplier' generally do not have an economic impact on the logistics provider, since when they occur the suppliers are charged for the extra trip. However, they have a considerable impact on the overall transport cost and environmental performance of the whole supply chain.

In the week of data collection, three other 'extra distance' causes were recorded. Firstly, when 'unplanned road congestion' causes sufficiently severe delays, this generates the need for an extra trip. 'Unplanned road congestion' represents 4% of the 'extra distance' found and 5% of the total number of incidents observed in the data collection. Within the total delivery time, there is generally about an hour of slack time embedded in the transport plan to tackle unplanned road congestion.



No	'Extra distance' cause
1	Late notification of extra volume to be moved
2	Physical load smaller than advised
3	Planning failure
4	Loading delays at shippers
5	Unplanned road congestion
6	Product not loaded
7	Product mis-loaded

Figure 7.2 Risk assessment of 'extra distance' causes

'Late notification of extra volume to be moved' occurs about 1.7% of the total trips run in the network, which means that it is very important to intensify its monitoring and control. Although it has the lower impact per incident, 103 kilometres per incident, it occurs relatively far more frequently than the other six 'extra distance' causes. Meanwhile, 'physical load smaller than advised' has an impact of about 260 kilometres per incident but occurs about 0.6% of the total trips run in the network. It

is important to note that the probability of 'physical load smaller than advised' is lower than 'late notification of extra volume to be moved'. These two types of 'extra distance' are caused due to inaccuracy of volume forecast at suppliers. Therefore, they should have similar probabilities. The potential reason why 'physical load smaller than advised' has a lower probability is that this type of 'extra distance' was calculated for two suppliers that were identified as the main culprits of the problem. However, both these causes of 'extra distance' can be mitigated by improving the accuracy of volumes to be moved.

The other five causes of 'extra distance' have a medium impact in terms of kilometres per incident, but they occur as rarely as less than 0.35% of the total trips run in the network. Therefore, they should be of a lower priority for the logistics provider and its partners.

7.6.3 Linking 'extra distance', uncertainty and risk

In this section of the chapter, the link between supply chain uncertainty and risk and 'extra distance' is explicitly drawn to connect cause and effect. The types of uncertainty actually observed in the case study have been categorised according to the framework presented in the focus group findings chapter. In some instances, the uncertainty arises from more than one source. These are then mapped against the cause of 'extra distance' observed in the case study. The results can be seen in Figure 7.3.

It can be seen from Figure 7.3 that the research suggests that operational issues tend to be generated to a greater extent at the supplier and control systems rather than at the carrier. Variable demand and/or inaccurate volume forecast is the major supply chain uncertainty found in this case study. This uncertainty cluster generates 75% of the extra Kg of CO₂ and 75 % of the extra cost measured in the case study in the form of extra kilometres. 'Late notification of extra volume to be moved' is recorded as a supplier and control systems uncertainty source since the volume forecast process is one of the control systems of the whole supply chain, and if it is tightly integrated, volumes could be more accurate. Other issues relating to the size of loads are also focused upon the supplier and control systems within the supply

chain, reflecting the roles of both of these in generating transport demand in the primary distribution network studied.

It is important to state that delays in the form of loading delays at the supplier and due to unplanned road congestion did seem to have a lower risk in comparison to variable demand and/or inaccurate forecast. However, this could be due to the fact that the research has currently failed to identify any links to route diversion. This is very possibly due to the data collection approach which did not track each and every individual trip.

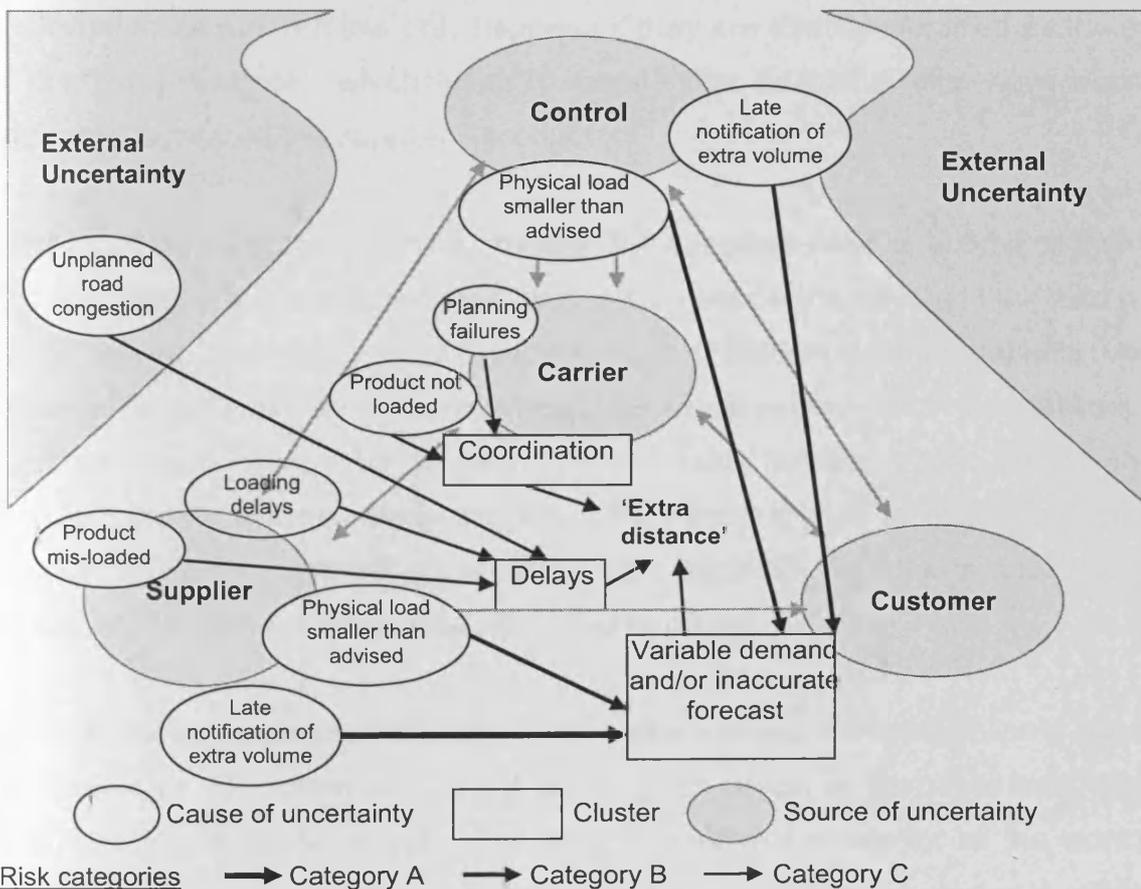


Figure 7.3 Link between uncertainty, risk and 'extra distance'

7.7 Transport uncertainty mitigation approach

Table 7.4 summarises how the context in which the logistics provider is influenced how they respond to uncertainty. The approach that the logistics provider takes to

mitigate uncertainty is influenced by the fact that, for the customer, it is equally important to ensure that the products are available at the customer facilities at all times so as to minimise the transport cost. Also, cost factors drive the fact that the logistics provider considers cost as a highly important attribute. Labour cost and fuel cost in the UK are very high in comparison to developing countries, and also the fixed cost of transport is very high. The vehicle acquisition and fuel costs are high in the UK due to the fact that the tax duty on acquisition of vehicles and of fuel prices is very high there. Hence, throughout the fleet, an average vehicle capacity utilisation of 85% is generally achieved, so if there is a disturbance or disruption 'extra distance' is very likely to be generated. The suppliers sometimes are charged for additional miles run, but this only happens if they are directly identified as the cause of the 'extra distance', which typically means that additional trips have been run dedicated to moving the supplier's product.

In terms of the transport planning process, the suppliers need to submit all their final and confirmed volume requirements by mid morning on the day that their load needs to be moved. Furthermore, the secondary distribution centres tranship volume movements between them to optimise the movements within the network and minimise empty miles. The transport plan is fairly flexible; it can be changed if volume patterns change within the UK. The transport plan is elaborated with the volume requirement information received from suppliers, vehicles available in each depot and the existent restrictions within the network.

After the transport plan is completed, any extra volume from a supplier is allocated either own or subcontracted fleet depending on which is the more cost-effective given the time available to plan. The most economical routes for all the extra trips generated by uncertainty are identified by looking at all the movements within the whole network.

It is important to highlight that the logistics provider charges the suppliers for the 'extra distance' generated by them as long as they are identified as the entity that directly originates the 'extra distance'. In this particular case study, 82% of the 'extra distance' recorded is generated by suppliers. When the 'extra distance' is generated due to 'physical load smaller than advised' the extra kilometres were calculated by

re-planning the trips considering the actual volumes, so the suppliers could not be charged for their volume inaccuracy, since the logistics provider was not aware of this problem. However, as long as the suppliers are charged for their extra kilometres, the suppliers have an economic incentive to reduce them.

Customer main targets	Product availability	High priority
	Transport cost	High priority
Cost factors	Labour cost	High
	Fuel cost	High due to tax duty
	Fixed cost	High due to tax duty
Cost structure	Type of contract	Not disclosed
Transport planning	Daily deadline	By mid morning
	Volume requirements driven by	Supplier and distribution centres
	Flexibility	The transport plan is fairly flexible, it can be changed if volume patterns change throughout the UK
	Average vehicle capacity utilisation	85%
	Fleet ownership	Mix of owned, leased and subcontracted fleet
	ICT transport system	Information on the volume requirements are received from suppliers through an order electronic system and the distribution centres report in other system when the loads are received, and the planners draw up the transport plan in Excel
Response to uncertainty	Capacity available in transport plan?	Any extra volume from a supplier is allocated either an own or subcontracted fleet depending on which is the more cost-effective given the time available to plan
	Location of the load?	If the load is on a location where a reasonably close backload cannot be found, the transport planner gives the load to a subcontractor
	Who will run the extra trip?	If a vehicle is not available internally within the network or the cost of running the trip is lower, an extra consignment is given to a subcontractor
	Route re-optimisation	The most economical route is selected for the extra trip, depending on the availability of fleet and time to plan
	Who pay for the load?	The entity that is generating the extra kilometres, if it is identified the same day. If not, the logistics provider absorbs the hidden cost
	Monitoring	Every day a report that summarises all the added trips and economical knock-on effect of them is produced

Table 7.4 How the logistics provider mitigates uncertainty

7.8 Managerial implications

Even though the case study presented in this chapter is a FMCG primary distribution network run by a logistics provider from the UK, the research has identified a number of opportunities applicable to other transport operations within the UK and other countries. From this, some generic managerial implications can be established. The chapter has emphasised why it is important to measure the impact that supply chain uncertainty has on road transport performance. Previous research works have primarily proposed transport time-based performance measurement tools. However, from a road transport operation viewpoint, it is equally important to evaluate transport performance in terms of distance.

The 'extra distance' assessment applied in this case study can be used as a diagnostic tool in other road transport operations, especially within the FMCG sector. In this way, a more explicit link between supply chain uncertainty and unplanned incidents in the execution of the transport plan could be made. A more explicit link between uncertainty and extra cost and extra CO₂ emissions generated due to 'extra distance' can also be drawn. Moreover, the 'extra distance' assessment has informed future decision making within the logistics provider studied.

Furthermore, variable demand and/or inaccurate forecast of volumes to be moved generates about three quarters of the 'extra distance' recorded. In this case study, the suppliers forecast the volume from the customer. Therefore, it is necessary to establish which is the root cause of this 'extra distance' cause. In many cases, 'extra distance' generated due to demand variability and/or inaccurate forecast is originated at suppliers, but in some other cases the customer has a considerable share of responsibility for this 'extra distance' cause. In order to mitigate this uncertainty cluster, the logistics provider re-plans the extra trips in the most optimal way possible. However, in some cases, the suppliers inform of the extra volume requirements at very short-notice, so the logistics provider cannot find the most economical route for moving the extra loads. Therefore, in order to reduce the extra cost and extra CO₂ emissions generated by this uncertainty cluster, the volume forecast process of the whole supply chain should be reviewed. However, the logistics provider needs the support of the other supply chain partners to do so.

One issue that needs addressing is that in order to reduce 'extra distance', there is a need for the logistics provider to actively engage with the suppliers and retailers, and that while there are overall supply chain benefits, these may not be evenly distributed between the all parties. When the logistics provider identifies that a supplier directly generates 'extra distance', that supplier would generally have an economic incentive to reduce extra distance, although in many cases suppliers are driven primarily by their customer demand. However, the challenge is that in many cases it is not possible for the logistics provider to identify a supplier as the main cause of the 'extra distance' incident. This can be considered a significant barrier for the reduction of 'extra distance' and the extra CO₂ emitted by the logistics provider's partners. Previous research has highlighted the fact that transport is often seen as a commodity within the supply chain (Stank and Goldsby, 2000) and so suppliers may want to take the cost benefit. However, others have argued that the supplier, carrier and customer should work together and share benefits, through a concept termed the logistics triad (Beier, 1989). This would enable all to gain from a reduction in empty kilometres.

7.9 Concluding remarks

So far, the 'extra distance' measure has been defined as any non value-added distance run within a distribution network. This chapter presents a tool that applies 'extra distance' as a measure to assess road transport functions within distribution networks. It can be applied to assess the efficiency of road freight transport operations in terms of distance, or more specifically in terms of unnecessary vehicle usages and fuel consumption. Also, it can be used to evaluate the causes of unnecessary mileage and estimate the risk that they represent. Table 7.5 shows the strengths and weaknesses of the 'extra distance' assessment undertaken in this case study.

Strengths	Weaknesses
<ul style="list-style-type: none"> • It draws a clear link between uncertainty and transport performance. • It can be used to estimate the marginal impact of uncertainty on cost and CO2 emissions. • It causes the researcher to interact continuously with the planners, so the validity of the data collection was continuously verified. 	<ul style="list-style-type: none"> • It does not measure the impact of route diversion on 'extra distance'. • It does not measure the impact of uncertainty on the time dimension of transport performance. • It can be considerably labour intensive. For example, the researcher needed to spend a significant amount of time per day over a seven day period in the planning office of the primary distribution operation and act as a liaison between all the transport planners involved.

Table 7.5 Strengths and weaknesses of the 'extra distance' assessment

According to the results of this study, in this UK-based primary distribution network, 2.4% of the total kilometres run are 'extra distance' or non-value added kilometres. The two main 'extra distance' causes recorded are 'late notification of extra volume to be moved' and 'physical load smaller than advised'. Jointly, they represent approximately 75% of the 'extra distance' found. When suppliers are charged for their failures, they are incentivised to improve the accuracy of their volume forecast. However, when the inaccuracy is caused by their customers rather than themselves, they need to communicate with their customers in order to reduce 'extra distance'. Moreover, the logistics provider moves any extra load either with own or subcontracted fleet depending on which is the more cost-effective, given the time available to plan. In addition, the assessment of the seven causes of 'extra distance' has been done by calculating the risk that they represent, in terms of their probability and impact. In order to reduce 'extra distance' the logistics provider needs to find a mechanism to encourage the suppliers to improve the forecast accuracy of volumes to be moved.

Before embarking in any 'extra distance' reduction programme, the logistics provider should monitor 'extra distance' for a longer period of time. The results of the case study presented in this chapter are based on data collected over an average week. Therefore, the outcome of this exercise should be taken as a guide for future decision making, but the exercise needs to be repeated in order to verify the recurrence of the findings.

In this chapter, 'extra distance' as a measure has been developed and tested in a primary distribution network in the UK FMCG sector. The validity of the 'extra distance' measure requires testing in other road transport operations, if possible, including a case study from another country. Therefore, the 'extra distance' measure has been applied in two other case studies, two secondary distribution networks, one based in the UK and the other based in South Africa. The findings from these two case studies will be presented in the following two chapters. Additionally, in these two case studies, the time dimension of transport performance is included in the assessments due to the fact that the time dimension is also important for assessing the impact of uncertainty on cost, while 'extra distance' is a measure that can be used to evaluate the environmental effects of uncertainty. Moreover, in this case study, the effect that unplanned road congestion has on 'extra distance' due to route diversion was not measured due to the fact that planned and actual kilometres of individual planned trips were not available to the researcher. Therefore, the researcher observed the re-planning and execution of the transport process to gather data on the 'extra distance' generated by uncertainty events that occurred after the original transport plan was made. In order to address this limitation, data on the effect that unplanned road congestion has on 'extra distance' will be included in the analysis undertaken in the case study undertaken in the UK secondary distribution operation presented in Chapter 9. Finally, information on the efficiency of road transport operations varies from company to company. Therefore, before applying the 'extra distance' measure in the two case studies presented in the following two chapters, a detailed review has been undertaken of how information on the delivery process is recorded, so data can be collected in the most effective way possible.

7.10 Contribution

To methodology in logistics research

The chapter shows that when there is no archival data of the effect of different types of uncertainty on transport performance, it is still possible to gather the data live while the transport planners elaborate and execute the transport plan. Furthermore, the chapter shows that when a company does not measure a problem, it is important

to clarify the problem with the practitioners in charge of the operation before starting to collect data. Most of the incidents collected in these case studies required the careful consideration of the context involved in each incident. This can be used as a guide for the application of new uncertainty measurement systems in operations when there is a lack of historical data at the start of the case study.

To the PhD

In this chapter, the application of the 'extra distance' measure defined in the previous chapter has been demonstrated. Also, variable demand and/or inaccurate forecast, one of the four main uncertainty clusters found in the focus groups and confirmed in the survey, represent 75% of the extra kilometres recorded in the study, although delays and coordination problems caused a proportion of the extra kilometres found. It should also be remembered that the direct effect of route diversion due to unplanned congestion on 'extra distance' has not been measured, unless the consequent delays directly resulted in subsequent 'extra distance' being run.

To the topic

In this chapter, a FMCG primary distribution operation from the UK has been studied to show the effects that uncertainty has in this type of operation in the UK. Variable demand and/or inaccurate forecast cause a significant proportion of inefficiency within this distribution network. Therefore, this demonstrates the impact that the demand forecast inaccuracy and lack of visibility of information from shippers and the customer have on the performance of a primary distribution operation run by a logistics provider.

8.0 Diagnosis of 'extra distance' and 'extra time' in a South African FMCG secondary distribution network

8.1 Introduction

In the previous chapter, a case study was used to test the findings of the initial stages of this PhD. In order to do that, 'extra distance' as measure has been developed. That case study was based on data collected in a UK logistics provider that operates the primary distribution network of a FMCG customer. An 'extra distance' assessment has been developed and tested in that case study. However, in order to improve its validity, the 'extra distance' assessment needs to be tested further in another FMCG supply chain. Time as a dimension of performance is as important as distance. Therefore, an 'extra time' assessment to quantitatively evaluate the risk that delays represent to the supply chain will be shown. Therefore, the objective of this chapter is to quantitatively evaluate the consequences of different uncertainty causes, using the 'extra distance' measure applied in the previous chapter and complement that assessment by also including 'extra time'. This case study introduces the definition of 'extra time'. The assessment has been undertaken by combining two measures, 'extra distance' and 'extra time'. In chapters 8 and 9, a combined assessment of 'extra distance' and 'extra time' has been undertaken to assist the author in achieving the sixth objective of this PhD to:

Develop a decision-making tool, based on a combined assessment of 'extra distance' and 'extra time', for the diagnosis of the effects that different causes of uncertainty have on the performance of road freight transport operations, in terms of cost and CO₂ emissions.

In order to achieve this objective, a case application from the FMCG sector based in South Africa is used.

The chapter proceeds by briefly introducing the case study company. Following that, the method applied to undertake the research is explained. Subsequently, the findings are outlined. Also, the existent connections between uncertainty and risk and 'extra distance' are explicitly drawn. Finally, the chapter is concluded by

highlighting the managerial implications and limitations of the research and contribution to knowledge of the chapter.

8.2 Case study context

In this case study, the 'extra distance' measure has been put in practice to the secondary distribution network of a South African FMCG customer, shown schematically in Figure 8.1. The customer has over 200 outlets throughout South Africa, serviced by a network of three distribution centres (DCs) located in Johannesburg, Cape Town and Durban. The transport operations within this network are outsourced to a third party provider and, during data collection, the researcher was based in this company. However, the warehousing function and the customer outlets are operated by the customer. This logistics provider is the sole organisation involved in secondary distribution, as well as being responsible for a small proportion of primary distribution movements. The secondary distribution section of this logistics provider, which sits between DCs and the customer, was selected for the case study. The assessment of 'extra distance' and 'extra time' was undertaken in the Johannesburg and Cape Town DCs, which represent about 90% of the transport movements of the whole network.

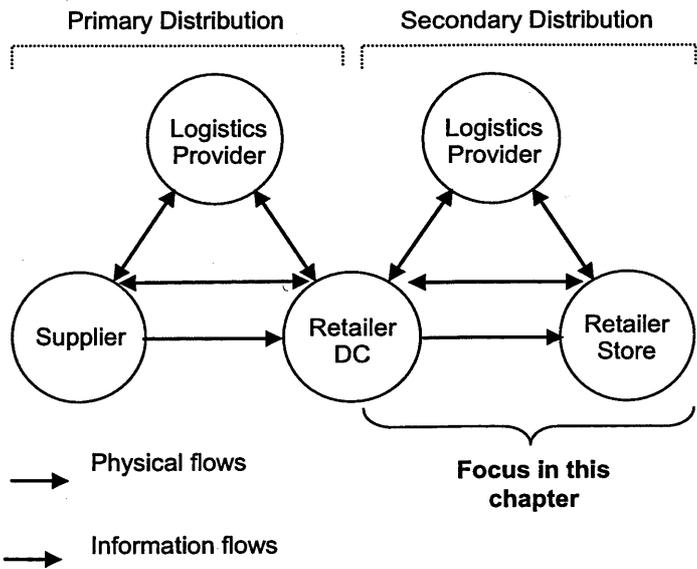


Figure 8.1 Logistics provider position within South African FMCG secondary distribution network

The transport planning process is almost fixed and dictated by the FMCG customer. On the day before the execution of the plan, the transport manager of the DC run by the customer gives the logistics provider the extra trips required due to increases in volume and operational problems at the DC. Following that, the logistics provider adds extra vehicles to the fleet available to achieve the original transport plan. In this distribution network, product availability and on-time deliveries to customer outlets are considered more important than vehicle utilisation.

There are a number of reasons why this particular case was chosen:

- The 'extra distance' measure was developed in the context of UK operations and so an international comparison aids generalisation
- While similar logistics challenges exist between, for example, European countries, additional challenges unique to South Africa/developing countries may create different causes of uncertainty (King 2008)
- By looking at the FMCG retail sector, comparisons with UK case study applications are possible.

8.3 Method

As in the first case study, in order to undertake the 'extra distance' assessment in this secondary distribution network from South Africa, the principles of the case study method have been applied, since the tool needed to be tested in a different distribution network. The unit of analysis of this case study is a FMCG retail secondary distribution operation. This operation was chosen since the objective was to test the 'extra distance' measure in another logistics context, so the validity of the measure can be confirmed. Furthermore, a secondary distribution network was selected, since after developing the 'Extra distance' measure in a primary distribution network, the measure needed to be tested also in secondary distribution networks.

In the planning stage of the case study, the findings from the first case study were presented to the logistics provider's management staff in a teleconference meeting. The main objective of this meeting was to set the planning of the case study and decide the scale and scope of the project. Also, another objective of this meeting

was to present the 'extra distance' measure to the practitioners from the company, so they could evaluate the suitability of the measure in their operation. As noted earlier, the customer has three secondary DCs in South Africa. However, in order to keep the project on a realistic scale, a decision was made to concentrate on the two larger DCs, in Johannesburg and Cape Town. In order to maximise the time spent in South Africa, during the data collection, the author was assisted by another researcher from the South African CSIR, and a supply chain analyst from the case study company.

In addition, a number of managers from the secondary distribution operation studied were constantly validating the data collected. Firstly, the operation managers in both of the DCs were validating the data collection on a daily basis. Moreover, after collecting the data in Johannesburg, a presentation with the initial findings was delivered to the management board of the company and other key operational staff from the Cape Town DC. The reason for this constant validation of the data was to ensure that the data collected reflect the realities of the operation, so the final results could be used for setting future improvement initiatives within the logistics provider and at a supply chain level.

The 'extra distance' data used for the analysis was gathered in the last two weeks of January 2009. Due to the fact that the company had archival data available, the week commencing 5th January 2009 was selected. As in the first case study, this period was considered by the company staff as a typical or average week that fairly represents what happens over a twelve-month period. Also, as in the first case study, the sampling strategy applied in this study was attribute-based sampling, since the main objective was the same, to find incidents generating 'extra distance'.

All incidents that generated 'extra distance' were identified from the company historical reports and input into an Excel spreadsheet. The role of this Excel spreadsheet was to determine the main causes of 'extra distance'. In the study, there was a particular interest in determining the causes of 'extra distance'. Therefore, the frequency and impact of each of the 'extra distance' causes could be quantified. As in the first case study, a risk assessment was undertaken to support the decision

makers in evaluating the 'extra distance' causes found in terms of their relative priority.

The data collection approach is based on archival data. Although the same data was collected overall, different reports were used for each DC. In the Johannesburg DC, two reports were used to gather the 'extra distance' data. One of them was the additional volume report, which summarised the extra trips run due to short-noticed volume increases. The other report used was the one that summarised the extra trips run due to operational failures at the DC, stores and within the delivery process. In the Cape Town DC, the data was gathered from a single report, which summarised the service levels and delivery performance for the operation. The differences in terms of how the two DCs record transport performance data did not affect the data collected for the case study, since the final data gathered for the 'extra distance' assessment was arranged in the Excel spreadsheet, so performance data was transformed to 'extra distance' data, taking account of how the two secondary distribution operations record performance data. In this process, the researcher had the support of the operation managers.

As in the first case study, detailed information about the trips that caused 'extra distance' was gathered; this information included: store location, kilometres run, 'extra distance' source, visible cause and root cause. In this chapter, 'extra distance' is calculated in kilometres. This information was gathered from a daily report that specifies all the additional trips, so the pro-forma used to collect the data in the first case study (see Appendix 3) was not used in this case study. The Excel spreadsheet presented in Appendix 5 was used to calculate the 'extra distance' generated by every incident identified and categorise all the incidents depending on their causes. In the spreadsheet, the number of 'extra distance' generated by each uncertainty cause was calculated. The extra kilometres generated by every 'extra distance' incident gathered were estimated by using Google maps. The relative accuracy of Google against Paragon and AutoRoute has been estimated in Chapter 7 (see Table 7.1). The cost of every incident of 'extra distance' was calculated by multiplying the cost per kilometres that the logistics provider charges their customer, which is 29.67 ZAR per kilometres. Also, the kg of CO₂ emitted due to every incident of 'extra distance' was calculated by multiplying the 'extra distance' generated by every 'extra

distance' incident by the average fuel consumption in the week of data collection (0.37 lt per Km), provided by the logistics provider, and the road freight transport conversion factor for diesel recommended by Defra (2007), 2.63. Also, the cost of delays was calculated by multiplying the 'extra time' generated by every incident of 'extra time' by the labour cost per extra hour (60.5 ZAR per hour) provided by the operation.

Furthermore, as in the first case study, a risk assessment of the different 'extra distance' causes found was undertaken, so the probability and impact of each 'extra distance' cause were calculated. Similarly to the first case study, due to the fact that an accurate telematics system was not available in the logistics provider, the impact and probability of unplanned road congestion on planned trips and on extra or extended trips could not be estimated.

In addition, while conducting the data collection to evaluate the different 'extra distance' causes, the existent causes of 'extra time' in terms of delays within the delivery process were also recorded. This was done by gathering information about all the delays that occurred at the operations of the DCs during the same week of data collection. This information was gathered from a management report at the two DCs. The information includes the causes of delays and impact of the delays in terms of time.

To understand more about the root causes of 'extra distance' and the causes of 'extra time', informal interviews and discussions were held with managers and transport planners within the secondary distribution operations, both from the logistics provider and the customer. These discussions also helped to confirm the validity of the exercise.

After finishing the analysis, a feedback presentation was delivered to the management board of the logistics provider. In that meeting, all the managers validated the findings. From their perspective, this presentation represents a starting point towards identifying the potential mitigation strategies to reduce 'extra distance'.

8.4 Results and analysis

In this section of the chapter, the overall results of the data collection will be presented first (Table 8.1). This includes the two secondary DCs involved in the study. After that, the impact of the causes of 'extra distance' will be discussed, highlighting their potential root causes. Subsequently, a risk assessment of all the causes of 'extra distance' found will be shown.

	Johannesburg	Cape Town	Overall
Km run	172,000	35,000	207,000
'Extra distance' (km)	11,538	1,605	13,143
Cost (ZAR)	342,332	47,620	389,952
Kg of CO2	11,228	1,562	12,789
% of 'Extra distance'	6.71	4.59	6.35
'extra time' (hr)	63	4	67
Cost (ZAR)	3,812	242	4,053
% 'extra time'	0.86	0.24	0.74

Table 8.1 Overall impact of 'extra kilometres on the two South African secondary DCs

During the week of data collection, 6.71% of the kilometres run within the secondary distribution network studied were 'extra distance'. A total of 90 incidents of 'extra distance' were recorded during that week, which represents approximately 4.28% of the total number of trips run in that period. Even though the total 'extra distance' found is 6.35%, it still represents a substantial monetary value for the logistics provider studied. The cost of this is estimated to be ZAR 390,000 (£29,000). More specifically, this cost can be decoupled into variable and fixed costs. The fixed cost is ZAR 328,000. The total 'extra distance' gathered in the week of data collection represents 20,591 Kg of CO₂ emissions. This is due to the fact that if 'extra distance'

does not occur, the required fleet could be smaller than the current fleet. The variable cost is ZAR 63,000 and is related to the running cost of the vehicles.

In addition, during the week of data collection, there were several 'extra time' incidents, in the form of delays that did not cause 'extra distance', but still impacted on the variable cost of transport. In total, there were 67 hours of delays within the delivery process. Economically speaking, these delays impact only on the variable transport cost (the running cost of vehicles), since they do not generate extra trips. Nevertheless, they still increase the labour cost. The 'extra time' found during the week of data collection represents 0.74% of the total running time of the whole fleet and an extra cost of ZAR 4,053 (£310). Hence, in this case study, when 'extra time' does not generate 'extra distance', it does represent a relatively much smaller economic impact.

In the remainder of this section, more in-depth insights from the analysis will be discussed.

8.4.1 Main causes of 'extra distance'

As Table 8.2 depicts, the four causes of 'extra distance' found during the data collection are 'product not loaded', 'late notification of extra volume to be moved', 'physical load smaller than advised' and 'planning failures'. Table 8.2 has been drawn based on Table 7.2 (see Chapter 7). From these four causes of 'extra distance', 'product not loaded' at DCs is the one that generated most of the 'extra distance' gathered and 'late notification of extra volume to be moved' also generated a very significant amount of 'extra distance'. These two 'extra distance' causes represent about 90% of the 'extra distance' found and 84% of the number of 'extra distance' incidents observed in the data collection.

'Product not loaded' at DCs was the main cause of 'extra distance' recorded in the study. As shown in Table 8.2, 41% of the incidents gathered and 50% of the 'extra distance' recorded was caused by this issue. According to the staff involved in the data collection, this 'extra distance' cause is originated in the picking process at the two DCs. The DCs are operated by the customer rather than the logistics provider.

Picking delays occur due to the fact that there are insufficient staff members for picking and sorting products.

'Extra distance' type	'Extra distance' Cause	Extra Distance (%)	
Extra distance due to route diversion	Unplanned road congestion	Not measured	
Extra distance/trips due to delays	Loading delays at shippers	No incidents found	
	Unplanned road congestion	No incidents found	
Extra distance/trips due to load more than advised	Late notification of extra volume to be moved	40	43
Extra distance/trips due to load less than advised	Physical load smaller than advised	6	8
Extra distance/trips due to inappropriate vehicle size	Technical vehicle failure	No incidents found	
Not considered	Planning failure	4	8
	Product not loaded	50	41
	Product mis-loaded	No incidents found	

Table 8.2 Overall impact and frequency of the different 'extra distance' causes found in the South African secondary distribution network

'Late notification of extra volume to be moved' was the second most important 'extra distance' cause found. It represents 40% of the total 'extra distance' generated in the week of data collection. Furthermore, it was the most frequent cause of 'extra distance' gathered, with 43% of a total of 90 incidents of 'extra distance' observed. According to the logistics provider's staff, this issue primarily occurs because the forecast of volumes is not sufficiently accurate.

The other two causes of 'extra distance' found are 'physical load smaller than advised' and 'planning failures'. The first represents 6% of the total 'extra distance' and the second is 4% of the 'extra distance' recorded. These two 'extra distance' causes were found in the Cape Town operation only. In Cape Town, the transport planning process is undertaken by the customer instead of by the logistics provider. In Cape Town DC, the planned volumes are more than the actual volumes, since the

customer over-plans the resources to have more flexibility during the delivery process. However, the fact that the retailer creates an artificial need for spare capacity has a knock-on effect on vehicle capacity utilisation. There are between 3 and 6 vehicles a day that have less than 30% capacity utilisation. Therefore, the transport network could be better optimised if forecasted volumes were more accurate.

'Planning failures' occur primarily due to the fact that the vehicle size is less than planned because of breakdowns of vehicles returning from store deliveries. When there is a breakdown of a vehicle and only a smaller vehicle size is available, there is the need to use two vehicles instead of one. However, vehicle size less than planned represents only 4% of the total 'extra distance' found.

8.5 'Extra time' as a measure to evaluate delivery time reliability

Due to the fact that secondary distribution operations tend to be very sensitive to delays, the researcher perceived a need to measure the amount of unnecessary time that is generated during the delivery process due to uncertainty. In many cases, 'extra distance' and 'extra time' have a significant impact on the performance of road transport operations. Delays can occur in the execution of the transport plan and also there could be 'extra distance' generated in a previous delivery cycle. Moreover, unplanned road congestion can either delay the vehicle or add 'extra distance' to the optimal route originally planned for the trip. Therefore, when road freight transport operations are significantly sensitive to these two dimensions of transport performance, the assessment should include both. Also, when archival data is available to undertake a combined time-and-distance assessment, this opportunity should be taken to demonstrate which of the two dimensions are more important.

By applying a combined time-and-distance assessment, a holistic analysis of the impact that different causes of uncertainty have on road freight transport performance can be undertaken. In this way, the potential tradeoffs within road transport operations between the time and distance dimensions of performance can be clarified.

Simons et al's (2004) OVE assesses different dimensions of the delivery process. However, the application of this measure can prove difficult in a road transport environment, since it combines factors that are very complex to measure at the same time. According to the focus group and survey findings, delays in the delivery process are the main cause of uncertainty in transport operations. However, the marginal impact of different causes of delays on the economic performance of transport operations needs to be examined. Previously, other researchers have evaluated the different causes of delays using the survey method to assess the delivery process of the grocery retail sector (Fowkes et al 2004; McKinnon and Ge 2004). They have measured delays in terms of the extent to which vehicles arrive late to their loading and/or unloading destinations relative to the delivery windows that have been set to them in the transport schedule. In this PhD, unnecessary time is measured from the time vehicles depart for their destination up to when vehicles arrive back at their distribution centres. In this way, uncertainty can be connected to extra cost in terms of extra driver labour cost. Hence, 'extra time' is defined as:

Any additional or unnecessary time used in the delivery process that is a consequence of disruptions that can occur from the time that products are manufactured and loaded to the moment the products are received at the destination that requested them in the first place

Table 8.3 shows all the types of 'extra times' found in the literature and the focus group stage of this research project. According to the conceptual model and focus group findings, 'extra time' can be originated due to a number of reasons. These causes are:

Type of 'extra time'	Example of uncertainty cause from literature
'Extra time' due to unplanned road congestion	Unplanned road congestion (Boughton 2003)
'Extra time' due to delays at loading bays	Loading delays at shippers (Geary et al 2003)
'Extra time' due to delays at unloading bays	Unload time uncertainty (Esper and Williams 2003)
'Extra time' due to internal transport failures	Transport delays due to internal reasons e.g. defective vehicle or lack of driver (Mason et al., 2003)

Table 8.3 Types of 'extra time' and potential causes

8.5.1 Unplanned road congestion

When a traffic jam occurs, either due to an accident or unexpected road works, the vehicle usually does not have time to divert from the optimal route selected in the transport plan. Thus, load arrival at the destination is delayed. Transport operations usually mitigate this by using real time information of the delivery process monitoring deliveries throughout the day with track-and-trace systems. In addition, transport operations include a slack on their delivery time based on DfT data on the average speed on every UK road and the standard deviation of these speeds.

8.5.2 Delays at loading bays

There can be two sorts of delays at loading bays, those that occur at suppliers and those that occur at distribution centres. Products can be delayed at supplier facilities due to production delays and also due to queues at loading bays. Usually when there is a delay at loading bays, a trade-off arises on holding the vehicle or scheduling an extra trip for loads left behind. When the vehicle is held, there is an impact on cost in terms of staff upstream in the supply chain, including warehousing and transport staff, and there could also be an economic cost for not having the product on time at the store shelf.

8.5.3 Delays at unloading facilities

There are two types of delays at unloading bays, those that originate at distribution centres and those that originate at the customer outlets. When product is delayed at a distribution centre usually is because of the fact that the vehicle is waiting for other vehicles to be unloaded, but sometimes, delays at distribution centres happen due to lack of staff at distribution centres when the vehicle needed to be unloaded. At customer outlets, delays occur due to insufficient staff for unloading the product. When the vehicle is held, there is an impact on cost in terms of staff upstream in the supply chain, including warehousing and transport staff,

8.5.4 Internal transport failures

Internal transport failures, such as planning errors and technical vehicle failures, can originate a delay within the delivery process. This type of delay can occur before the vehicle starts running, when the vehicle is on the road, and when the load is dropped at its destination. This type of delay can increase the variable cost of transport in terms of staff extra hours.

8.5.5 Main causes of 'extra time'

As Table 8.4 shows, the three causes of 'extra time' gathered during the data collection are 'delays at DCs', 'delays at stores' and 'transport failures'. These causes of 'extra time' were recorded in the Excel spreadsheet that is shown in Appendix 6. 'Delays at DCs' are the cause that generated most of the 'extra time' gathered. This 'extra time' cause represents about 62% of the 'extra time' found and 71% of the number of incidents of delays observed in the data collection. According to the staff involved in the data collection, this 'extra time' cause is due to either insufficient staff and/or excessive queues at the distribution centres.

Delays originated at customer outlets is another significant 'extra time' cause recorded in the study. As depicted in Table 8.4, 3.15% of the incidents gathered and 19% of the 'extra time' recorded was generated by the customer outlets. The root cause of this issue is that there is insufficient staff for unloading at customer outlets.

'Transport failures' was the other cause of 'extra time' found. These represented 19% of the total 'extra time' generated in the week of data collection. In addition, it was the less frequent cause of 'extra time' collected, with 14% of a total of 71 incidents of 'extra time' found. According to the logistics provider's staff, this issue occurs due to two reasons. The first is failures in the vehicles that delay the delivery process. The second is lack of coordination within the distribution network, so the vehicle scheduled is not available at the loading time.

'Extra time' type	'Extra time' Cause	'Extra time' (%)	Frequency (%)
'Extra time' due to unplanned road congestion	Unplanned road congestion	Not measured	
'Extra time' due to delays at loading bays	Delays at DCs	62	71
'Extra time' due to delays at unloading bays	Delays at stores	19	15
'Extra time' due to internal transport failures	Transport failures	19	14

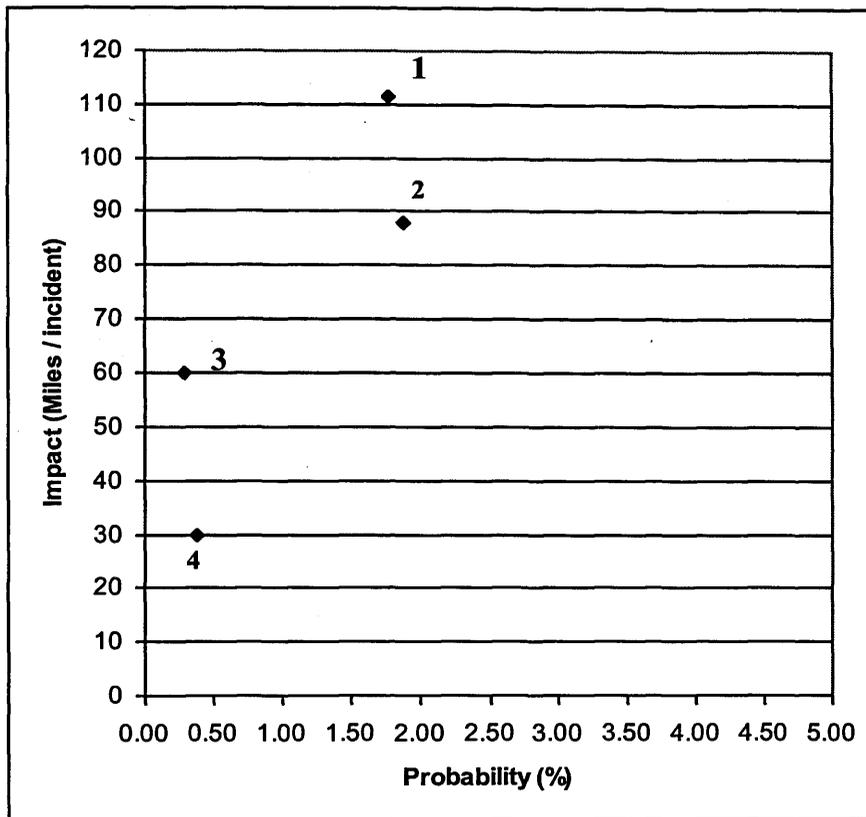
Table 8.4 Overall impact and frequency of the different 'extra time' causes found in the South African secondary distribution network

Due to the fact that the impact of 'extra distance' found in this case study is 100 times greater than the impact of 'extra time', in the next section of the chapter, only the risk associated with 'extra distance' will be estimated and presented.

8.5.6 Risk assessment of 'extra distance' causes

In order to assess the relative importance of all the 'extra distance' causes, the risk of all them has been calculated as function of impact and probability. Figure 8.2 shows the impact and probability of the four 'extra distance' causes found in the data collection.

As Figure 8.2 depicts, 'product not loaded' at DCs and 'late notification of extra volume to be moved' have relatively high impact and medium probability. A 'product not loaded' at DCs occurs on average just over 110 extra kilometres and occurs about 1.85% of the time, or to be more specific, approximately five times a day. Therefore, this 'extra distance' cause needs to be closely monitored and controlled. Also, in order to reduce this 'extra distance' cause, the logistics provider and the retailer should evaluate the process of picking and sorting of products, especially within the Johannesburg DC.



No	'Extra distance' cause
1	Product not loaded
2	Late notification of extra volume to be moved
3	Physical load smaller than advised
4	Planning failure

Figure 8.2 Risk assessment of 'extra distance' in the South African FMCG secondary distribution network

A late notification of extra volume from the customer originates just over 85 extra kilometres and happens around 1.75% of the time, or about 5 times a day. Therefore, the logistics provider needs to concentrate on it in order to reduce 'extra distance'. This issue is caused by inaccuracy of volume forecast by the customer, hence in order to minimise it, the customer needs to revise their product demand forecast process.

As shown in Figure 8.2, according to the assessment, 'physical load smaller than advised' occurs less than once a day (with a probability of about 0.29%) and generates about 60 extra kilometres per incident. Therefore, this 'extra distance'

cause is of medium priority, which means that the logistics provider should not focus on it in the initial stage of any 'extra distance' reduction programme, but it should be considered at a later stage. In order to mitigate this cause of 'extra distance', the transport planning process at the Cape Town DC requires revision.

The other 'extra distance' cause evaluated in this risk assessment exercise is vehicle size less than planned. This happens approximately once a day (with a probability of 0.39%) and generates 30 extra kilometres per incident. Therefore, in order to reduce 'extra distance', the logistics provider should focus on the other 'extra distance' causes found in the data collection.

According to the risk assessment undertaken, the logistics provider should focus on better monitoring and control of the volume demand forecast. However, due to the fact that the customer is in charge of the product demand forecast and the operation of the two DCs, the customer has an essential role to play in the reduction of these two 'extra distance' causes.

8.5.7 Linking 'extra distance', uncertainty and risk

As in the previous chapter, the causes of uncertainty observed in the case study have been categorised according to the framework presented in Chapter 5. In some cases, the uncertainty arises from more than one source. These are then mapped against the uncertainty causes observed in the case study. In order to assess the relative importance of all the uncertainty causes found, the cost and CO₂ emissions generated by the 'extra distance' and/or 'extra time' generated by them have been calculated, as can be seen in Table 8.5. To link uncertainty with 'extra distance' and 'extra time', three different categories have been identified. These categories are considered in Figure 8.3 by increasing the thickness of the arrows that connect uncertainty causes with uncertainty clusters.

Extra distance' type	Uncertainty causes	'Extra distance' due to extra trips (Km)	'Extra time' due to delay (hr)	Cost (£)	Kg of CO2	Priority category
Extra distance due to route diversion due to	No measured					
Extra distance/ trips caused by	Store		41.54	2,513		C
	Suppliers		12.73	770		C
	Carrier		12.73	770		C
Extra distance due to load more than advised due to	Late notification of extra volume from stores	6,648		197,246	6,469	A
	Physical load smaller than advised	385		11,423	375	B
Extra distance / trips due to inappropriate vehicle size due to	Planning failure	580		17,209	564	B
Other	Product not loaded at distribution centres	5,530		164,075	5,381	A
Total Cost (£)		389,953	4,054			
Total CO2 (Kg)		12,789				

Cost (£/Km)	29.67
Labour cost (ZAR/hr)	60.5
Average Fuel Consumption	0.37
Defra factor	2.63
Conversion to Kg of CO2	0.973

Table 8.5 Cost and CO2 of uncertainty causes

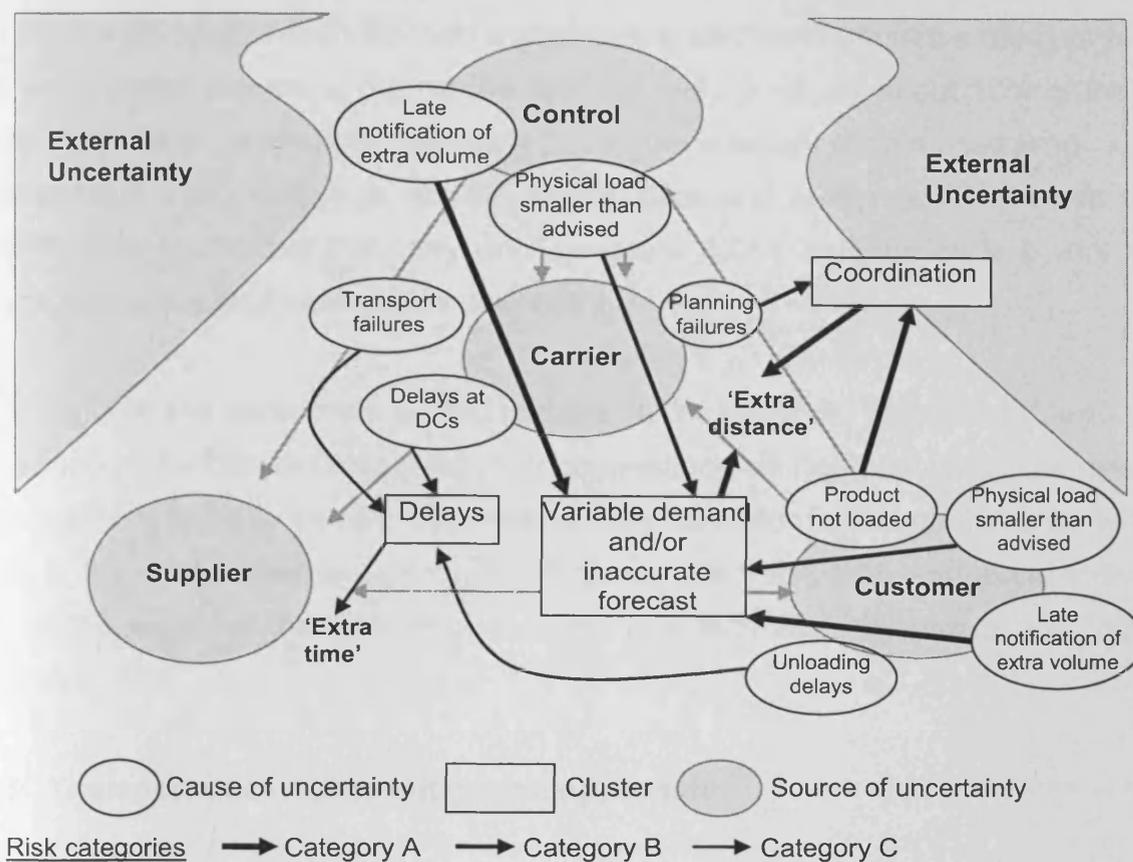


Figure 8.3 Link between uncertainty, risk and 'extra distance'

As depicted in Figure 8.3, it can be observed that the research suggests that operational issues tend to be generated to a greater extent at the customer and control systems rather than at the carrier. Lack of coordination at the DCs managed by the customer is the major supply chain uncertainty found in this case study. Frequently, products are not loaded on time for the deliveries due to insufficient staff for picking and sorting at the DCs, so this issue generates a sheer volume that needs to be moved by the carrier the next day and as a consequence, extra cost and CO₂ emissions are generated. Variable demand and/or inaccurate forecast in the form of 'late notification of extra volume to be moved' is recorded as the customer and control systems uncertainty sources because the volume forecast process is one of the control systems of the whole supply chain. If it is tightly integrated, volumes could be more accurate. However, other issues relating to the size of load are more focused upon how the customer manages the volumes at distribution centres. This issue generates unnecessary cost and CO₂ emissions as well.

Physical load smaller than advised and planning failures represent a medium priority for the logistics providers, due to the fact that they generate about 10% of the total cost and CO2 emissions generated by uncertainty events gathered in the assessment. Also, delays at stores, at suppliers and at the carrier present a low priority, due to the fact that they only generate 4,054 ZAR, which is a very small proportion of the total cost due to uncertainty.

It is important to state once again, that the 'extra distance' generated due to route diversion in the form of unplanned road congestion was not measured. The research has currently failed to identify any links to route diversion, although this is likely to be due to the data collection approach which did not track each and every individual trip, on account of the lack of an appropriate telematics system at the logistics provider.

8.6 Transport uncertainty mitigation approach

Table 8.5 shows the approaches that the logistics provider uses to prepare for and mitigate uncertainty and the context in which their business is influenced by their behaviour towards uncertainty. For the customer, it is much more important to ensure that the products are available at the customer outlets at all times than to keep the transport cost down. As in the previous case study, distribution centres are cross-docking operations rather than inventory holding operations. Moreover, the logistics provider considered service far more important than cost, due to the fact that in South Africa the labour cost and the fuel cost are comparatively lower than in the UK. The fixed cost of transport is as high in South Africa as in the UK; this is primarily due to the fact that vehicles are imported from Europe or Asia to the UK and South Africa. Hence, the target vehicle capacity utilisation through the fleet is 55%, so, in the case of demand uncertainty, extra volume can theoretically be allocated within spare capacity of originally planned trips. However, that does not occur since the customer imposes very tight and rigid delivery windows on the logistics provider.

In addition, the fact that the vehicles are owned by the logistics provider is a driving factor in the uncertainty mitigation approach that is applied in this secondary

distribution network. However, the customer pays a fixed sum of money weekly to cover the fixed cost of vehicles and to ensure that vehicles are available for their operation. Additionally, the customer is charged the variable cost of the trips after the outlets receive the volumes.

On each planning day, the customer needs to send all their final and confirmed volume requirements by 07:00 am on the day outlet drops are executed. In addition, the secondary distribution centres drive volume movements between them to optimise the movements within the network and minimise empty miles. The transport plan is very rigid, so any changes due to uncertainty are added on top of the transport plan with extra vehicles. The customer imposes very tight time windows on the deliveries. Furthermore, delivery windows of outlets located at close proximity one to another are at different times of the day. The transport plan is fixed every day of the week and extra trips are added to this transport plan approved by the customer. All the transport planning and re-planning activities are undertaken in Excel.

If an extra load is generated due to operational failures within the logistics triad and/or due to volume increases from customer outlets, the transport planners first check in the transport plan whether there is space available within a vehicle or a number of vehicles that have spare capacity within originally planned trips. However, the transport planner very often decides to add a new vehicle due to the fact that delivery window restrictions imposed by the customer make it very difficult for the planner to find a planned trip with spare capacity that is scheduled for a drop in a store located within the area where and when the extra volume is needed.

It is important to highlight that 'extra distance' generated by the customer is paid by the customer. In the secondary distribution network studied, 90% of the 'extra distance' found is generated by the customer. Thus, the logistics provider very often receives an economical benefit when 'extra distance' is generated within the network. Also, it is important to note that delays do not generate 'extra distance', but cause 67 hours of 'extra time'. This is because of the fact that in the case of delays, the scheduled trip, which a delayed vehicle has to make, is re-allocated to another

vehicle, and when the delayed vehicle arrives the load originally allocated to the other vehicle is re-allocated to the delayed vehicle.

Customer main targets	Product availability	High priority
	Transport cost	Medium priority
Cost factors	Labour cost	Low
	Fuel cost	Medium
	Fixed cost	High due to import and also health and safety, vehicles are replaced every three years
Cost structure	Vehicle ownership	The logistics provider, but customer pay an amount at front to have vehicle available
	Fixed cost paid by	Paid by customer in front
	Variable cost paid by	Paid by customer when trip is completed
Transport planning	Daily deadline	Fixed transport plan, extra trips are received from the customer at 07:00 am
	Volume requirements driven by	Distribution centres
	Flexibility	Rigid, any changes are added with extra vehicles. Customer imposes time restrictions on the stores
	Vehicle capacity utilisation	55%
	Fleet ownership	Logistics provider
	Transport plan	Fixed transport plan in Excel, the operation manager take the decision to fit the extra trips into the transport plan
Response to uncertainty	Capacity available in transport plan?	Capacity utilisation is not the main target, customer imposes a considerable degree of restrictions in the delivery windows at unloading bays of stores
	Proximity of the load?	If the additional load is more than 200 kilometres away, a supplier is integrated into the trip
	Who will run the extra trip?	Always the logistics provider, but vehicle can be provided by other fleet from other operation within the group the logistics provider belongs
	Route re-optimisation	Due to the restricted time windows of store deliveries, there are not multi-store drops, usually single deliveries
	Who pay for the load?	The entity that is generating the extra kilometres
	Monitoring	There are two reports that summarise the extra trips due to late notification of volume increases and product left over at distribution centre

Table 8.6 How the logistics provider mitigates uncertainty

8.7 Managerial implications

Although the case study presented in this chapter is a logistics provider from South Africa, the research has identified a number of opportunities to other transport operations within South Africa and other countries. From this, it is possible to identify some generic managerial implications. The chapter has highlighted the importance of measuring the impact that uncertainty has on transport performance. Previous research has primarily focused on proposed transport time-based performance measurement tools. However, from a transport operation perspective, it is equally important to measure transport performance in terms of distance. In this case study, 'extra distance' and 'extra time' have been measured. The results of this combined assessment show that 'extra distance' in this case study is much more important than 'extra time'. This is due to the fact that 'extra distance' impacts on the variable and fixed cost of transport, whereas 'extra time' only impacts on the variable cost of transport.

The combined time-and-distance assessment applied in this case study can be used as a diagnostic tool in other transport operations, especially within the FMCG sector. In that way, a more explicit link between uncertainty and transport performance could be made. Furthermore, the assessment has informed future decision making within the logistics provider studied.

In addition, 'product not loaded' at DCs generate about half of the 'extra distance' found. In the supply chain studied, the transport operation is run by the logistics provider and the warehousing operation is run by the customer. This can be regarded as a significant barrier between these two supply chain functions. Therefore, both companies need to review the warehousing process to improve the coordination between the DCs and the transport network. Moreover, due to the fact that about 40% of the 'extra distance' found are generated by 'late notification of extra volumes', the customer needs to evaluate the process of volume forecast from the stores to the logistics provider.

One issue that needs addressing is that in order to reduce 'extra distance', there is a need for the logistics provider to actively engage with the customer (as the shipper

and receiver of the products), and that while there are overall supply chain benefits, these may not be evenly distributed between the two parties.

8.8 Concluding remarks

This chapter presents a combined tool that applied the 'extra distance' and 'extra time' measures to assess road transport functions within distribution networks. As in the previous chapter, the 'extra distance' measure can be applied to assess the efficiency of road transport operations in terms of distance, or more specifically in terms of unnecessary vehicle usages and fuel consumption. However, it is also important to comparatively assess the impact of 'extra time'. In this particular case study, 'extra distance' has 100 times more impact than 'extra time'. This is due to the fact that only 'extra distance' impact on the fixed cost of transport and also because of the fact that in South Africa labour cost represents a much smaller proportion of the overall transport cost than in the UK.

According to the results of this study, in this South Africa-based secondary distribution network, 6.35% of the total kilometres run are 'extra distance'. The two main 'extra distance' causes recorded are 'product not loaded at DCs' and 'late notification of extra volume to be moved'. Jointly, they represent approximately 90% of the 'extra distance' found. In addition, the assessment of the four causes of 'extra distance' has been carried out by calculating the risk that they represent, in terms of their probability and impact. In order to reduce 'extra distance', the logistics provider needs to find a mechanism to encourage the customer to improve their warehousing processes and their volume forecast process. Due to tight and rigid delivery windows imposed by the customer, the transport planning process is very rigid and very often the logistics provider responds to uncertainty by adding extra trips to the transport plan.

It is important to note that, because most of the opportunities of reducing 'extra distance' found are generated by the customer, it is the customer who will be the entity that can achieve most of the economical benefits, and conversely, any reduction of 'extra distance' will represent a reduction in revenue for the logistics provider. This is a point found in the case study presented in Chapter 7 as well and

means that, when a logistics provider plans, manages and runs the distribution network, in order to achieve any reduction of 'extra distance', the logistics provider's customer needs to find a mechanism to share the benefits with the logistics provider.

As mentioned in the previous chapter, before initiating any 'extra distance' reduction programme, the logistics provider should measure 'extra distance' for a longer period of time. The results of this study are based on data collected over a fairly average week. Therefore, the outcome of this exercise should inform future decision making. However, it is necessary to repeat the exercise in order to confirm the recurrence of the findings.

Up to this point, the 'extra distance' as a measure has been developed and tested in two FMCG distribution networks, one UK-based primary distribution network and one South Africa-based secondary distribution network. Moreover, due to the fact that 'extra time' could be of significant importance in secondary distribution operations, the assessment undertaken in this case study also includes 'extra time' as a measure. The validity of the combined time-and-distance assessment requires further testing in another secondary distribution network from the UK. Furthermore, data on the effect that unplanned road congestion has on 'extra time' and 'extra distance' will be included on the analysis undertaken in the secondary distribution operation from the UK.

8.9 Contribution

To methodology in logistics research

The chapter shows that when there is archival data of the effect of different types of uncertainty on transport performance, it is possible to collect data from different distribution centres within the same secondary distribution network. Also, the chapter demonstrates how a quantitative assessment of uncertainty can be undertaken by deciding the data collection approach with the practitioners that manage the operations prior to starting data collection. The case study identified data sources that could be used for the assessment. In addition, it demonstrates how quantitative findings can be complemented by interviews with the decision makers from the operation. Also, the chapter includes the 'extra time' as part of the assessment and

shows how uncertainty can be evaluated in terms of time and distance in one assessment.

To the PhD

In this chapter, the 'extra distance' assessment applied in the previous chapter has been improved by measuring 'extra time' in terms of delays. Furthermore, the application of the tool in a secondary distribution network from another country shows the differences between UK and South African operations, and how the tool can be implemented in different networks in the world, not only in the UK. The application of the tool in this secondary distribution network is a foundation for the third case study, where a combined assessment of 'extra distance' and 'extra time' will be applied in a UK secondary distribution network.

To the topic

In this chapter, a FMCG secondary distribution operation from South Africa has been studied to show how the different causes of uncertainty can be evaluated in this type of operation. Variable demand and/or inaccurate forecast and lack of coordination represent 90% of the 'extra distance' gathered during the data collection. They are two of the main uncertainty clusters found in earlier stages in the research. The findings of this chapter can be used to compare the effect of uncertainty on FMCG transport operations in South Africa and the UK.

9.0 Diagnosis of 'extra distance' and 'extra time' in a UK FMCG secondary distribution operation

9.1 Introduction

In the previous chapters, two case studies were applied to test the findings of the initial stages of the PhD at the micro level. In order to achieve that, 'extra distance' as measure was first developed and subsequently tested in the two case studies. These two case studies were based on data collected in two logistics providers that manage and run two different distribution networks, the primary one from the UK and the secondary one from South Africa. In both cases, the effect of unplanned road congestion on 'extra distance' and 'extra time' could not be measured on every trip planned by the logistics provider. Therefore, the aim of this chapter is to quantitatively evaluate the consequences of different uncertainty causes, using the 'extra distance' measure applied in the previous chapter and complementing that assessment by also including 'extra time'. This assessment will also consider route diversion generated due to unplanned road congestion. In order to achieve this aim, a UK FMCG secondary distribution network was studied.

The chapter proceeds by briefly presenting the case study company. Subsequently, the method applied to conduct the case study is discussed. Following that, the findings from the assessment are outlined. Also, the existent connections between uncertainty and risk and 'extra distance' and 'extra time' are explicitly drawn. Moreover, a section on the tools applied by the case study company to mitigate uncertainty will be included to link the results of the survey in previous chapters and how the case study company mitigates uncertainty. Finally, the chapter ends by highlighting the managerial implications and limitations of the research and the contribution to knowledge of the chapter.

9.2 Case study context

In this case study, the 'extra distance' measure has been applied to the UK secondary distribution network, depicted in Figure 9.1. This secondary distribution network is managed and run entirely by one of the biggest FMCG companies in the

UK. They have a considerable number of secondary distribution centres within the UK. This network includes 172 locations most of which are outlets (about 89 outlets, 59 suppliers and 24 distribution centres). Outlet deliveries represent about 85% of the forward flows of the network, but the operations of this distribution centre include backloads performed for suppliers and other distribution centres in the South of England. For this case study, a secondary distribution centre located in North London has been selected. The transport operation within this network is managed and run by the case study company, and during the data collection, the researcher spent five days training to use the transport ICT (Information and Communication Technology) system that the company uses to optimise, track and trace, and re-optimize the whole network. This company manages and runs the secondary distribution network, but they outsource a significant proportion of the primary distribution network to a number of logistics providers. The North London secondary distribution section of this company, which sits between the DC and outlets, will be the focus of this case study, but also a small proportion of backhaul and primary flows will be included in the assessment.

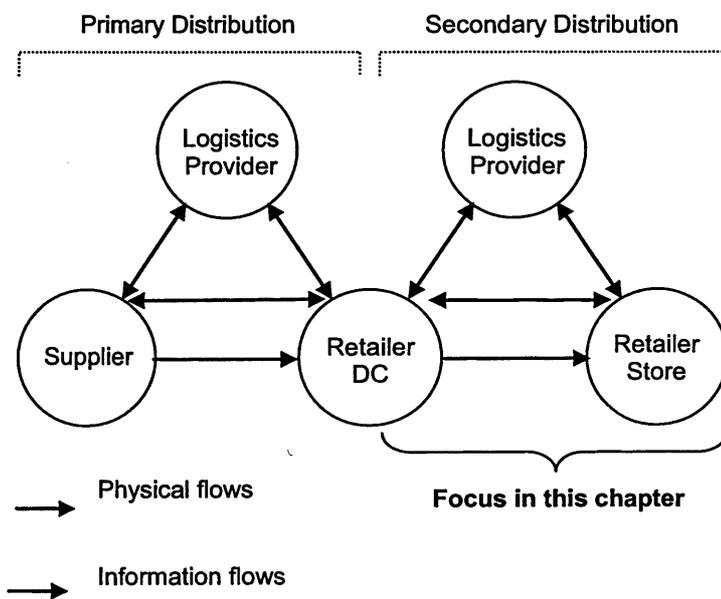


Figure 9.1 Transport operation position within UK FMCG secondary distribution network

The transport planning process is run by the case study company. They use an ICT transport system that includes three modules. One of the modules optimises the

network, including backhaul opportunities, volume demand from outlets, locations from all the outlets and any primary volumes required from suppliers that can fit within the secondary distribution fleet available. Following that, when the deliveries are executed, another module tracks and traces the vehicles to determine whether the vehicles are either late or too early. That information is fed into another device that controls the vehicles within the transport fleet. This information is fed into the third module where updated information, in terms of vehicle availability, is used to re-optimize the network. This process is repeated several times during the same day.

There are a number of reasons why this particular case was selected:

- The 'extra distance' tool was applied to a secondary distribution network in South Africa, so it was interesting to apply the measure in another secondary distribution from the UK
- It was also necessary to draw a comparison between primary and secondary distribution operations within the UK
- The network studied has the appropriate Telematics system to measure the impact of external uncertainty causes such as unplanned road congestion in terms of 'extra distance' and 'extra time'
- The secondary distribution centre located in North London was selected due to the fact that its network includes a combination of locations that together are different from the rest of the UK. The secondary distribution network managed and run by this distribution centre includes flows from areas in London located to the north of the River Thames. These areas could present considerable problems of unplanned road congestion. In addition, the network studied also covered areas of the East Midlands that are located to the north of the River Thames.

9.3 Method

As in the first case study, in order to undertake the 'extra distance' assessment in this secondary distribution network from the UK, the principles of the case study method have been applied, since the tool needed to be tested in a different distribution network. The unit of analysis of this case study is a FMCG secondary

distribution operation. This operation was chosen since the aim was to undertake a comprehensive assessment of 'extra distance' and 'extra time'.

In the planning stage of the study, a presentation based on the findings from the first case study was delivered at a meeting with the management staff of the transport operation of the company studied. The main objective of this presentation was to set the planning of the case study and decide the scale and scope of the project. Another objective of this meeting was to evaluate the suitability of the 'extra distance' measure in their operation. As noted earlier, the case study company has several secondary distribution centres located within the UK. However, in order to keep the project on a realistic scale, the North London secondary distribution network was selected for the assessment.

Before starting data collection, the author spent five days in the transport office of the secondary distribution centre. The reason for this was that the author needed to identify data sources for the assessment and familiarise himself with the case study company ICT transport system. Subsequently, the data was collected remotely from the researcher's workplace. This made the process more productive and reduced the cost of the data collection.

During the data collection, two separate assessments were undertaken. These two assessments were undertaken in the week between 27th November at 19:00 and 4th December at 19:00. This week was regarded by the case study company as an average week. The reasons for conducting two separate assessments were: (1) to measure 'extra distance' by applying the same principles applied in the other two case studies; (2) to measure 'extra time' in terms of delays as was measured in the South African secondary distribution network; and (3) to include route diversion in analysis since in the other case studies the information was not available. The first assessment was undertaken by gathering all the extra trips caused by uncertainty that occurred during the week of data collection. In this assessment, as in the second case study, the extra trips that occurred in the week of data collection were gathered from a report produced manually in the transport department of the secondary distribution centre studied. All 'extra distance' incidents identified were input into an Excel spreadsheet, which is shown in Appendix 7. The role of this Excel

spreadsheet was to undertake an evaluation of the different causes of uncertainty. Therefore, the frequency and impact of each of the 'extra distance' causes was quantified. As in the first case study, a risk assessment was undertaken to support the decision makers in evaluating the 'extra distance' causes found in terms of their relative priority.

In the first assessment, as in the first case study, detailed information about the trips that generate 'extra distance' was recorded; this information includes: outlet location, kilometres run, fuel consumption of the trip, 'extra distance' cause. As in the other two case studies, in this chapter, 'extra distance' is calculated in kilometres, due to the fact that this is the metric unit used by the company. The extra kilometres of all the extra trips identified were calculated by using Paragon. As in the previous two chapters, the relative accuracy of Paragon against Google and AutoRoute was checked (see Table 7.1). In the spreadsheet, the number of 'extra distance' incidents generated by each uncertainty cause was calculated. The cost of every incident of 'extra distance' was calculated by multiplying the cost per kilometres that the logistics provider charges their customer, which is £1 per kilometre. Also, the kg of CO₂ emitted due to every incident of 'extra distance' was calculated by multiplying the extra kilometres generated for every 'extra distance' incident by the actual fuel consumption of the trip, as recommended by the Carbon Trust (2009), provided by the case study company, and by the road freight transport conversion factor for diesel recommended by Defra (2007), 2.63. In addition, the cost of delays was calculated by multiplying the 'extra time' generated by every incident of 'extra time' by the labour cost per hour, £14 per hour. Furthermore, as in the first case study, a risk assessment of the 'extra distance' causes found was undertaken, so the probability and impact of each cause were calculated.

The second assessment was undertaken by comparing the original transport plan with the actual execution of the delivery process during the week of data collection. This week can be described as a typical average week that fairly reflects what happened through a twelve month period. In order to collect the data, a stratified sampling strategy was applied based on three attributes, location, time of day and day of the week. Forty-one per cent of the planned picks and/or drops served by the North London secondary distribution were selected for the second assessment. In

fact, 30% of the trips for every location covered in the network were selected. In addition, for every hour within the 24 hrs of every seven days of the week, 30% of the trips were selected. The researcher chose 30% of the trips and not 100%, since the data gathering process was very time consuming and the researcher had limited time to finish the data collection. Furthermore, 30% of the trips gathered are a fair reflection of what happened in 100% of the trips.

In the second assessment, for every trip identified, the planned and actual turnaround times for every dropping and/or loading point within the trips were gathered. Moreover, the planned and actual total delivery times were collected from the system, together with any unplanned stops reported by drivers. Apart from that, planned and actual data on fuel consumption and kilometres run were gathered. With this data, the difference between actual and plan was calculated in terms of percentage for four variables: turnaround time, vehicle running time, and total extra kilometres run for each of the trips gathered. These calculations were conducted in the Excel spreadsheet shown in Appendix 8.

In this assessment, two different factors were explored: the causes of 'extra time' within the network and the causes of 'extra distance' due to route diversion within the network. In the case of delays, the reason why vehicles were delayed was identified and categorised and the cumulative time delayed for each cause of delay was calculated. The cost of delays was calculated by multiplying the 'extra time' generated by every incident of 'extra time' by the driver labour cost per hour. In the case of 'extra distance' due to route diversion, the extra kilometres run within the networks were categorised depending on the cause of 'extra distance' due to route diversion found. The cost and CO₂ emissions of every incident of 'extra distance' were calculated in the same way as in the first assessment.

Apart from that, in the second assessment, a variance analysis of the four variables named previously was undertaken using four factors identified during the analysis: geographical location of the trips, time of the day and day of the week, and the number of locations that each trip involved. The reason for analysing the variance based on these four variables was to identify different degrees of variances generated by these four factors. Eleven geographical locations were selected using

two referential locations: the secondary distribution centre and central London. Also, five time periods were identified: 22:00 till 04:00, 04:00 till 09:00, 09:00 till 12:00, 12:00 till 17:00 and 17:00 till 22:00. These time periods were selected based on the degree of traffic congestion and the number of staff available in the company outlets. They were approved by the management staff within the transport function of the company. Moreover, the variance analysis was undertaken by considering the day of the week when the deliveries were executed, since it was intended to consider the difference in volume and traffic congestion in the seven days of the week. Furthermore, trips with one, two and three loading and/or unloading locations were identified and they were categorised depending on the number of locations had. Thus, the impact of having more or fewer locations within a trip was considered by undertaking a variance analysis. In this exercise, a risk assessment was undertaken to establish the level of importance of the different causes of 'extra distance' identified due to route diversion. Also, a risk assessment was undertaken to estimate the probability and impact of 'extra time' in terms of delays.

In addition, a calculation of the cost and CO₂ emissions of all the causes of 'extra distance' and 'extra time' recorded in the two assessments was undertaken. The extra kilometres of the two causes of route diversion calculated from the second assessment were scaled to 100% of the kilometres run in the network. This scaling factor is 3.51, which is the result of dividing the total kilometres run in the network, 300,341 kilometres, by the kilometres of all of the trips gathered in the second assessment, 85,477 Kilometres. In order to scale the 'extra time' gathered in the second assessment to the total number of trips run in the network, a time scaling factor was calculated dividing the total trips run in the week of data collection, 1,957 trips, by the total number of trips gathered in the second assessment, 585 trips.

To understand more about the root causes of 'extra distance' and 'extra time' and the tools the company applied to mitigate uncertainty, informal interviews and discussions were held with management staff within the secondary distribution operation studied from the company transport department. These discussions also helped confirm the validity of the exercise.

After finishing the analysis of the data, the findings from the study were fed back to the management staff directly involved with the study. In that meeting, all the

managers involved validated the findings. From their perspective, this presentation represented a starting point towards identifying the potential mitigation strategies to reduce 'extra distance' and 'extra time'.

9.4 Results and analysis

In this section of the chapter, the overall results of the data collection will be presented first (Table 9.1). This includes the two assessments undertaken in the study. Following that, the causes of 'extra distance' derived from the two assessments will be evaluated and also the relative risk that the two sorts of 'extra distance' raise: 'extra distance' due to extra trips; and 'extra distance' due to route diversion of originally planned trips. Subsequently, the causes of 'extra time' found in the second exercise will be assessed together with an evaluation of their risk. For the two assessments, a variance analysis of time and distance will also be included in this section. Moreover, the link between these and uncertainty will be explicitly drawn based on a cost analysis of the different causes of 'extra distance' and 'extra time'.

First Assessment	Kilometres run	300,341
	Extra distance' due to extra trips	9,170
	% 'Extra distance'	3.05
	Cost (£)	9,170
	Kg of CO ₂	7,705
Second Assessment	Kilometres run	85,477
	Extra distance' due to route diversion of planned trips	4080
	% 'Extra distance'	4.77
	Cost (£)	4,008
	Kg of CO ₂	3,368
	Total delivery time (hr)	2902
	Delays (hr)	276
	Early deliveries (hr)	-200
	'Extra time'	76
	%	2.62
	Cost (£)	1,064

Table 9.1 Overall findings of 'extra distance' and 'extra time' on the secondary distribution centre network

In the first assessment, a total of 9,170 km were run due to uncertainty. This represents 3.05% of the total kilometres run in the secondary distribution network, which represents £9,170 and 7,705 Kg of CO₂. On the other hand, in the second assessment, from a total of 85,477 km run in the network, 4.77% were run due to route diversion generated by either unplanned road congestion or ad-hoc and unexpected road restrictions imposed by the 27 London boroughs that the distribution centre covered. When the data sample is scaled to 100% of the trips, route diversion represents about £14,083 of extra cost and 11,820 extra Kg of CO₂ in the week of data collection. Even though route diversion has a larger impact on transport cost and CO₂ emissions, a great proportion of it is generated by ad-hoc and unexpected road restrictions that are imposed by 27 London boroughs. Thus, the case study company needs first to concentrate on mitigating the uncertainties generated internally in their operations or their partners' operations and subsequently working together with the government to mitigate route diversion. This will be discussed in more detail in the following section of the chapter.

In addition, in the second assessment, 2.62% of the total hours dedicated for the deliveries, 2,902 hr, were 'extra time'. In fact, 276 hr of delays and 200 hr of early deliveries were found, so the net figure is 76 hr, which is the estimate of extra driver hours generated by delays, although it is important to say that overall there is a considerable degree of unreliability in the delivery time. When the data sample is scaled to 100% of the trips, 'extra time' added £3,739 to the total transport cost. It is important to say delays always cause 'extra time', but do not always cause 'extra distance'. When a delay causes 'extra distance', it has a greater impact on cost and the environment, since it increases the fixed cost of transport and also generates extra CO₂ emissions, but when they generate 'extra time', delays only increase the variable labour cost incurred during the delivery process .

In the rest of this section, more in-depth insights from the analysis will be discussed.

9.4.1 Assessment of 'extra distance' due to extra trips

9.4.1.1 Main causes of 'extra distance'

As Table 9.2 shows, in the first assessment, eight causes of 'extra distance' due to extra trips were found. Delays within the delivery process generated 69% of the extra kilometres found in the assessment and 62% of the 'extra distance' incidents recorded during the assessment. Outlets generated a greater proportion of the extra kilometres caused by delays (56%) in comparison to suppliers (6%) and unplanned road congestion (7%). Meanwhile, another less important, but still considerable, cause of 'extra distance' found was late notification of extra volume from either outlets (15%) or suppliers (4%). It is important to note that at outlets these two causes of 'extra distance' together generated 71% of the 'extra distance' measured in the first assessment.

'Extra distance' type	'Extra distance' Cause	Extra Distance' (%)	Frequency (%)
Extra distance due to route diversion	Unplanned road congestion	Measured in the second assessment	
Extra distance/trips due to delays	Loading delays at shippers	6	8
	Loading delays at outlets	56	59
	Unplanned road congestion	7	5
Extra distance/trips due to load more than advised	Late notification of extra volume from suppliers	4	4
	Late notification of extra volume from outlets	19	20
Extra distance/trips due to load less than advised	Physical load smaller than advised	0	0
Extra distance/trips due to inappropriate vehicle size	Technical vehicle failure	4	1
	Product not loaded at DC	3	3
	Product not loaded at supplier	2	1
	Product mis-loaded	0	0

Table 9.2 Overall impact and frequency of the different 'extra distance' causes due to extra distance found in the UK secondary distribution network

The other three causes of 'extra distance' found are 'technical vehicle failure', 'product not loaded' at the secondary distribution centre studied and 'product not loaded at suppliers'. The first generates 4% of the total extra kilometres found and the second represents 3% of the 'extra distance' recorded. 'Product not loaded at suppliers' represents only 2% of the total extra kilometres gathered in the assessment. 'Technical vehicle failure' generates 'extra distance' since when a vehicle presenting a technical failure is not available for departure and in some cases only other smaller sized vehicles are available, then two small-sized vehicles are needed instead of one large-sized vehicle. On the other hand, when the product is not loaded at the distribution centre or suppliers, a sheer volume accumulates for the next day and this product ultimately needs to be moved, adding extra kilometres to the original transport plan. However, these three causes of 'extra distance' should not be at the top of the priority list of any 'extra distance' reduction programme.

9.4.1.2 Risk assessment of 'extra distance' causes due to extra trips

In order to assess the relative importance of all the 'extra distance' causes, the risk of all them has been calculated as function of impact and probability. Figure 9.2 shows the impact and probability of the four 'extra distance' causes found in the data collection.

As Figure 9.2 depicts, 'delays at outlets' has a relatively much higher risk than the rest of 'extra distance' causes found. This is due, to a large extent, to its relatively higher probability of occurrence. There seems to be a considerable level of inefficiency in the unloading process at outlets, so, in order to mitigate this cause of 'extra distance', the productivity of the unloading process at outlets, including the capacity of unloading bays, should be reviewed. Furthermore, other 'extra distance' cause that represent a considerable risk for the operation is 'late notification of extra volume to be moved at outlets'. This cause presents the second highest probability of occurrence, about 1.00%, of all the causes of 'extra distance' found.

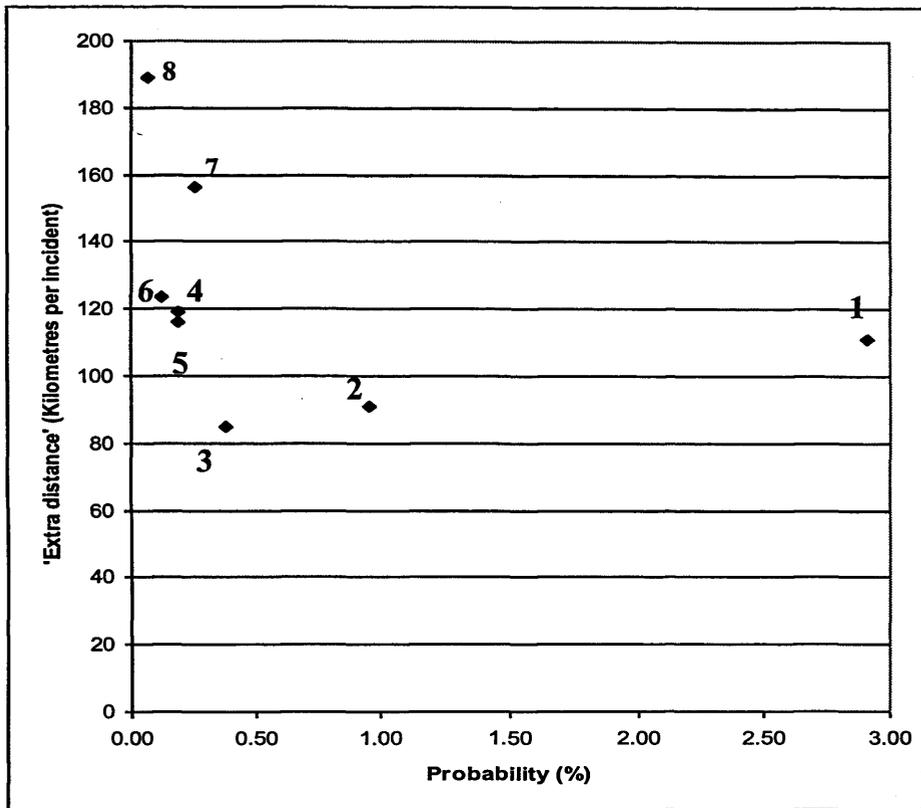
due to either delays and/or volume increases. Therefore, these two problems should be corrected locally rather than centrally throughout the network.

According to the risk assessment undertaken, the company should focus on better monitoring and control of the delivery process to lessen the delays at outlets. Also, they need to check how certain outlets are forecasting their volume requirements.

9.4.2 Assessment of 'extra distance' due to route diversion of originally planned trips

9.4.2.1 Main causes of route diversion

Table 9.3 shows the results of the assessment of 'extra distance' due to route diversion of originally planned trips. Two main causes of 'extra distance' due to route diversion were found: unplanned road congestion and ad-hoc and unexpected road restrictions. Both are external causes originating outside the logistics triad. There are restrictions that are not pre-established and informed to the case study company by the local government in London. The 27 London boroughs impose road restriction to truck operators in an ad-hoc and unexpected manner. These restrictions are imposed since trucks are perceived to generate noise during the night, so the government decided to restrict access to a considerable number of roads in Central London. These restrictions change very frequently and are regarded as ad-hoc by the management staff of the operation. The issue is that each London borough changes the restrictions in an uncoordinated manner. This cause of 'extra distance' generates 61% of the extra kilometres caused by route diversion of originally planned trips and 14% of the incidents gathered in the second assessment are route diversion due to ad-hoc and unexpected road restrictions. The company could ask the government to be more flexible and avoid restricting certain roads, but this is a problem that is very difficult to eliminate, since the government has the role of protecting residential and commercial neighbourhoods. Therefore, ad-hoc and unexpected road restriction should be better embedded into the transport plan, so the planned kilometres of the restricted routes are more accurate, but the case study company need the support of the local London government.



No	'Extra distance' cause
1	Delays at outlets
2	Late notification of extra volume to be moved at outlets
3	Delays at suppliers
4	Technical vehicle failures
5	Late notification of extra volume to be moved at suppliers
6	Unplanned road congestion
7	Product not loaded at suppliers
8	Product not loaded at DCs

Figure 9.2 Risk assessment of 'extra distance' causes due to extra trips

A total of six causes of 'extra distance' represent less risk for the operation than the other two 'extra distance' causes discussed previously. These six causes of 'extra distance' are: 'volume increase at outlets'; 'volume increase at suppliers'; delays at suppliers', 'product not loaded at suppliers' 'product not loaded at DC' and 'technical vehicle failure'. From all these causes of 'extra distance', the only causes that should be carefully considered are: volume increases in particular generated by outlets. This means that the forecast process undertaken to estimate the product demand requirement at outlets needs to be revised. It is important to state that out of the outlets in the network, eight outlets generated the vast majority of 'extra distance'

'Extra distance' type	'Extra distance' Cause	Extra Distance' (%)	Frequency (%)
Extra distance due to route diversion	Unplanned road congestion	39	86
	Ad-hoc and unexpected road restrictions	61	14

Table 9.3 Overall impact and frequency of the different 'extra distance' causes due to route diversion of existent trips found in the UK secondary distribution network

In addition, unplanned road congestion was the other 'extra distance' cause found in the second assessment due to route diversion. It generated 39% of the extra kilometres gathered, but it occurs 86% of the time. Route diversion due to unplanned road congestion occurs due to the fact that most of the time drivers select the quickest route, but that route is not always the most environmentally friendly. Within the case study company, the sales department is a customer of the transport department. From an economical viewpoint, the sales department wants the products to be on time at outlets. Therefore, drivers feel that they need to take the quickest route possible. Furthermore, as in the case of the incidents due to ad-hoc and unexpected road restrictions, the planned kilometres need to be revised and made more accurate with the support of the London City authorities.

According to the variance analysis, the coverage areas that presented more variance in terms of extra kilometres are Central London, East London, North West London and South West London. These areas are the areas covered by the London distribution centre network that are affected by ad-hoc and unexpected road restrictions. Moreover, the greater variance in terms of extra kilometres occurs within the time period from 04:00 to 12:00. Within this time, most of the outlets are stocked for the rest of the day, and that combined with a higher intensity of passenger transport movements generates a greater degree of and more variability in traffic congestion on the road that considerably builds from 06:00 until 12:00. Additionally, greater variation in terms of extra kilometres is generated from Tuesday to Friday. There is more variation from Tuesday to Friday since there is more chance of diversion due to unplanned road congestion on weekdays than at weekends. Furthermore, the trips with only one supply chain link are the ones that present

greater variation. It is important to say that these single trips are most of the time outlet deliveries to London areas located in Zone 1, so they tend to have more traffic congestion problems than those that involve two or three links, as with supplier collections outside London. These types of trips are generally run on motorways that have much less traffic congestion problems than roads inside the London area.

9.4.2.2 Risk assessment of 'extra distance' causes due to route diversion

In order to assess the relative importance of all the 'extra distance' causes due to route diversion, the risk of all them has been calculated as function of impact and probability.

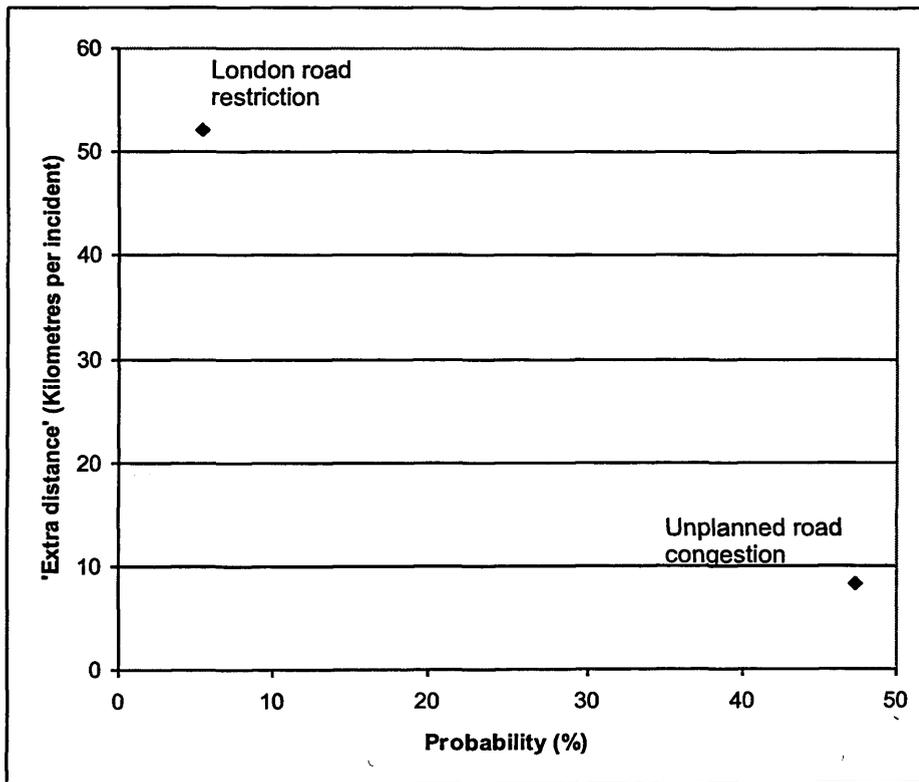


Figure 9.3 Risk assessment of 'extra distance' causes due to route diversion

As explained in the previous section, unplanned road congestion is an 'extra distance' cause that cannot possibly be mitigated and in this risk assessment has relatively high occurrence but low impact, while ad-hoc and unexpected road restrictions have relatively low occurrence but high impact (Figure 9.3). However, it is important to conduct a joint analysis of the cost and CO₂ emissions of all the uncertainty causes found in this case study, including route diversion and delays.

Thus, the magnitude of all uncertainty causes found can be better compared. This will be done after presenting the assessment of 'extra time' due to delays.

9.4.3 Assessment of 'extra time' due to delays

9.4.3.1 Main causes of 'extra time'

As Table 9.4 depicts, the four causes of 'extra time' gathered during the data collection are 'delays at suppliers', 'delays at outlets', 'delays due to unplanned stops' and 'delays due to unplanned road congestion'. 'Delays due to unplanned stops' made by drivers are the 'extra time' cause that generated more hours of delays and occurred more frequently. This 'extra time' cause occurs since legally drivers have the right of a break if the journey is more than 7 hours. The issue in this case is that these stops are not included in the initial transport plan. The case study company cannot possibly mitigate this 'extra time' cause, since it occurs due to a government regulation, so it is a restriction that needs to be included into the transport plan but cannot be eliminated.

'Extra time' type	'Extra time' Cause	'Extra time' (%)	Frequency (%)
'Extra time' due to delays at loading bays	Delays at DCs	0	0
	Delays at suppliers	30	21
'Extra time' due to delays at unloading bays	Delays at outlets	33	31
'Extra time' due to internal transport failures	Unplanned stops	34	45
	Unplanned road congestion	3	3

Table 9.4 Overall impact and frequency of the different 'extra time' causes found in the UK secondary distribution network

The two causes of 'extra time' that can be mitigated by the retailer and its partners are delays originated at outlets and suppliers. 'Delays at outlets' represents 33% of the total hours of delays gathered in the data collection and are a third of the total incidents of delays found. Furthermore, 'delays at suppliers' generated 30% of the

hours of delays and are a fifth of the total incidents found. These delays are generated by operational problems at loading and unloading bays. At unloading bays, the vehicles need to wait excessively to be unloaded, so they arrive late at the distribution centre. This problem is caused primarily by lack of productivity at outlets or perhaps insufficient staff for unloading. At loading bays, the loads to be collected are not ready, so vehicles need to wait for the complete load. These two causes of 'extra time' increase the labour cost of transport, since drivers need to work overtime.

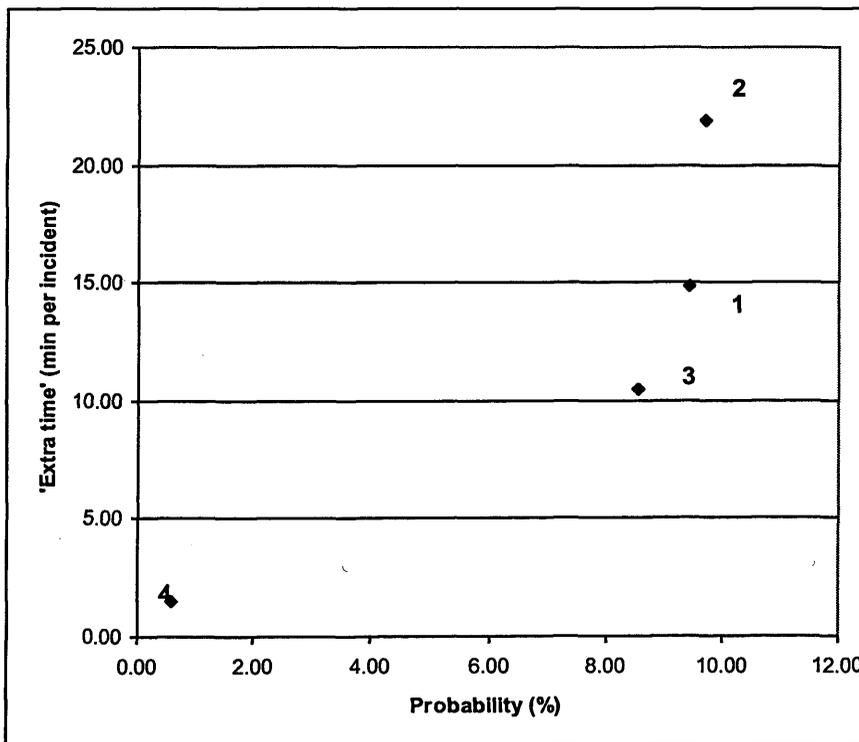
In terms of variance, the areas that presented more variance in terms of outlet turnaround time are East London, South West London, North and North East. There are a number of outlets in these areas that have insufficient staff available to unload products. Also, the variance analysis shows greater variance between 22:00 and 09:00. In these two periods of time, most of the outlets are stocked for the rest of the day, so the outlets receive a disproportionate volume of products in comparison with the rest of the day. Moreover, much of the variation in turnaround time is generated from Tuesday to Thursday and on Sunday. On these days, there is more variation due to the fact that there are greater volumes coming to the outlets. Meanwhile there are insufficient staffs available to unload the products in the outlets. Furthermore, the trips with only one supply chain link are the ones that show more variation in terms of turnaround time and net vehicle running time. This is because of the fact that outlets tend to be more unreliable in terms of turnaround time than suppliers.

The other 'extra time' cause found is unplanned road congestion. This represents 3% of the extra hours gathered during the exercise. Unplanned road congestion has a much smaller impact than delays at outlets and suppliers, since this uncertainty cause usually generates more kilometres but not delays. In fact, this uncertainty cause can cause vehicles to arrive earlier at their destination, since by using Telematics systems; the driver can take a quicker but longer route if traffic congestion problems are promptly anticipated. Generally across all the DC coverage areas, the variation is more skewed towards the negative side of the scatter plot which means that most of the trips lasted less time than their planned vehicle running time. This is a reflection of the fact that in this supply chain, time is more

important than distance, so drivers are encouraged to arrive on time at their destinations no matter the kilometres they need to run.

9.4.3.2 Risk assessment of 'extra time' causes due to delays

In order to assess the relative importance of all the 'extra time' causes, the risk of all of them has been calculated as function of impact and probability. Figure 9.4 shows the risk assessment of 'extra time' causes due to delays generated in the data collection. Even though delays due to unplanned stops have the highest impact and probability of occurrence, it does not represent an important priority for the company, since drivers are entitled to a break by law. The two 'extra time' causes that have medium risk for the operation are delays at outlets and at suppliers. These two causes are the areas of greater opportunity where the retailer can look for reduction of 'extra time'.



No	'Extra distance' cause
1	Delays at outlets
2	Delays due to unplanned stops
3	Delays at suppliers
4	Delays due to unplanned road congestion

Figure 9.4 Risk assessment of 'extra time' causes due to delays

9.4.4 Linking 'extra distance' and 'extra time' to uncertainty

In order to assess the relative importance of all the uncertainty causes found in the study, the cost and CO₂ emissions generated by their 'extra distance' and/or 'extra time' have been calculated, as can be seen in Table 9.5. To link uncertainty with 'extra distance' and 'extra time', three different categories have been identified. These categories are considered in Figure 9.5 by increasing the thickness of the arrows that connect uncertainty causes with uncertainty clusters.

Extra distance' type	Uncertainty causes	'Extra distance' due to extra trips (Km)	'Extra distance' due to route diversion (Km)	'Extra time' due to delay (hr)	Cost (£)	Kg of CO ₂	Priority category
Extra distance due to route diversion due to	Ad-hoc and unexpected road restrictions		2,520		8,845	7,517	A
	Unplanned Road Congestion		1,488	6	5,523	4,713	A
Extra distance/ trips caused by	Outlets	5,173		92	6,461	4,362	A
	Suppliers	510		83	1,672	438	B
	Unplanned stops			95	1,330	0	B
	Unplanned Road Congestion	625			625	535	A
Extra distance due to load more than advised due to	Late notification of extra volume from outlets	1,721			1,721	1,189	B
	Late notification of extra volume from suppliers	348			348	286	C
Extra distance / trips due to inappropriate vehicle size due to	Technical vehicle failure	357			357	306	C
Other	Product not loaded at distribution centres	247			247	210	C
	Product not loaded at suppliers	189			189	154	C
	Early deliveries			-200			
Total Cost (£)		9,170	14,068	3,301			
Total CO ₂ (Kg)		7,705	11,820	0			

Factors used for the calculation

First Assessment (Km)	300341
Second Assessment (Km)	85477
Kilometre scaling factor	3.51
Time scaling factor	3.30
Cost (£/Km)	1
Labour cost (£/hr)	14
Defra factor	2.63

Table 9.5 Cost and CO₂ of uncertainty causes

As in the previous two chapters, the causes of uncertainty gathered in this case study have been clustered according to the framework developed in Chapter 5. In some instances, uncertainty arises from more than one source. These are then mapped against the cause of 'extra distance' and/or 'extra time' observed in the case study. The results can be seen in Figure 9.5.

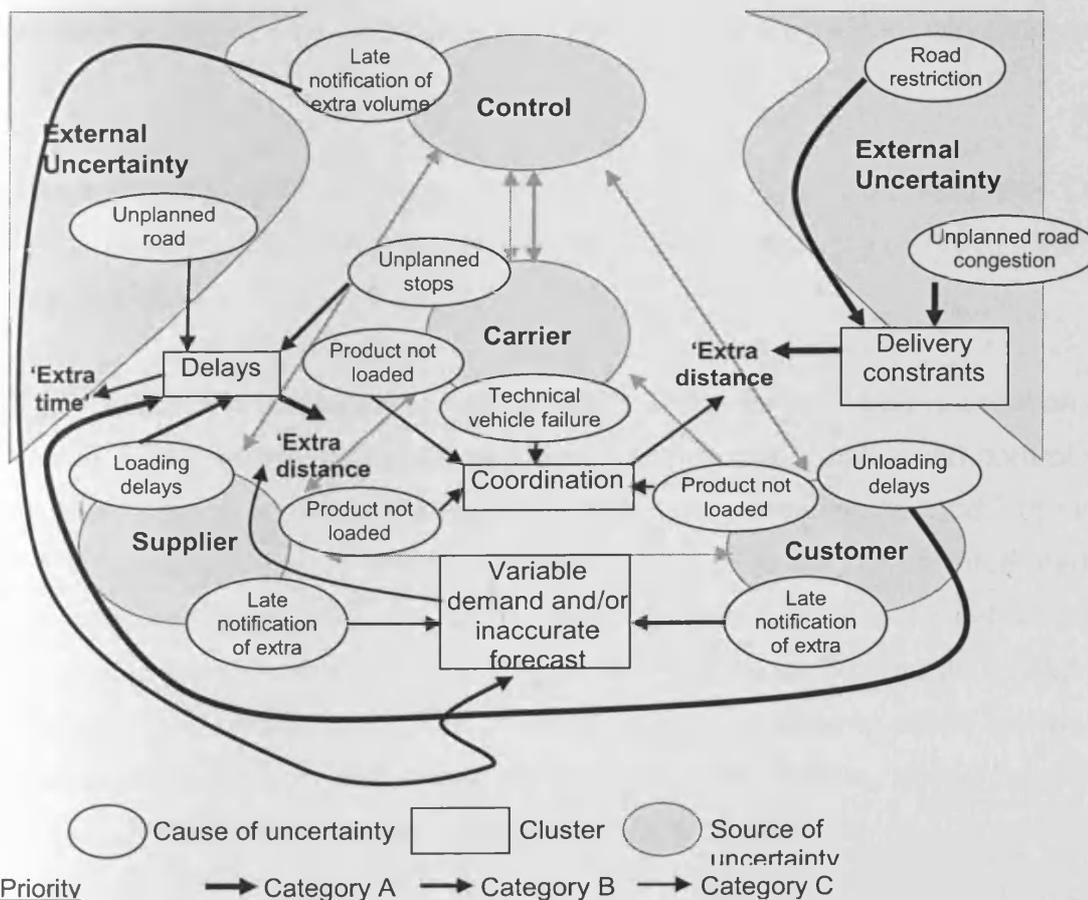


Figure 9.5 Link between uncertainty, 'extra distance' and 'extra time'

As Figure 9.5 shows, it can be observed that operational issues within the delivery process tend to be generated to a greater extent at the customer and supplier, rather than at the carrier. External sources of uncertainty, such as route diversion due to unplanned road congestion and ad-hoc and unexpected road restrictions, are the main uncertainty causes found in this case study. Together they represent £14,083 of extra cost and 11,820 kg of additional CO₂. These external causes of uncertainty can be linked back to the uncertainty cluster of delivery constraints found in the focus groups (see Chapter 5). However, in these two uncertainty causes the influence on them of the case study company can be marginal, since they are generated by government regulations and/or traffic congestion problems. Therefore, it is more a case of embedding them better into the transport plan to budget their cost more realistically and also to internalise their environmental impact. Unloading delays at outlets are the main internal cause of uncertainty found in the case study. These generate extra trips that increase the economic and environmental cost of transport, and they also generate 'extra time' that is added to the time originally planned for the trips.

Delays are originated at outlets to a greater extent than at the suppliers. Delays at outlets generated £6,461 of extra cost and 4,346 of extra kg of CO₂ in the week of data collection.

Variable demand and/or inaccurate forecast in the form of 'late notification of extra volume to be moved' is recorded as the customer, the supplier and control systems uncertainty sources, since the volume forecast process is embedded into the ICT of the case study company and the suppliers are supposed to be integrated with it. However, just fewer than 10% of the outlets generate most of the extra trips due to 'late notification of extra volume'. This uncertainty cause represents £1,720 of extra cost and 1,446 extra Kg of CO₂. Therefore, this uncertainty cause seems to be a local operational problem generated at the specific outlets, rather than a central issue originating in the company central planning department.

All four clusters of uncertainty found in the focus groups have been recorded in this case study. These are: delays, variable demand and/or inaccurate forecast, delivery constraints and insufficient supply chain coordination. Delays always generate 'extra

time' in terms of extra driver cost, but do not always generate 'extra distance' in terms of extra kilometres run. Consequently, they have a greater impact on cost and on the environment if they cause vehicles to miss the next load scheduled for them, and as a result, extra trips are added to the transport plan. On the other hand, variable demand and/or inaccurate forecast and lack of coordination always generate 'extra distance' but not 'extra time'.

In the previous two case studies, the extra kilometres generated due to route diversion were not measured due to the absence of an appropriate Telematics system. Owing to the fact that the case study company possesses a very advanced ICT transport system capable of comparing plan and actual, the 'extra distance' generated due to unplanned road congestion and ad-hoc and unexpected road restrictions has been measured.

9.5 Transport uncertainty mitigation approach

The approaches that the case study company take are shown in Table 9.6. They are driven by the fact that it is equally important to ensure that the products are available at stores at all times so as to keep the transport cost as low as possible. As in the previous two case studies, distribution centres are cross-docking operations rather than inventory holding operations. As in the first case study, high labour cost, high fuel prices and high fixed cost of vehicles economically encourage the customer to optimise the network tightly. Also, as in the UK primary distribution network, the target vehicle capacity utilisation through this network is 85%, so disturbances or disruptions are very likely to generate 'extra distance'.

In terms of the transport planning process, the outlets need to submit all their final and confirmed volume requirements by 07:00 am on the day that loads need to be moved. In addition, the secondary distribution centre studied moves volume from other secondary distribution centres. The transport plan is completely flexible; if there is a vehicle that is delayed, the transport system allocates the next load initially scheduled for that vehicle to other vehicles. Also, if there is a vehicle that arrives early at its destination, the system allocates other loads to that vehicle. The ICT transport system plans and re-optimises the network. It can be described as a

transport system that continuously optimises the network. This system consists of three modules: Paragon, IsoTrack and Fleet Controller. Paragon is the network optimisation tool, IsoTrack is the track-and-trace tool and Fleet controller is the tool that updates the availability of vehicles and feeds this information into Paragon which then re-optimises the network.

Customer main targets	Product availability	High priority
	Transport cost	High priority
Cost factors	Labour cost	High
	Fuel cost	High due to tax duty
	Fixed cost	High due to tax duty
Cost structure	Vehicle ownership	Customer owns all the vehicles used for secondary deliveries and these vehicles are used to do 20% of the primary collections through backhaul of store vehicles, the rest of them are undertaken by logistics providers
	Fixed cost paid by	Internal and control by the customer
	Variable cost paid by	Internal and control by the customer
Transport planning	Daily deadline	Inputted into Paragon by 07:00 am
	Volume requirements driven by	Stores and suppliers
	Flexibility	Totally flexible, if there is a vehicle that is delayed the transport system allocates the next load initially scheduled for that vehicle to other vehicle. Also, if there is a vehicle that is early, the system allocate other load to that vehicle
	Vehicle capacity utilisation	85%
	Fleet ownership	Customer
	Transport ICT system	This can be described as a transport system that continuously optimises the network. There are three systems: Paragon- the network optimisation tool, IsoTrack- the track-and-trace tool and Fleet controller- the tool that update the availability and location of vehicles and feed this information into Paragon and Paragon then re-optimize the network
Response to uncertainty	Capacity available in transport plan?	Paragon re-optimises the network if there is capacity available within the system, but usually uncertainty generates extra trips due to the fact that the network is run very tightly
	Proximity of the load?	If supplier is remotely located, a logistics provider, if it is an extra trip generated by a store, the trip is run in house
	Who will run the extra trip?	Most of the time own fleet, but during peak times, e.g. at Christmas, logistics providers
	Route re-optimisation	Paragon is continuously updated by IsoTrack and Fleet Controller about the availability of vehicles and re-optimises the network according to that information
	Who pay for the load?	Internal transaction within the customer
	Monitoring	Most of the monitoring is in terms of time, but there is no 'extra distance' monitoring at an individual trip level

Table 9.6 How the logistics provider mitigates uncertainty

In addition, the case study company invested a considerable amount of funds in a new, state of the art ICT transport system to mitigate more effectively the uncertainty generated within the delivery process that caused 'extra distance' and 'extra time'. However, physically the extra trips are still required. If an extra load is generated by operational errors within the logistics triad and/or due to late notification of extra volumes from outlets and suppliers, the system first checks in the transport plan whether there is space available within the originally planned fleet. However, due to the fact that the network is run at 85% overall vehicle capacity utilisation, uncertainty often generates the need for extra trips, which are added manually by the transport planners.

In the secondary distribution network studied, a large proportion of the cost and CO₂ emissions generated by uncertainties are originated both externally and at the company outlets. In the case of the uncertainties that are generated externally, the company accommodates them by embedding them into the delivery time. In addition, it is important to note that 'extra time' due to delays generates a comparatively larger proportion of increases in cost than in the South African secondary distribution network; this is due to the fact that in the UK the labour cost is much higher than in South Africa. The distribution centre studied is monitored in terms of time merely by two Key Performance Indicators (KPI), location turnaround time and net vehicle running time. However, the only distance-related indicator monitored is the fuel consumption of vehicles, but currently there is no monitoring of extra trips generated by uncertainty.

9.6 Managerial implications

Although the case study presented in this chapter is a secondary distribution network from the UK, the research has identified a number of opportunities to other secondary distribution operations within the UK and other countries. From this, it is possible to identify some generic managerial implications. The chapter has shown the importance of measuring the effects of uncertainty in terms of 'extra distance' and 'extra time'. As in the previous two chapters, this chapter shows the assessment of uncertainty in terms of distance, but also considers the time dimension of performance. The results of this combined assessment show that in this case study

'extra distance' is more important than 'extra time'. However, due to the fact that labour cost is higher than in developing countries like South Africa, the results of the assessment show that 'extra time' causes have a greater economic impact in this case study than in the South African one.

In this case study, two assessments have been undertaken, an 'extra distance' assessment based on the extra trips added to the transport plan and a comprehensive assessment that compares the transport plan with the actual performance. This combined time-and-distance assessment can be applied as a diagnostic tool in other transport operations, especially within the FMCG sector. In that way, a more explicit connection between uncertainty and its economic and environmental consequences can be drawn. Furthermore, the assessment has informed future decision making within the company studied.

In addition, route diversion generated on the road, either by ad-hoc and unexpected road restrictions or traffic congestion, has been the greatest source of uncertainty identified in this study. It is estimated that these two uncertainty causes generated £14,083 of extra cost and 11,820 of extra Kg of CO₂ in the week of data collection. The results of this case study can inform local government in London about the impact that external uncertainty has on cost and on CO₂ emissions. On the other hand, delays at outlets have been the main internal cause of uncertainty found. These can be reduced by improving the control and monitoring of the unloading process at certain outlets. Also, a minority of outlets generates increases in volume that cause extra trips. This issue can be mitigated internally by the case study company.

9.7 Concluding remarks

In the previous chapter, an assessment was undertaken to estimate the impact of uncertainty in terms of time and distance, but route diversion could not be included in that exercise. This case study demonstrates the application of a combined tool that considers the 'extra distance' and 'extra time' measures to assess road transport functions within a secondary distribution network. In this way, a clear link between uncertainty and the economic and environmental performance of road freight

transport operations can be made. As in the previous two chapters, the 'extra distance' measure can be used to evaluate the efficiency of road transport operations in terms of distance, or more specifically, in terms of unnecessary vehicle usage and fuel consumption. However, it is also vital to comparatively evaluate the impact of 'extra time'. In this particular case study, 'extra distance' has about six times more impact than 'extra time'. This is due to the fact that only 'extra distance' impacts on the fixed cost of transport and generates extra fuel consumption. However, the difference between the economic impact of 'extra distance' and of 'extra time' is greater in the South African secondary distribution network than in this UK secondary distribution network. This is because the labour cost in the UK is much higher than the labour cost in South Africa. Furthermore, even though the ICT transport system continuously re-optimises the network, a more physical and formal system is needed to control and reduce extra distance.

According to the results of this study, in this UK-based secondary distribution network, 3.05% of the total kilometres run are 'extra distance' due to extra trips and 'extra distance' due to route diversion is 4.77% of the total kilometres run in the network. The three main 'extra distance' causes are route diversion due to unplanned road congestion, route diversion due to ad-hoc and unexpected road restriction and unplanned road congestion and 'delays at unloading bays'. Jointly, they generated £20,829 and 16,427 kg of CO₂ emissions in the week of data collection. In addition, the assessment of all the causes of 'extra distance' and 'extra time' has been undertaken by calculating the risk that they represent in terms of their probability and impact.

Internally at the case study company, in most of the cases, the case study company plans the transport in the most optimal way; nevertheless, ad-hoc and unexpected road restrictions are included in the transport plan. Moreover, when uncertainty affects the network, the ICT transport system re-plans the network automatically. However, a significant proportion of 'extra distance' is generated due to delays at outlets, so physical monitoring of the unloading processes at these outlets needed to be revised. In order to reduce 'extra distance' and 'extra time' generated externally, the case study company needs to find a mechanism to encourage the government to reduce the ad-hoc and unexpected road restrictions they have imposed on

commercial transport operators, possibly by communicating with FMCG businesses that could share the same problem.

As mentioned in the previous chapter, before initiating any 'extra distance' and/or 'extra time' reduction programme, the retailer should apply the assessment for a longer period of time. The results of this study are based on data collected over a fairly average week. Therefore, the outcome of this exercise should inform future decision making, but the exercise should be repeated in order to verify the reoccurrence of the findings.

9.8 Contribution

To methodology in logistics research

In this chapter, the application of an assessment tool that links uncertainty and transport performance has been demonstrated. The chapter highlights the importance of measuring the effect of uncertainty in terms of 'extra distance' as well as in terms of 'extra time'. In addition, when measuring the effects of uncertainty on performance, the assessment tool includes the variance analysis of four indicators, two time-based indicators and two distance-based indicators. Moreover, in the variance analysis undertaken in the chapter, four factors have been used to support the findings.

To the PhD

In this chapter, the assessment exercise applied in the previous two chapters has been improved. First, in measuring 'extra distance', the effect of route diversion on extra kilometres has quantitatively been assessed by monitoring a sample of 30% of the deliveries to outlets and suppliers of a secondary distribution operation. This adds strength to the findings of the first two case studies. In the previous chapter, only a list of the trips that were delayed was included in the analysis. Secondly, a variance analysis of the performance of the sample used in the case study has been undertaken to demonstrate the effects of uncertainty on 'extra time'; this includes early and delayed deliveries. In terms of findings, the chapter highlights which are the uncertainties that greatly affect the transport performance of secondary distribution operations.

To the topic

In this chapter, the findings from the two previous case studies are complemented. This is a FMCG secondary distribution operation from the UK that is highly affected by delays at unloading bays and variable demand and inaccurate forecast. These were two of the four uncertainty clusters found in the focus groups and confirmed in the survey. Also, a secondary distribution operation that covers the North River Thames areas can be considered as an exemplar case, since it highlights the effect of unplanned road congestion and city restrictions on the economic and environmental performance of road transport operations.

10.0 Discussion

In this chapter, the overall findings of the PhD will be discussed. In the previous chapters, the topic has evolved and the research objectives have been addressed. Also, this PhD has developed a guide for applied research in logistics, so the key contribution to knowledge from the application of logistics research will be highlighted. The main aim of this chapter is to discuss the overall contribution to knowledge of this research. The chapter proceeds by discussing the methodological path applied in this research study. Following that, based on the advantages and limitations of the methods used, the knowledge learned from the application of all the methods and in particular how they complement each other, will be discussed. Subsequently, a discussion on the new and innovative tools applied to collect and analysed data in the focus groups, survey and the case studies will be undertaken. Moreover, the findings from each of the stages of the research will be compared, highlighting the uncertainty causes that were confirmed in all the stages and any differences between the opinion-based research stage and the case studies. In addition, a refined decision-making framework, developed to diagnose and mitigate uncertainty in road freight transport operations, will be presented. Furthermore, the final section of this chapter will consist of a brief synthesis of the contribution to knowledge of this research work.

10.1 Multi-methodological research path

In this PhD study, as Figure 10.1 depicts, the researcher took a combined deductive-inductive approach, as in the case of Kerksen-van Drongelen (2001). In the initial stages of the research, although there were works on uncertainty and supply chain management, little attention had been focused on uncertainty and freight transport. Therefore, the existent supply chain uncertainty frameworks were extended to develop the conceptual model. The conceptual model consists of five uncertainty sources based on the logistics triad. These uncertainty sources were populated with literature examples of uncertainty that can affect transport operations. Following that, the conceptual model was refined through the application of seven focus groups and

the focus group findings were confirmed in an online structured questionnaire. Up to that point, the research approach taken was deductive.

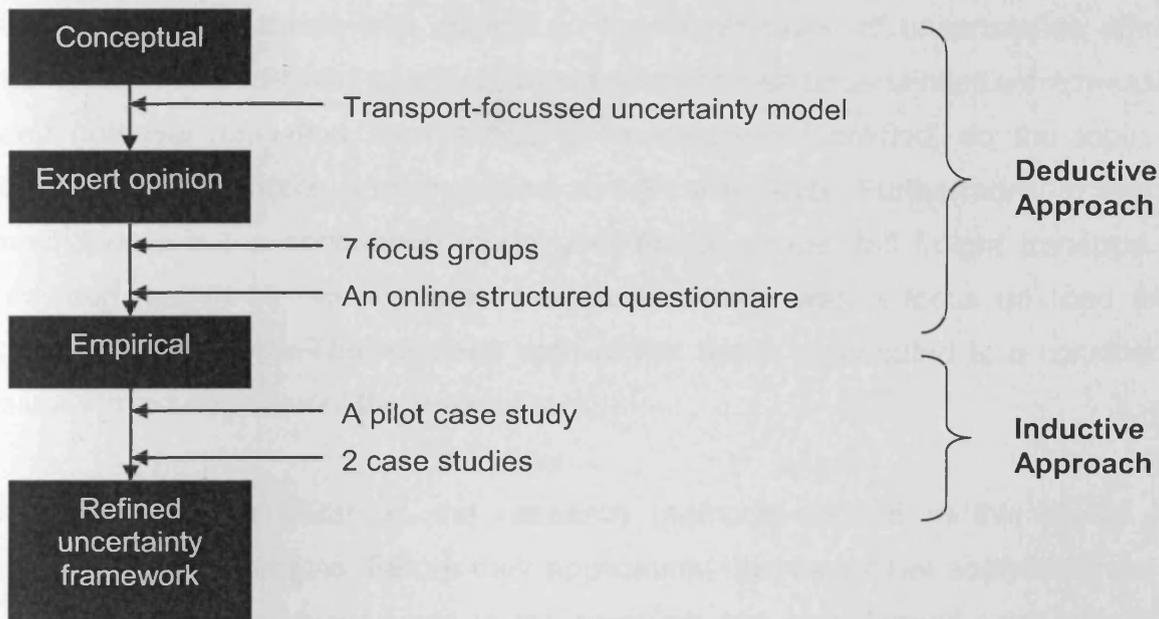


Figure 10.1 Methodological path to achieve the evolution of the PhD topic

After completing the survey, the refined transport-focused uncertainty model needed to be tested in real distribution networks. The objective was to connect uncertainty with transport performance in terms of cost and CO₂ emissions. However, the researcher did not find an appropriate measurement tool in the literature to achieve that objective. Therefore, a new and innovative measurement tool was developed and applied in a pilot case study. The learning experience of this demonstrated that theory cannot always be developed from the literature. This contradicts the positivist research paradigm. In this PhD, knowledge was developed initially from the literature, but a large proportion of the knowledge creation came from industry, which is what renders this PhD truly innovative.

In addition, methodological triangulation was used to validate and refine the findings throughout the PhD research path. Methodological triangulation has recently been recommended by a number of researchers in the logistics discipline. According to Dunn et al. (1993), 'a given discipline may be underachieving if all of its research is being conducted within a narrow methodological domain'. The methodological

approach of this thesis can be used as a guide for future doctoral works in the logistics discipline. The application of multiple methods has supported the research by iteratively refining the scope and boundaries of the thesis. In terms of the topic, the scope of the thesis was initially on the identification of uncertainties affecting transport operations, and after that, the impact of those uncertainties were measured and potential mitigation approaches to tackle them identified, so the topic was explored in its surface and explained at the micro level. Furthermore, in terms of boundaries, in the conceptual model and focus groups, rail freight transport was included, but in the survey and case studies there was a focus on road freight transport operations. The research path of this thesis contributed to a considerable extent to the evolution of the PhD topic.

According to the literature, the research methods applied in this thesis have strengths and limitations. Before their application, the researcher analysed them and decided that the methods used in the research can complement each other. This could improve the validity of the overall research findings. However, after undertaking the research, the researcher reflected on the strengths and limitations of the methods applied. This will be included in the next section, highlighting the complementary features between the methods and also the limitations learnt in their application.

10.2 Methodological synergies found between the methods applied in this thesis

Through the application of the research methods used in this PhD, as Table 10.1 shows, the researcher has reflected on the strengths and limitations of these methods to demonstrate how they have complemented each other in reality. Initially, it was clear in the literature that a conceptual model is applied to explore existent gaps and integrate knowledge within a research topic. Also, according to the literature a conceptual model is the starting point for knowledge creation. However, the literature emphasises that a conceptual model is still not scientifically proven. On the other hand, in the thesis, the researcher learnt that a conceptual model can be used to set direction for the rest of the PhD and synthesise and extend the body of knowledge on a topic. However, the findings from a conceptual model still need to be

refined by applying exploratory research methods that involve practitioners in the research process.

It is very difficult to verify a conceptual model by applying a structured survey. A method was needed that could support the transition between a conceptual model and a survey. Therefore, the focus group method was identified in the literature as a method capable of providing focus to a research topic offering a high degree of flexibility during the research process, since the interactions of participants from relatively small groups representing a large population can support the refinement of the conceptual model. On the other hand, the literature highlighted the fact that focus groups are an effective method to explore topics at the macro level but not at the micro level. Furthermore, in the conduction of focus groups, a facilitator with specific skills is required. This was overcome in the research by facilitating the group sessions with multiple researchers who could provide feedback to each other. From the literature, the researcher was aware that participants' personalities can negatively influence group discussions. This was an issue that was overcome by asking participants to record their opinion before the discussions began.

With regard to the conduct of the focus groups, it is important to highlight that this method is a very effective exploratory data collection technique. Moreover, due to the fact that practitioners are very interested in learning from each other, the attendance rate from the focus groups is considerably high, which compensates for the low response rate obtained in the survey, even after applying all the literature recommendations. However, given the fact that the focus group method is usually exploratory and a comprehensive contribution from each participant is required, a purposive sampling strategy was applied, so the findings still needed to be confirmed. This was overcome by applying the survey method, because the literature states that the survey method is an effective data collection technique capable of refining and testing theory. Furthermore, in the focus groups, theory saturation could be reached only at the micro level, but within individual sub-segments that took part in the focus groups.

Method	Type of RQs	Literature		Reflection	
		Strengths	Limitations	Strengths	Limitations
Conceptual model	What? Which?	<ul style="list-style-type: none"> - Capable of exploring existent gaps in the literature - Knowledge within the literature can be integrated - Support learning and knowledge creation 	<ul style="list-style-type: none"> - It is not scientifically proven 	<ul style="list-style-type: none"> - Can set direction of research - Capable of synthesising and extending body of knowledge in a topic 	<ul style="list-style-type: none"> - It is conceptual and needs to be refined by applying primary research - The scope of the research is still not well defined
Focus groups	Which?	<ul style="list-style-type: none"> - Give focus to a research topic - Provide high degree of flexibility in the process - Small groups that can represent a large population - Participants' interactions enhance data quality 	<ul style="list-style-type: none"> - Flexible facilitation is needed - Explore the macro but not the micro - Group personality can negatively influence the findings 	<ul style="list-style-type: none"> - Effective exploratory research method - Practitioners are very willing to contribute, so response rate is fairly high 	<ul style="list-style-type: none"> - Purposive sampling applied, further confirmation needed - According to the literature, it was difficult to record the opinion of participants, but their opinions were recorded before starting the discussion. - Theory saturation can be reached at the macro level but not at individual sub-segments of the groups
Survey	Which? How?	<ul style="list-style-type: none"> - Effective to refine and test theory - Findings can be statistically proven - Capable of achieving academic rigour 	<ul style="list-style-type: none"> - Only capable of describing and/or explaining the surface of a topic - Typically low response rate 	<ul style="list-style-type: none"> - Effective confirmatory method - Effective method to undertake sub-segment analysis - Jointly with the focus group defines the scope of the research 	<ul style="list-style-type: none"> - Low response rate, even after following all the literature recommendations - Subjectivity involved in quantifying qualitative constructs - Provides breadth but not depth to the study
Pilot case study	Which? How? Why?	<ul style="list-style-type: none"> - Inductive in nature, so new and innovative knowledge can be developed - Provides depth to a topic that has not been explored at the micro level 	<ul style="list-style-type: none"> - Single case studies are only valid if they are exemplar cases - In many instances, case studies do not have a network perspective - Findings from qualitative case studies are based only on a few interviews are anecdotal 	<ul style="list-style-type: none"> - Capable of developing and testing a concept not explored before in an industrial setting - Continuous feedback from the actors - Depth is achieved through triangulation of hard data and interviews 	<ul style="list-style-type: none"> - A topic that was not previously measured in the company, so it needed time to be developed - The researcher and planners spent a day refining the measure - Telematics data on planned and actual kilometres was not available to the researcher, so 'extra distance' due to route diversion could not be measured
Further case studies	How? Why?			<ul style="list-style-type: none"> - Learning from the pilot case study can be used to improve the data collection - Breadth is added to improve the study validity 	<ul style="list-style-type: none"> - More case studies needed to generalise the findings - Automated data collection needed to be more productive - Simulation is needed to generalise the results

Table 10.1 How the methods applied in the PhD complement each other

The findings from the online structured questionnaire assisted the researcher to complement the results of the focus groups and undertake an analysis based on the participants' sectors and supply chain roles. Moreover, it is important to state that the focus groups and survey jointly helped the researcher to define the scope of the research undertaken in the empirical stage of the methodological path.

In terms of the limitations of the survey method, the researcher also learnt that there is a considerable degree of subjectivity when respondents scored on the basis of their opinions. This was partially overcome by initially providing respondents with the definitions of the constructs before they began answering the questionnaire. However, the hard data and the interviews collected in the case studies helped the researcher to test the findings from the survey and focus groups. The empirical findings from the case studies tested and validated the opinions of the focus group participants and the survey respondents, since a continuous feedback from practitioners gave depth to the analysis and complemented the findings from the focus groups and survey.

According to the literature, case studies are inductive in nature, so new and innovative knowledge can be developed. In addition, the case study method is capable of providing depth to a topic that has not been explored at the micro level. However, the literature emphasises that multiple case studies are needed to ensure the validity of the research and a single case study is only valid if that is an exemplar case. According to methodological papers from the logistics discipline, findings from logistics case studies are often based on a single company rather than taking a holistic network approach. In the three case studies undertaken in this PhD, a network perspective has been taken including suppliers, the carrier and the customer. Furthermore, the literature provides a constructive critique of case studies in logistics, because many of them based their findings on anecdotal data from interviews. In the case of this PhD, hard data collected from the transport systems and processes of the companies has been triangulated with interviews with operating and management staffs.

While undertaking the case studies, the researcher experienced some additional strengths and limitations that were not highlighted in the literature. The empirical

research stage of this PhD consists of two parts: a pilot case study and two further case studies. Through the pilot case study a measure, the 'extra distance' measure, which had not previously been applied, could be developed. One of the limitations observed in the pilot case study was that the 'extra distance' measure was first applied to the first case study company when the case study started, so the researcher spent a considerable amount of time explaining the measurement to the planners. Additionally, on the first day of the data collection, the data gathered needed to be refined, since the planners still did not have a clear view of what incidents generate 'extra distance'. Furthermore, 'extra distance' due to route diversion was not gathered because data on planned and actual kilometres was not available to the researcher during the week when the data was collected. The lessons learnt in the pilot case study were used to improve the measurement tool, including route diversion and the time dimension of performance. Moreover, the two case studies add breadth to the findings from the first case study. One of the key learning points from this PhD is that when a concept, system and/or measure has not been studied before in the literature, an inductive pilot case study is needed to properly develop the topic explored, after which the topic can be tested in that and other case studies.

Nevertheless, there remain some limitations to the case studies applied in this thesis. The findings found on the topic of uncertainty and road freight transport operations cannot be generalised, since further case studies from the FMCG sector are needed. The researcher needed to spend a considerable amount of time in the case study companies collecting and analysing data. This could be avoided if the data collection were automated. Furthermore, in order to generalise, the findings data from the three case studies could be used to simulate different uncertainty events so that their frequency and impact, in terms of 'extra distance' and 'extra time', could be estimated.

10.3 New and innovative measurement tools for data collection in logistics research

In the data collection, two new and innovative data collection and analysis techniques have been developed and applied. At all the stages of the focus groups, frameworks and techniques were developed to undertake the research. In addition, throughout the case studies, a measurement system was developed and improved by taking an inductive approach. These two techniques will be discussed in the next section of the chapter.

10.3.1 Tools applied to gather and analyse data in focus groups

In order to apply the focus group method, as presented in Figure 10.2, a series of frameworks and techniques were developed. This is one of the key contributions of this PhD. First, the literature on focus group research from the management field provides an initial guide to the researcher. A generic framework for designing and conducting focus groups and analysing data collected from focus groups was developed from the literature (Krueger 1998, Morgan 1998), but also adapted to logistics research. Furthermore, from the lessons learnt in the focus group process, a framework was developed to guide the design and conduct of future focus groups in logistics. As shown in Figure 5.3 in Chapter 5, this framework highlights the factors that influence the effectiveness of focus groups.

In addition, according to the literature in logistics, focus groups are regarded as a method lacking in academic rigor, since the discussions tend to be biased due to the fact that participants with strong personalities can mislead the group. In this PhD, the data collection approach was intended to mitigate that limitation by asking participants to record their opinion in Post-It notes. Although one could argue that this arrangement might inhibit the group discussion, this was not the case, since a discussion was facilitated where participants had the opportunity to explain their Post-It notes while other participants contributed to the discussion. After that, the participants clustered all the Post-It notes and a cause-and-effect exercise was run from the cluster that had more Post-It notes. By starting with the individual comments

from the Post-It notes, the data collection technique gave equal opportunity to all participants to intervene in the group discussion; this gave breadth to the data collected. Meanwhile, the cause-and-effect exercise provided depth to the analysis.

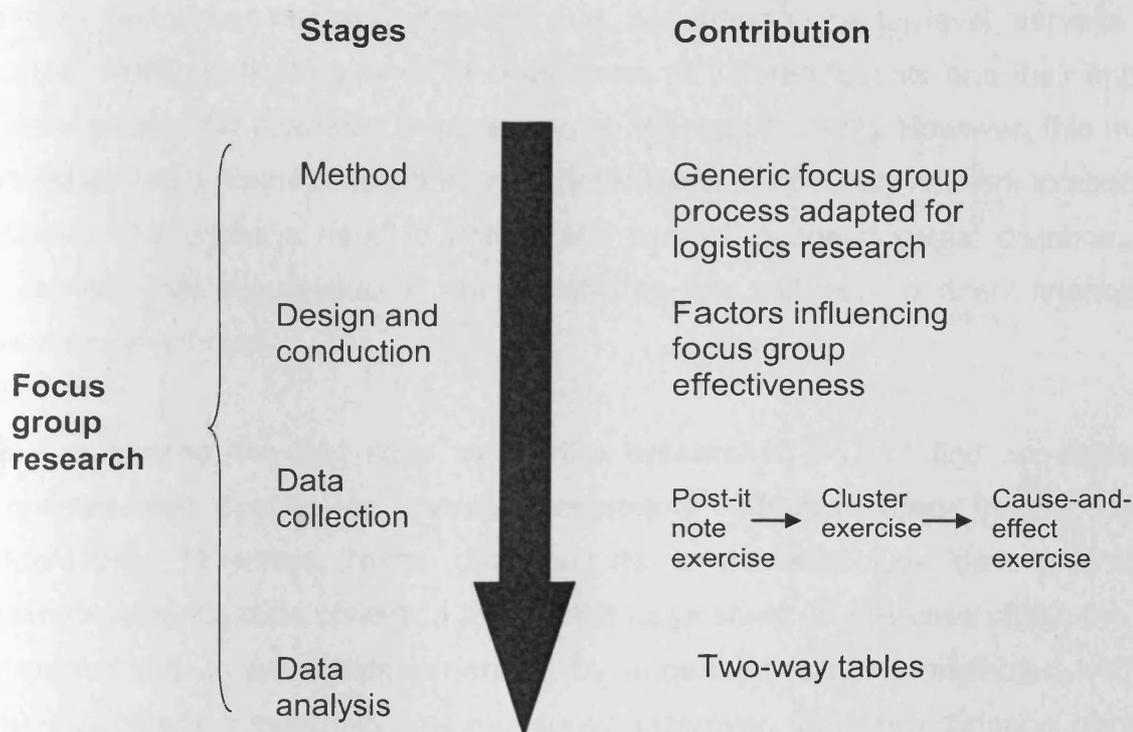


Figure 10.2 Tools used to apply the focus group method in logistics research

Additionally, due to the fact that the data presented a number of dimensions, uncertainty causes, uncertainty clusters, participant's sector and participant's supply chain role, two-way tables were used to analyse the findings. This is a technique that was not found in the literature, but can support the analysis of future focus groups undertaken in logistics research.

10.3.2 Transport uncertainty evaluation tool

Previously, researchers have focussed on measuring the absolute and/or average performance of road freight transport operations (Fowkes et al. 2004; McKinnon and Ge, 2004). However, the link between difference uncertainty causes and the economic and environmental performance of road freight transport operations have not been previously researched. In this PhD, this gap has been addressed by

developing and testing a transport uncertainty evaluation tool. In the case studies undertaken in this study, as Table 10.2 shows, a transport uncertainty evaluation tool has been developed and improved. The sector chosen to develop this tool was the FMCG sector, which encompasses grocery and clothing. The decision to select the FMCG sector was based on the fact that, according to sector level, surveys in the UK do highlight the frequency of occurrence of different events and their impact in terms of time (for example, Department for Transport, 2007). However, this may not translate into a financial cost if there is flexibility in the delivery network to absorb the delays. There was a need to understand more fully the marginal distance, 'extra distance', that occurs due to uncertainty, as this will have a direct financial and environmental cost.

Before starting the first case study, the researcher did not find an appropriate measurement system to assess uncertainty affecting road freight transport operations. Therefore, 'extra distance' as a measure was developed before commencing the data collection in the pilot case study. In this case study, the 'extra distance' due to extra trips generated by uncertainty causes originated within the supply chain and externally was measured. However, the 'extra distance' generated due to route diversion was not measured because the logistics providers did not make available to the researcher telematics data at individual planned trip level, so the researcher could not compare the planned and actual kilometres of every trip. Also, in the first case study, the time dimension of performance was not included in the assessment, since the most important objective was to develop and test the 'extra distance' measure.

In the second case study, the 'extra distance' measure was improved from the lessons learnt in the first case study. The assessment used company reports instead, collecting the data live. The logistics provider records all the extra trips generated due to unforeseen events. In addition, the researcher used the experience of applying the tool in the UK and provided training to the practitioners involved in the data collection. In the assessment, the 'extra distance' measure was complemented by an additional measure of 'extra time' developed after the second case study. This measure was developed from the literature on delays (Fowkes et al, 2004; McKinnon and Ge, 2004). The uncertainty causes that generate delays, but not extra trips,

were gathered from a company report. This case study did not measure route diversion of individual trips and variance in terms of time and distance within all the planned trips.

Case study	Supply-chain uncertainty assessment			External uncertainty evaluation				Measure(s)	Limitations and improvement
	'Extra distance' due to extra trips	'Extra time'	Variance analysis	'Extra distance' due to extra trips	'Extra time'	'Extra distance' due to route diversion	Variance analysis		
UK primary distribution network (Chapter 8)	✓			✓				'Extra distance'	- Route diversion was not measured - The time dimension of performance was not considered
South African secondary distribution network (Chapter 9)	✓	✓		✓	✓			'Extra distance' complemented by the causes of delays	- A trip-level assessment was not undertaken
UK secondary distribution network (Chapter 10)	✓	✓	✓	✓	✓	✓	✓	Combined assessment of 'extra distance' and 'extra time'	- Time-consuming assessment, it needs to be automated.

Table 10.2 Evolution of the transport uncertainty assessment tool

The limitations from the second case study were used in the third case study to improve the transport uncertainty evaluation tool. In the final case study, two assessment exercises were undertaken. The first was based on data recorded by the transport operation on the extra trips generated due to uncertainty originated within the supply chain and externally; basically the same approach used in other two case studies was applied. However, an additional assessment was included to compare the transport plan with the execution of the delivery, including the two dimensions of transport performance, distance and time. This assessment was undertaken at individual trip level. Also, a variance analysis was undertaken to assist the researcher in identifying key patterns within the data gathered.

10.4 Transport uncertainties found throughout the PhD

In the first stage of this PhD, a transport-focussed uncertainty model was developed from the literature. This model was developed based on previous supply chain uncertainty frameworks (Davis, 1993; Mason-Jones and Towill, 1999; Peck et al. 2003). The objective of the model was to identify the uncertainty causes that generate inefficiency within transport operations. The literature on uncertainty and transport operations was fragmented and disjointed. The aim of this section is to review the main uncertainty causes found throughout the research stages of the thesis.

Main uncertainty causes from the conceptual model	Main uncertainty causes from the focus groups	Uncertainty causes found in the case studies	Where identified		Uncertainty clusters developed in the focus groups and the survey					Consequences measured in the case studies			
			Focus groups	Case study	Delays	Variable demand and/or inaccurate forecast	Lack of supply chain integration and coordination	Delivery constraints	Other	Extra trips	Extra distance	Extra time	
Demand and inventory management issues (25 papers)	Demand forecast accuracy	Late notification of extra volume	✓	(1), (2) & (3)		✓					✓		
	Product demand volatility		✓			✓							
	Lack of information visibility		✓			✓							
	Sub-optimal inventory policy		✓			✓							
		Physical load smaller than advised		(1)		✓					✓		
Supplier inefficiency (25 papers)	Supply disruptions		✓		✓								
	Loading delays	Loading delays	✓	(1), (2) & (3)	✓					✓		✓	
		Product not loaded at supplier		(1), (2) & (3)			✓			✓			

in uncertainty causes from the conceptual model	Main uncertainty causes from the focus groups	Uncertainty causes found in the case studies	Where identified		Uncertainty clusters developed in the focus groups and the survey					Consequences measured in the case studies			
			Focus groups	Case study	Delays	Variable demand and/or inaccurate forecast	Lack of supply chain integration and coordination	Delivery constraints	Other	Extra trips	Extra distance	Extra time	
Unloading inefficiency (8 papers)	Unloading delays	Unloading delays	✓	(2) & (3)	✓						✓		✓
Insufficient fleet capacity (6 papers)							✓						
Internal carrier inefficiency (11 papers)		Technical vehicle failure		(2) & (3)			✓				✓		
		Product not loaded at distribution centres		(2) & (3)			✓				✓		
		Planning failures		(1), (2) & (3)			✓				✓		
		Unplanned stops		(3)	✓								✓
Macroeconomic factors that impact on cost (13 paper)									✓				
Unplanned road congestion and road restrictions (7 papers)	Unplanned road congestion	Unplanned road congestion	✓	(1) & (3)	✓						✓	✓	✓
	Delivery curfews	Road restrictions	✓	(3)				✓					
		Road restriction	✓		✓			✓			✓		
Insufficient supply chain integration (13 papers)	Sales not connected to logistics		✓				✓						
	Carrier not integrated to the supply chain		✓				✓						
Issues related to unloading restrictions (8 papers)	Limited storage capacity		✓					✓					
	Tight delivery windows		✓					✓					

Table 10.3 Uncertainty causes found throughout the PhD

In the focus groups, 15 uncertainty clusters were developed. Furthermore, the focus group findings highlight that the main four uncertainty clusters affecting transport operations are: delays, variable demand and/or inaccurate forecast, lack of coordination and delivery constraints. These uncertainty clusters were confirmed in the survey. As Table 10.3 shows, uncertainties relating to these uncertainty clusters

have connections with the main uncertainty themes found in the conceptual model. In addition, Table 10.3 draws connections between the uncertainty causes gathered in the case studies and uncertainty causes and clusters found in the earlier stages of the research. Moreover, it shows the consequences, in terms of extra trips, 'extra distance' and 'extra time', that the uncertainty causes can have.

10.4.1 Delays

The main uncertainty cluster found in the focus groups was delays. The main uncertainty causes related to delays populated in the conceptual model are: supplier inefficiency, unloading inefficiency, internal carrier inefficiency and unplanned road congestions and road restrictions. All these uncertainty causes found in the literature occurred within the delivery process. In the literature, there is considerable emphasis on delays generated during the delivery process (Esper and Williams, 2003; Fowkes et al. 2004; McKinnon et al. 2009). However, the literature does not clarify how delays can negatively affect the economic and environmental performance of road freight transport operations. With the exception of carrier inefficiency, all these uncertainty causes were found in the focus groups and confirmed in the survey. However, all of these causes were gathered in the case studies. Also, delays throughout the delivery process always generate 'extra time', but only generate extra trips if the vehicle that is delayed missed the next load scheduled for it, so an extra vehicle needs to be added to the operation. Furthermore, delays due to unplanned road congestion can generate 'extra distance' if the vehicle is diverted from its optimal route, 'extra time' if the vehicle is held in a traffic jam and extra trips if that vehicle missed its next consignment assigned in the transport schedule. This is one of the main findings of this PhD, since the previous literature does connect unplanned road congestion with delays (Boughton, 2003; Fowkes et al. 2004; McKinnon and Ge, 2004; McKinnon et al. 2009) but not to 'extra distance'. This will be explained further in the next section.

10.4.2 Variable demand and/or inaccurate forecast

'Variable demand and/or inaccurate forecast' was the second most important uncertainty cluster gathered in the focus groups. This was confirmed in the survey. In

the conceptual model, the main uncertainty theme that relates to this cluster is 'demand and inventory management issues'. A number of authors emphasise that difficult and non-standard orders can have a negative impact on the delivery process (Boughton, 2003; Fowkes et al. 2004; Vickery et al. 1999). However, the literature does not link 'variable demand and/or inaccurate forecast' with unnecessary or extra transport movements run within distribution networks. During the focus groups, this uncertainty cluster was linked either with demand and forecast issues or inventory issues. On the other hand, although uncertainty causes related to 'variable demand and/or inaccurate forecast' were recorded in all three case studies, the level of importance of this uncertainty cluster was bigger in the first two case studies than in the third case study. A possible reason for this difference is that route diversion due to unplanned road congestion and ad-hoc and unexpected road restrictions was not measured in the first two case studies, but was measured in the third case study.

One of the main limitations that the first two case studies have is the fact that 'extra distance' due to route diversion could not be measured. This could make the effects of 'variable demand and/or inaccurate forecast' slightly larger in these two case studies. 'Variable demand and/or inaccurate forecast' was found in the case studies in two forms: 'late notification of extra volume' and 'physical load smaller than advised'. 'Late notification of extra volume' occurs when the suppliers and/or the customer increase their volume requirements but give less than two hours notice to the carrier to arrange and start the delivery process. This problem generates extra trips due to the fact that the load is not moved in the most efficient way, whereas 'physical load smaller than advised' occurs when vehicles arrive at loading bays and the actual load is less than the planned load. Thus extra trips are generated because these movements are sub-optimally run. This will be discussed to a greater extent in the following section.

10.4.3 Insufficient supply chain integration and coordination

Another main uncertainty cluster found in focus groups and confirmed in the survey was 'insufficient supply chain integration and coordination'. In the conceptual model, the main uncertainty themes that can be linked to this uncertainty cluster are:

supplier inefficiency, insufficient fleet capacity, internal carrier inefficiency and insufficient supply chain integration. A considerable number of authors emphasise the importance of supply chain coordination (Fowkes et al. 2004; Mason et al. 2003; Morash and Clinton, 1997). Also, a number of research works highlight the fact that insufficient supply chain integration can affect the overall performance of the supply chain (Fowkes et al. 2004; Mason et al. 2003; Naim et al. 2006). However, the impact of this uncertainty cluster on the performance of road transport operation is not clarified in the literature. In the focus groups, the uncertainty causes under this cluster that had more Post-It notes were 'sales not collected to logistics' and 'carrier not integrated to the supply chain'. These two uncertainty causes are caused by problems of communication within the carrier and the shipper and/or an adversarial relationship between the customer and the carrier.

These are uncertainty causes that are difficult to measure at the micro level, since they are intangible and qualitative factors. Hence, they were not found in the case study quantitative assessments, but insufficient supply chain integration was an important theme that leads to most of the 'extra distance' gathered. For example, in the South African secondary distribution operation, most of the 'extra distance' gathered was generated due to communication and relationship barriers between the customer and the carrier. Also, in the UK primary distribution operation, a large proportion of the 'extra distance' found was generated due to a lack of integration in the volume forecast process within the logistics triad. On the other hand, in the case studies, there were three uncertainty causes that generate extra trips that can be linked with insufficient coordination and integration. These are technical vehicle failure, planning failures and product not loaded at distribution centres. When there is a technical vehicle failure and the vehicle available to replace the broken vehicle is of a smaller size than the required size according to the transport plan, the need for an extra trip is generated. Similarly, when there is a planning failure in terms of the size of the load required, more trips are run in a suboptimal manner when the delivery is executed.

10.4.4 Delivery constraints

Other important uncertainty cluster gathered in the focus groups and also confirmed in the survey was 'delivery constraints'. In the conceptual model, the main themes that are related to this uncertainty cluster are: 'unplanned road congestion and road restrictions' and 'issues related to unloading restrictions'. Unplanned road congestion and road restrictions have been identified in previous research works as a major barrier in the delivery process (Fowkes et al. 2004; Golob and Regan, 2001; McKinnon and Ge, 2004; McKinnon et al. 2009). These authors have stated that unplanned road congestion and road restrictions are two of the main causes of delays. However, in the third case study, these two uncertainty causes generate 'extra distance' due to route diversion rather than delays. This adds a new dimension to the literature on unplanned road congestion and road restrictions. In the focus groups, there were two 'delivery constraints' issues originated in unloading facilities and one that can be originated while the vehicle is running. According to the focus group participants, limited storage capacity and tight delivery windows at customer facilities can generate confusion and excessive queues at unloading bays. Although these two uncertainty causes were not recorded in the case studies, they were one of the main causes of delays at outlets in the third case study, the UK secondary distribution operation.

In the case studies, the only 'delivery constraint' uncertainty cause found was ad-hoc and unexpected road restriction. The distribution network study in this case study is a UK secondary distribution network that covers the North River-Thames London areas and areas of South East Midlands. One of the key findings from the third case study is that this issue generate 'extra distance', since the vehicles need to be diverted from the most optimal route. However, road restrictions should not generate extra trips, because they are considered, in the form of slack time within the delivery time of night deliveries, when the transport plan is undertaken.

10.5 Refined decision-making framework for the diagnosis and mitigation of uncertainty in transport operations

In this section of the chapter, the main findings of the PhD are synthesised into the framework that is shown in Figure 10.3. The objective of this framework is to guide future diagnosis of uncertainty in road freight transport operations. Also, this refined framework connects the causes and clusters of uncertainty recorded in the case studies with the mitigation approaches applied by the three road freight transport operations studied.

10.5.1 Delays

In the case studies, delays originated at unloading and loading bays, and due to unplanned stops and unplanned road congestion. In the literature on delays, there was an emphasis on measuring and evaluating the different causes of delays in terms of time (Esper and Williams, 2003; Fowkes et al. 2004; McKinnon et al. 2009). However, in the case studies, the impact that delays have on road freight transport performance is measured in terms of 'extra distance' and 'extra time'. In this way, it is possible to connect delays with the extra transport cost and extra CO₂ emissions that they generate. In the UK primary distribution network, delays at loading bays only generate 7% of the extra kilometres gathered. On the other hand, in the South African secondary distribution operation, 62% of delays generate at loading bays, but they do not generate extra trips since the transport planners re-scheduled the loads within the vehicles that are available in the distribution centres. So, delays in this transport operation generate 'extra time' but not extra trips. This is due to the fact that this operation has a considerable degree of contingency embedded within the delivery process in the form of a comparatively low target vehicle capacity utilisation (55%) and more slack time within the delivery time. Whereas, in the UK secondary distribution operation, the target vehicle capacity utilisation is 85% and there is not as much slack time within the delivery time as in the South African secondary distribution operation. For this reason, in this UK secondary distribution operation, delays at unloading bays represent a greater proportion of the 'extra distance' generated.

Mitigation approaches	Carrier internal control	✓	✓	✓	✓				✓		
	Economical incentives		✓		✓	✓	✓	✓			
	ICT transport systems						✓	✓	✓	✓	✓
	Effective transport planning		✓	✓			✓	✓	✓	✓	✓
	Effective transport re-planning					✓	✓	✓		✓	
	Effective volume forecast				✓	✓					
Uncertainty sources	External									✓	✓
	Carrier	✓	✓	✓					✓		
	Control systems					✓					
	Customer					✓		✓			
	Shipper		✓		✓	✓	✓				

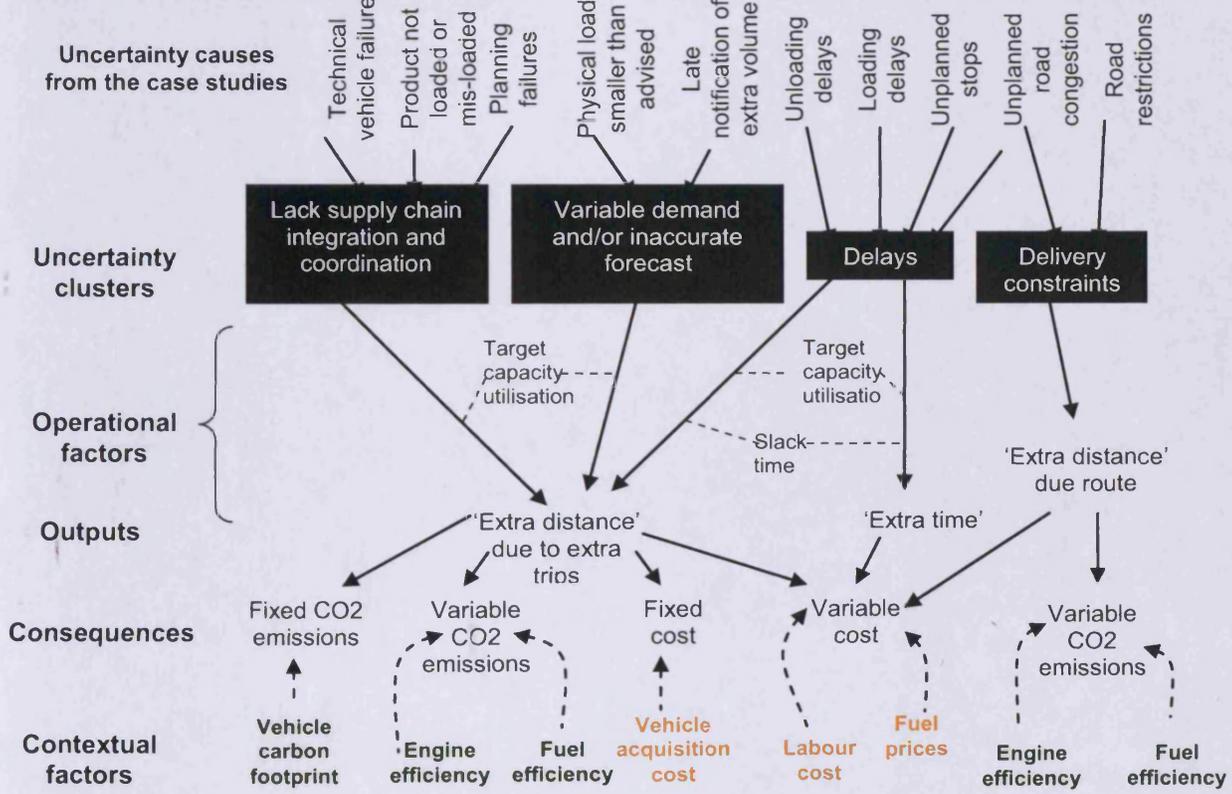


Figure 10.3 Diagnosis and mitigation of uncertainty in road freight transport

In the first case study, only 4% of the extra kilometres recorded were generated due to extra trips caused by unplanned road congestion. However, the effect that unplanned road congestion has on route diversion was not measured in this case study. Also, the amount of 'extra time' that unplanned road congestion generates was not measured in this case study. However, in the UK secondary distribution operation, the impact of unplanned road congestion was measured in terms of both 'extra time' and 'extra distance' due to route diversion. In this operation, unplanned road congestion generates 1,448 extra kilometres but only 6 hrs of 'extra time' in 30% of the trips planned in the week of data collection. This contradicts the freight best practice report published by the Department for Transport (2007) on key performance indicators in the food and drinks supply chains. This report stated that 19% of delays within the delivery process occur due to traffic congestion. However, according to the findings from the third case study, unplanned road congestion is much more likely to generate extra kilometres rather than extra delivery hours. Since, the transport operation is frequently able to anticipate unplanned traffic jams, drivers are encouraged by the case study company sales department to arrive on time at outlets, regardless of the amount of kilometres run during the journey. Therefore, when an unexpected traffic jam can be anticipated, unplanned road congestion generates 'extra distance' due to route diversion, but if the unforeseen traffic jam could not be anticipated, unplanned road congestion can generate 'extra time'. This is an aspect of unplanned road congestion that is not considered by the authors (Fowkes et al. 2004; Golob and Regan 2001,; McKinnon and Ge 2004; McKinnon et al. 2009) who have previously undertaken research in this topic. Therefore, unplanned road congestion can either generate 'extra distance' or delays. When unplanned road congestion generates 'extra distance' the variable cost of transport and the variable CO₂ emitted while the vehicle is running increase, but the fixed cost of transport remains the same, because of the fact that vehicles do not miss their next scheduled loads, so extra vehicles are not needed. On the other hand, when unplanned road congestion generate delays, 'extra time' always is generated but in some cases extra trips are required as well. 'Extra time' impact only in the variable cost of transport, whereas extra trips have a negative effect on both the fixed cost and the variable cost of transport, and also on the variable CO₂ emitted while the journey happens and the fixed CO₂ emitted when the vehicles are manufactured. The same principle applied to all causes of delays.

When delays generate extra trips, if a portion of the original volume is ready to be loaded and if that volume is very sensitive to the customer, it is despatched and sent to the customer's facilities and the transport operation delivers an extra vehicle later to collect the delayed load. These types of problems are linked to some of the McKinnon's CO₂ emissions ratios. They generate extra trips with lower capacity utilisation, so they decrease the average load in laden trips and potentially increase the average empty running. Also, they make the transport operation run twice the kilometres that were originally planned, so the average length of haul rises.

In addition, a number of approaches to mitigate and/or respond to delays were observed in the case studies. In the UK secondary distribution network, the ICT transport system available provides rich live information on the delivery process that assists the decision makers to minimise the impact of delays. Also, when a planner needs to intervene in the process, they have means to respond to delays as well. On the other hand, in the UK primary distribution network, delays are mitigated through effective transport planning undertaken in Excel. This operation has four transport planners that plan and follow the daily progress of all the primary movement throughout the UK. Furthermore, in the UK primary transport operation and in the South African secondary transport operations, due to contractual arrangements, the suppliers or the customer are charged for extra trips due to delays originated in their facilities as long as they are identified as the entity that directly originates the 'extra distance'. Thus, in these two case studies, the suppliers and the customer have an economic incentive to minimise delays, but the carrier perceives more revenue due to delays caused by their partners, because of the fact that more movements are needed. In the UK primary distribution operation, suppliers would generally be economically incentivised to minimise 'extra distance', even though in many cases suppliers respond primarily to their customer demand. However, the challenge is that most of the time it is not possible for the logistics provider to identify a supplier as the cause of the incident. On the other hand, in the UK secondary distribution network, the same company manages the transport function and the stores, when a delay at an outlet generates an extra trip, the outlet is not internally charged for the delay.

10.5.2 Variable demand and/or inaccurate forecast

In the case studies, variable demand and/or inaccurate forecast originated at the suppliers in the UK primary distribution network and the customer(s) in the two secondary distribution networks. In previous literature works, there is an emphasis on the excessive variation that this uncertainty cluster generates in the demand for transport (Boughton, 2003; Fowkes et al. 2004; Vickery et al. 1999). In two of the case studies, the proportion of 'extra distance' generated by this uncertainty cluster is very large. This has a negative impact on cost and CO₂ emissions. Overall, in the three case studies under this cluster, two uncertainty causes were observed: late notification of extra volume and physical load smaller than advised.

These two uncertainty causes affect three of the factors included in the McKinnon's (2007) framework: the average length of haul, the average load on laden trips and the average empty running. Most of the time, 'late notifications of extra volume' force the carrier to run deliveries with a low capacity utilisation and the carrier tends not to find a backload for these trips, so the average load on laden trips decreases and the average empty running rises. Also, sometimes the increase in volumes comes from remote geographical locations where the carrier cannot find the most economical subcontractor to run the trip. 'Physical load smaller than advised' reduces the average capacity utilisation of the vehicles, since when the carrier re-plans the trips after they were executed, they realise that they needed fewer trips, and as a result, fewer kilometres. Therefore, the average length of haul and the average empty running increases. In addition, empty running increases when a remote supplier needs a trip, because the carrier does not have sufficient time to find an economical subcontractor for the trip. Consequently, the extra load is moved with an in-house vehicle that needs to return empty to the distribution centre where the trip started.

In the UK secondary distribution operation, about 8% of economic losses and 9% of the CO₂ emitted due to uncertainty is generated due to 'late notification of extra volume' from a few outlets and a few suppliers. In this operation, variable demand and/or inaccurate forecast represent a relative small proportion of the problem. In the UK primary distribution operation, these two uncertainty causes generate 75% of the

extra kilometres recorded and 75% of the number of 'extra distance' incidents gathered during the week of data collection. Also, these two uncertainties contribute to the 'extra distance' recorded on a similar proportion. On the other hand, in the South African secondary distribution operation, 40% of extra kilometres gathered are caused by 'late notification of extra volume', but only 6% of the 'extra distance' recorded is generated due to 'physical load smaller than advised'. The reason for this is that the first case study is a UK primary distribution network that has more than 100 suppliers and only about a few of them have frequently very inaccurate forecast of volume demand. Meanwhile, in the South African secondary distribution operation, the customer tends to increase the volume, leaving very short notice for the carrier to respond efficiently to these changes, but 'physical load smaller than advised' only occurs in a small area of the network. The South African transport operation is very sensitive to volume increases, due to the fact that even though the overall vehicle capacity utilisation is 55%, the customer imposed very rigid and tight delivery windows to the carrier, so when an extra load is required, it is not possible to allocate that load in an existent trip that needs to go to the same neighbourhood because departure time of that vehicle is later in the day and is not changeable or negotiable.

By contrast, in the UK primary distribution operation, where the target vehicle capacity utilisation is 85%, extra trips are generated due to the fact that the transport planner does not have enough time to re-optimize the movement in the most economical way. A finding that needs to be highlighted is the fact that there are two operational factors that influence how large is the impact that variable demand and/or inaccurate forecast have on transport performance. These are the target vehicle capacity utilisation and how delivery windows are scheduled throughout the daily transport execution.

In the three case studies, variable demand and/or inaccurate forecast generates extra trips, so this uncertainty cluster increases the total number of kilometres and the total number of vehicles needed. Therefore, economically speaking, this uncertainty cluster increases the variable and fixed costs of transport. Similarly, from an environmental perspective, it generates unnecessary CO₂ emissions due to the extra kilometres run and due to the extra vehicle capacity that needs to be

manufactured. However, the variable CO₂ emissions generated due to 'extra distance' is an avoidable problem, but when a vehicle has been already manufactured, it represents a sunk cost and the CO₂ emissions previously generated cannot be avoided. However, if the supply chain volume demand forecast improves, in the long term, the total fleet capacity required within the network could be reduced.

In addition, it is important to discuss the approaches that can be applied in the three distribution networks studied to mitigate and/or respond to variable demand and/or inaccurate forecast. 'Physical load smaller than advised' is a problem that is generated in the first two case studies. This issue can be mitigated if the carrier improves the internal control of the load size, auditing whether the actual load is the same as the planned load. In this way, the carrier can detect the deviations and charge their customer, which is a supplier, for the extra trips generated by these types of abnormalities. Thus, this supplier will have an economic incentive to reduce the occurrence of this issue, although in many cases suppliers are driven primarily by their customer demand. However, the challenge is that in many cases it is not possible for the logistics provider to identify a supplier as the main cause of the 'extra distance' incident. On the other hand, in the UK primary and South African secondary transport operations, the carriers are charging their customers for the extra trips generated by 'late notification of extra volume', so the suppliers and/or the customers already have an economic incentive to lessen the effect of this issue, but in many cases, they are driven by the end customer demand. In the transport planning stage, these two causes of extra trips can be mitigated if the carrier works together with the suppliers and the customers to make the volume forecast process more accurate and holistic throughout the supply chain. Moreover, 'late notification of extra volume' can be reduced through a responsive approach to the extra volume requirements and subcontractors have a key role to play in this when they can move the load in a more cost-effective way than the carrier. This was particularly observed in the UK primary distribution network.

10.5.3 Insufficient supply chain integration and coordination

In the case studies, insufficient supply chain integration and coordination originates at distribution centres. The literature emphasises that operational problems at

distribution centres can originate delays, synchronisation problems and queues at unloading facilities (Esper and Williams, 2003; Morash and Clinton, 1997). However, the literature does not appear to identify the impact that internal inefficiencies at distribution centres have on 'extra distance'. This is something that has been addressed in this thesis. Overall, in the three case studies under this cluster, three uncertainty causes were observed: technical vehicle failure, product not loaded at the shipper and planning failure. In the UK primary distribution operation, lack of coordination generates about 14% of the total 'extra distance' gathered and three quarters of the 'lack of coordination' incidents gathered were caused by internal errors of coordination within the carrier. At this carrier, when the product was not loaded or mis-loaded at a distribution centre, additional movements were generated as a knock-on effect. When product is not loaded, the capacity utilisation of the vehicles is less than the original capacity utilisation planned for the trips. This lowers the average load in laden trips identified in McKinnon's (2007) framework. In addition, more trips are needed for the same volume of products, so the average length of haul and potentially the average empty running rise. Also, in the South African distribution network, when a considerable volume of products was left over to the next day, extra trips were needed. That generates 50% of the 'extra distance' recorded in the exercise. In contrast to the UK primary distribution network, this issue originates at the distribution centres run by the customer.

In the South African case study, the more typical causes of this type of coordination problem were insufficient picking and sorting staff and IT failures inside the distribution centres. When products are not loaded at their scheduled vehicles, this generates sheer volume, and as a result, later extra movements are required. On the other hand, 'product not loaded at distribution centres' only represents around 3% of the 'extra distance' recorded in the assessment undertaken in the UK primary distribution network. Furthermore, planning failures represent 8% of the 'extra distance' gathered in the UK primary distribution network and only 4% of the 'extra distance' recorded in the South African secondary distribution operation, but this problem was not found in the UK secondary distribution network. Planning failures and technical vehicle failures have the same knock-on effect, extra trips due to smaller vehicle than planned. In some cases, when there is a failure in the

distribution network the correct vehicle size is not available and only a smaller vehicle is available, so two trips are needed instead of one.

It is important to mention that the uncertainty causes found in the case studies that can be linked to the focus group cluster of lack of supply chain integration and coordination all relate to lack of coordination rather than insufficient supply chain integration. However, as has already been mentioned, insufficient supply chain integration is an intangible theme, that even if its effect on performance has not been explicitly quantified in the assessments, it generates a great proportion of the 'extra distance' in the three case studies, especially when 'extra distance' is produced due to lack of communication and insufficient information visibility within the logistics triad.

In the three case studies, lack of supply chain integration and coordination generates extra trips. Therefore, from an economical view-point, this uncertainty cluster increases the variable and fixed cost of transport. Also, environmentally speaking, it generates extra variable and extra fixed CO₂ emissions.

In most of the cases, the carrier is the entity that can mitigate the impact that lack of coordination has on transport performance. First of all, the control of the internal operational processes within the carrier can reduce 'extra distance'. For example, inside the distribution centres, in the process of picking and sorting of products, there is the need to minimise the errors that generate sheer volume that can cause extra trips. However, the planning of resources for this process, staffs and/or machines, need to be revised as well. Also, in the case of technical vehicle failures, only the maintenance of vehicles needs improvements. On the other hand, in the South African secondary transport operation, 'product not loaded at distribution centres' can only be reduced if the customer, the entity that managed the distribution centres, revised the process of picking and sorting of products. Due to contractual arrangements, the customer needs to pay extra for the additional vehicles needed and also extra for the unnecessary kilometres run due to this issue. Therefore, they have an economic incentive to correct this problem, but if this issue is mitigated the carrier will receive less revenue.

10.5.4 Delivery constraints

The only case study where the effect of delivery constraints was measured was the UK secondary distribution operation. Previous research works on delivery constraints have been primarily focussed on the effects that this uncertainty cluster has on the time dimension of performance (Esper and Williams, 2003; Fowkes et al. 2004; Morash and Clinton, 1997). However, they do not estimate the impact of delivery constraints in terms of 'extra distance'. The two dimensions of performance, time and distance, have been considered in two of the case studies. This is one of the main contributions of this thesis. Two causes of delivery constraints were observed in this case study: unplanned road congestion and road restrictions. As mentioned previously, unplanned road congestion can generate delays if drivers do not anticipate a traffic jam, but in this particular case study, the vast majority of the time drivers are able to anticipate traffic problems. This can be considered restrictions that generate the need for vehicles to be diverted from their originally planned routes, so 'extra distance' is added to existent trips. Route diversion due to unplanned road congestion generates 22% of the 'extra distance' recorded in this case study. On the other hand, road restrictions only generate route diversion, since there is slack time purposively added to the delivery process to tackle them. Ad-hoc and unexpected road restrictions generate 38% of the 'extra distance' measured in this assessment. When road restrictions and/or unplanned road congestion increases the distance of originally planned trips, the average length of haul, one of McKinnon's (2007) CO₂ emissions ratios, rises. These types of delivery constraints generate 'extra distance' within originally planned trips, so they increase only the variable cost and the variable CO₂ emissions of transport. Road restrictions should not be uncertainty per se, but the fact that the 27 London boroughs continuously change them in an uncoordinated and ad-hoc manner make this type of road restrictions uncertain events.

However, in the specific case of the South African case study, rigid delivery windows imposed by the customer inhibit the carrier to use the space available on originally planned vehicles. This type of problem can lower the average load on laden trips, one of the McKinnon's (2007) CO₂ emissions ratios, since the capacity utilisation of the vehicles is lower. For example, if an outlet located at the 'area A' needs an extra

half load at 12:00 and there is another vehicle that will drop half load at 14:00 to another outlet located in the same area, the customer does not allow changes in the delivery time. Thus, this inhibits the reduction of 'extra distance'. This type of restriction cannot be considered uncertainty since they are known before the transport plan is undertaken, but it worsens the effect of late notification of volume increases required by the customer.

In the UK secondary case study, the transport operation is planned and run in-house. The transport movements within the distribution network are planned and executed at the central planning office of the North London distribution centre. As mentioned in Chapter 10, the planning, monitoring and re-planning of the delivery process is undertaken in a fully automated transport system. This system is used to minimise the effect of unplanned road congestion and road restriction. However, in this study and also in the other two studies, the accuracy of the transport planning in terms of time and location restrictions are very important. If the transport planning is not effective, restrictions are not included in the transport plan in the form of contingency. Furthermore, an additional lesson learnt from the UK distribution networks studied is that having an effective transport re-planning process allows the operations to respond to unplanned road congestion, so if a vehicle is held in a traffic jam, transport planners can re-optimize the network in the best possible way.

10.5.5: Contextual factors

In this PhD, three case studies were undertaken, two from the UK and the other from South Africa, so it is important to highlight the contextual factors that can have an influence on the findings. Two types of contextual factors were identified in the case studies, economic factors and environmental factors. As mentioned previously, uncertainty can increase 'extra distance' of originally planned trips and/or add extra trips to the network. Therefore, 'extra distance' increases the variable and/or the fixed costs of transport, whereas 'extra time' can only increase the variable cost of transport. The increases in the variable cost of transport are much larger in the UK than in South Africa, since the labour cost and the fuel prices are considerably lower in South Africa than in the UK. In the case of the fixed cost of transport, the vehicle acquisition cost is the only factor that can influence the findings.

Meanwhile, three environmental factors were identified in the case studies. They can worsen the effect of uncertainty on transport performance. They are the vehicle carbon footprint, the vehicle engine efficiency and the fuel efficiency. The vehicle carbon footprint influences the fixed carbon emitted due to extra trips. If the vehicle manufacturer has a greener production process, the fixed CO₂ emissions generated due to extra trips can be less. Also, if the vehicle engine is more efficient, the variable CO₂ emissions due to extra trips and/or 'extra distance' due to route diversion can be lower. Moreover, the fuel efficiency, one of the McKinnon's (2007) CO₂ emissions ratios, is a factor that can positively impact on the variable CO₂ emitted due to extra trips and/or 'extra distance'.

10.6 Concluding remarks: overall contribution to knowledge of the PhD

In this chapter, the methodological synergies experienced in the application of the four methods used in the PhD have been discussed. This chapter intends to show how focus groups can contribute to research methodology in logistics. Focus groups have the role of supporting the findings from other research methods. Also, in this PhD, a framework for the application of focus groups in logistics has been developed. This framework can be used as a guide for future applications of the focus group method in logistics.

In this thesis, a new and innovative transport uncertainty evaluation tool has been developed. This tool can be used to evaluate the effect that different causes of uncertainty has on road freight transport performance, in terms of cost and CO₂ emissions. It can be applied to evaluate the impact of uncertainty on the performance of other road transport operations in the FMCG sector. The tool can assist road freight transport operations to assess the main uncertainties affecting transport performance and identify the potential approaches to mitigate them. Also, the tool can be used as a guide for future research on uncertainty and road transport performance.

The relative importance of the uncertainty themes identified in the conceptual model has been explored in the focus groups. Also, the main uncertainty clusters found in the focus groups have been confirmed by survey respondents by qualitatively

assessing their impact and frequency. Furthermore, in the case studies, a quantitative evaluation of the impact and frequency of the uncertainty causes observed have been undertaken. According to the findings of these case studies, the uncertainty clusters that have a greater economic and environmental impact on road transport performance are delivery constraints, variable demand and/or inaccurate forecast and delays. However, in order to lessen the effect of delivery constraints on transport performance, the government needs to intervene. The results of this PhD can be generalised with the combined findings from the focus groups and survey. However, even though the findings from the case studies cannot be generalised, they can be used as a guide for future case studies on uncertainty and road transport.

The final contribution of this PhD is the refined decision-making framework that can be used as a guide for future diagnosis of uncertainty in transport operations. Also, this framework identifies potential mitigation approaches that can be applied to reduce uncertainty in road freight transport operations. At this point of the research, this framework cannot be generalised, because other distribution networks from the FMCG sector and other industries need to be assessed.

The uncertainty evaluation tool has been developed and refined in the three case studies. However, in order to improve its validity, it needs to be tested in other freight transport operations from the FMCG sector in the UK and other countries. Also, its application needs to be tested in other industrial sectors. Hence, a generic tool for transport uncertainty evaluation could be developed and the relationship between uncertainty and road transport performance can be explored further.

11.0 Conclusions

In this chapter, each of research objectives outlined in Chapter 1 is matched with a concluding statement to show how the thesis has addressed them. In addition, the limitations and further enquiries of the thesis are discussed in this chapter.

The deductive stage of this PhD has three objectives (see Chapter 1). The following text summarises how these three objectives have been addressed:

A transport-focused uncertainty model has been developed by extending the Uncertainty Circle model (Mason-Jones and Towill (1999)). A process-based orientation has been taken to develop the conceptual model. Also, wider theories such as network and general systems theories have influenced the development of the model. The contribution to theory in this thesis has been achieved by contributing to the evidence in the topic rather than by developing new theories. The transport-focussed uncertainty model has been first developed conceptually. This model includes five uncertainty sources: shipper, customer, carrier, control systems and external uncertainty. It was developed from previous literature on supply chain uncertainty (Davis, 1993; Mason-Jones and Towill, 1999; Peck et al. 2003). This model has been refined in the focus groups and confirmed in the survey. The four main uncertainty clusters affecting freight transport operations in the UK are delays, variable demand and/or inaccurate forecast, delivery constraints and lack of supply chain integration and coordination. The uncertainty causes linked to these four uncertainty clusters have also been found in the case studies.

The 15 uncertainty clusters found in the focus groups have been assessed in the survey by interrogating the perception of respondents on their impact and frequency. The main uncertainty clusters found in the focus groups have been confirmed in the survey. Also, the importance of the uncertainty causes found in the case studies have been quantitatively evaluated in terms of 'extra distance', 'extra time' and frequency of occurrence. This complements previous research studies where authors have measured the average and/or absolute performance of road freight transport operations (Fowkes et al. 2004; McKinnon

et al. 2004; McKinnon et al. 2009). The four uncertainty clusters identified in the earlier stages of the research have also made a considerable contribution to increases in cost and CO₂ emissions in the three FMCG distribution networks studied. Overall, in the three case studies, variable demand and/or inaccurate forecast and delays are the uncertainty clusters that have a greater impact on the economic and environmental performance of transport operations. However, the negative effects of delivery constraints and insufficient supply chain integration and coordination were also identified in the case studies as root causes of most of the uncertainties measured.

The links between the main uncertainty clusters and the mitigation tools applied by the surveyed companies have been drawn. These links were not found in the literature. Companies applied strategic and operational transport optimisation tools to lessen the effect of delays and delivery constraints on the performance of road freight transport operations. Furthermore, the distribution networks studied applied effective transport planning tools to mitigate delays and embed delivery constraints into the transport plan. In the UK case studies, the importance of having an effective monitoring and re-planning of the delivery process has been identified as a key finding. These two transport operations lessen the effect of delays by re-optimising the distribution network constantly during the execution of the delivery process.

The inductive stage of the thesis also has three objectives; because the research objectives were derived from the first two case studies (see Chapter 1). The following statements summarise how these three objectives have been addressed:

'Extra distance' as a measure has been developed and tested in this PhD. Three assessments of the effect of uncertainties on road freight transport performance have been undertaken. In previous research works, the performance of road freight transport operations has primarily been assessed based on the time dimension of performance (Fowkes et al. 2004; McKinnon and Ge, 2004; McKinnon et al. 2009). The 'extra distance' measure has been complemented by including the time dimension of performance in the two assessments undertaken in the UK and South Africa. In this way, the

assessment can include the two dimensions of performance, time and distance. Hence, the relative importance of these two dimensions can be assessed.

Through the application of the 'extra distance' and 'extra time' measures, the uncertainty causes observed in the cases studied have been evaluated based on the additional cost and unnecessary CO₂ emissions they generated. These uncertainty causes can be linked to the four main uncertainty clusters identified in the focus groups. Based on the results of the case studies, a framework for the diagnosis and mitigation of uncertainty in road freight transport operations has been developed. As demonstrated in Chapter 10, the uncertainty clusters identified throughout the research can be connected back to the McKinnon's (2007) CO₂ emission reduction framework.

The framework developed in Chapter 10 is a new and innovative decision-making transport uncertainty evaluation tool, based on a combined assessment of 'extra distance' and 'extra time', that can be used for the diagnosis of the effect of different causes of uncertainty on the performance of road freight transport operations. This tool includes the causes, clusters and sources of uncertainty identified throughout the research. As explained in Chapter 10, this tool can be linked to most of the McKinnon's (2007) CO₂ emissions ratios. This tool can be used to evaluate the effects that different causes of uncertainty have on road freight transport performance, in terms of cost and CO₂ emissions. This tool can be applied to evaluate the impact of uncertainty on the performance of other road transport operations in the FMCG sector.

11.1 Limitations and further research

The development of the research topic has been achieved by taking a process-based orientation as well as influenced by the network and systems theories. In this thesis, transport has been considered as a supply chain process. Further research is needed to evaluate the application of other wider theoretical perspectives, such as resource dependency theory and transaction cost economics, in future evaluations of

the impact of different uncertainties on the economic and environmental performance of transport operations.

In the focus groups and survey, the analysis has been undertaken at aggregated and at more disaggregated levels. The findings from the analysis at aggregated level can be generalised, since the combined sample between the focus groups and survey consists of 114 observations. However, at more disaggregated levels, the analysis was undertaken at two dimensions, the first one based on the supply chain role of participants and the second one their sector. The findings from the focus groups and survey can only be generalised at aggregated level, but not at the sectoral and supply chain role levels. However, the findings from these two disaggregated analyses are a starting point for future research on uncertainty.

The overall aim of this PhD has been to clarify how uncertainty affects the economic and environmental performance of transport operations within the logistics triad. In the case studies, uncertainties affecting transport operations were evaluated based on two dependent variables, distance and time. These two variables are transport-based variables and can be directly linked to the delivery process. The three distribution networks assessed in this PhD are from the FMCG sector and their distribution centres are cross-docking rather than inventory-holding operations. This justifies the fact that the key aspect of these operations is transport. However, other supply chain indicators, such as loss of sales, inventory and refrigeration, have not been included in the assessments. Therefore, in future assessments of uncertainty affecting transport operations, these variables need to be included in the analysis.

Due to the fact that data on fuel consumption was available in different degrees of detail in the three case studies, different approaches were taken to estimate the kg of CO₂ emitted due to 'extra distance'. In estimating the CO₂ emission of road freight vehicles, the Carbon Trust (2009) recommends using the actual fuel consumption of vehicles. In the third case study, the researcher follows that recommendation, since data on the actual fuel consumption for all 'extra distance' incidents recorded in the assessment was available. On the other hand, if the actual fuel consumption of vehicles is not available, the Carbon Trust (2009) recommends deriving an equation from a sample of trips, where fuel consumption per distance travelled is the

dependant variable and volume capacity utilisation of vehicles is the independent variable, in order to estimate the fuel consumption of each trip. However, in the first two case studies, only the average fuel consumption of vehicles for the week of data collection was available to the researcher. This can be considered one of the limitations of the assessments undertaken in the case studies, since this can make the comparison between the findings, in terms of the CO₂ emissions generated due to 'extra distance' from the three case studies, difficult.

How companies mitigate the effect of different uncertainties has been one of the outcomes of this PhD. In the survey, the link between the four main clusters of uncertainty and the uncertainty mitigation tools that companies applied have been drawn. Also, in the case studies, different mitigation approaches have been included in the refined framework for uncertainty diagnosis and mitigation in road freight transport operations. However, the effectiveness of the different uncertainty mitigation approaches needs to be explored further.

Before starting the three case studies, Cardiff University and the case study companies signed three confidentiality agreements. The first case study company was generally stricter in what could and could not be included in this PhD, so sensitive data from the first case study company such as absolute kilometres, cost per kilometre, fixed cost, average fuel consumption and specific locations have not been included in the thesis. However, they were used to undertake the assessments, although the data shown is based only in percentages.

The research undertaken in this PhD can be developed further. Firstly, the impact of uncertainty on the performance of transport operations has been clarified. However, in future studies on supply chain uncertainty, the effects that uncertainty has on the whole supply chain need to be explored. There are tradeoffs between inventory, transportation, refrigeration and loss of sales. When evaluating the economic and environmental effects of different uncertainties on the whole supply chain, future assessment could include these variable to clarify how these tradeoffs influence on decision making.

The uncertainty evaluation tool has been applied in three FMCG distribution networks from the UK and South Africa. Two of them are secondary distribution networks and one of them is a primary distribution operation. Therefore, in order to improve its validity, the tool needs to be tested in other primary and secondary distribution networks based in the UK and other countries. Also, the application of the tool in other sectors needs to be explored, refining and adapting the tool to the realities of other sectors.

In addition, the geographical coverage of the distribution networks assessed in this PhD has been national in the first two case studies and regional within the UK in the third case study. In the future, it would be important to assess the impact of uncertainty on global and/or regional distribution networks. In order to do that, other modes of transport need to be included in the analysis. Hence, as well as transportation, other key independent variables such as inventory, loss of sales and refrigeration need to be considered in the assessments.

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13.0 Appendices

13.1 Appendix 1 - Summary of papers that include focus groups and other methods in their methodological path.

Author	Research Strategy	Role of Focus Group	Design	Conducting	Analysis
Descriptive					
Holweg and Miemczyk (2002)	Focus Group → Process Map → Survey → Modelling	To obtain background data on the supply chain and propose future state scenarios.	Involved research sponsors but no other information provided.	No information provided.	No information provided.
Exploratory – sole method					
Mangan and Christopher (2005)	Literature Review → Focus Group and Survey	Obtain the views of students of an executive education course on management skills.	1 focus group of 10 students from a Masters course run by authors.	No information provided.	No information provided.
Cullen and Webster (2007)	Literature Review → Focus Group	To determine the mechanisms used for the sale and purchase of products, and the role of e-commerce in these.	4 focus groups planned but only 3 carried out. Made up of 4 to 6 postgraduate students and individuals known to the researchers, selected by purposive sampling.	Round table, structured discussion.	Identified clusters of topics and also coding of results. Theory saturation tested.
Manuj and Mentzer (2008)	Focus Group and Interviews	Identify elements of risk in global supply chains and how they are mitigated.	1 focus group with 7 executives from a global manufacturing firm.	No	No, although theory saturation testing with the interviews.

Author	Research Strategy	Role of Focus Group	Design	Conducting	Analysis
Exploratory – construct development					
Sink et al. (1996) and Sink and Langley (1997)	Literature Review → Focus Group → Survey	Refined a comprehensive literature review undertaken on the 3PL theory. Also influenced the design process of a wider-scale questionnaire-based survey.	1 focus group of 11 members representing a broad base of industry. Some selection criteria.	Semi-structured discussion.	Identified clusters of issues.
Mentzer et al. (1997) and Mentzer et al. (1999)	Literature Review → Focus Group → Survey	Helped the researchers to understand the logistics service quality needs of the Defence Logistics Agency's customers. The focus groups findings supported the research team in refining a questionnaire.	13 focus groups with a broad base of opinions. All participants customers of the DLA.	Unstructured.	Identified clusters of topics and also coding of results. Also researcher triangulation.
Dinwoodie (2001)	Focus Group → Survey	Explore the motivations for students to study a Masters degree programme.	The number of focus groups is not stated but they involved enrolled students.	No information provided.	No information provided.
Lancioni et al. (2001)	Focus Group → Survey	Develop a list of barriers to developing logistics programmes.	4 focus groups of 5 to 6 administrators, faculty and deans from Business Schools.	No information provided.	List of barriers produced and duplicates removed.
Golicic et al. (2003)	Literature Review → Focus Group → Survey	Applied to explore and understand inter-organisational relationships.	2 focus groups, with 5 and 9 participants. Covered 7 industrial sectors.	Unstructured.	Coding of results and researcher triangulation.

Author	Research Strategy	Role of Focus Group	Design	Conducting	Analysis
Exploratory – construct development (continued)					
Guinipero et al. (2005)	Focus.Group → Survey	Gain information on trends, skill, knowledge and training for supply chain managers.	4 focus groups across the US. Participants invited from Fortune 1000 companies. 58 executives from 41 companies attended.	Unstructured.	Identified clusters of issues.
Evangelista and Sweeney (2006)	Focus Group → Survey	Verify completeness of the survey instrument and obtain further engagement in research.	2 focus groups in Milan and Rome with a total of 20 participants from industry and academia.	Structured, based around draft survey instrument.	No information provided.
Tian et al. (2008)	Literature Review → Focus Group → Survey	Confirm that the survey instrument was complete and understandable.	1 focus group involving 3 managers from 2 manufacturing firms.	Structured, based around draft survey instrument.	No information provided.
Exploratory – other					
Christopher and Jüttner (2000)	Focus Group → Case studies	Gain insights into current practice on managing supply chain relationships	12 focus groups arranged at a conference. Open invitation to conference delegates.	No information provided.	No information provided.
Rae-Smith and Ellinger (2002)	Action research → Focus Group	Applied to evaluate the extent an online logistics system (implemented through action research) was helping to improve customer service.	1 focus group for employees of the company involved in the action research	Structured.	No information provided.

Author	Research Strategy	Role of Focus Group	Design	Conducting	Analysis
Explanatory – survey results					
New and Payne (1995)	Survey → Focus Group	Applied to validate results of a survey (2.5% response rate) regarding supply chain integration in logistics.	7 focus groups across the UK. 51 participants from a range of industries with group sizes from 3 to 13. Invites sent to personal contacts of research team.	Organised as a dinner party with food and then an unstructured discussion.	Identified clusters of issues.
Rinehart et al. (2004)	Literature Review → Survey → Focus Group	Conducted in order to determine appropriate descriptive terms for each cluster identified in the survey.	3 focus groups of executive MBA students and company executives, all involved in relationship management. 75 participants in total.	Structured, with a range of descriptive terms provided for delegates to select from.	Ranking of the descriptive terms for each cluster based on frequency of selection.
Jüttner (2005)	Survey → Focus Group	Provide more depth and insights into survey findings especially as the survey had an 8% response rate	6 focus groups arranged at a conference. Open invitation to conference delegates. Each focus group had 7 to 8 participants.	Structured.	Identified clusters of issues.
Bernon and Cullen (2007)	Case studies → Survey → Focus Group	Compare case study and survey findings with participants' experiences in reverse logistics.	1 focus group with 6 sectors represented.	No information provided.	No information provided.
Explanatory – other opinion based methods					
Dainty et al. (2001)	Interviews → Focus Group	Refine a set of change requirements for improving supply chain integration, obtained through the interviews	3 focus groups across the UK. Composed of smaller construction sector companies and interviewees.	Semi-structured and facilitated by the research team.	Data analysed using NVIVO software.
Blackhurst et al. (2005)	Case studies → Interviews → Focus Group	To identify examples of supply chain disruptions to verify earlier findings	3 focus groups of between 10 and 14 participants from a number of industry sectors.	Structured.	Identified clusters of issues.
Jüttner et al. (2007)	Literature Review → Workshop → Focus Group	Verification and improvement of framework developed in workshop	1 focus group of 14 participants representing a range of industries.	No information provided.	No information provided.
Melnyk et al. (2008)	Literature Review → Delphi Study → Focus Group	Discuss and refine the findings from the Delphi study	1 focus group of 25 participants drawn from the Delphi study respondents	Semi-structured with a clustering exercise.	Identified clusters of issues.

13.2 Appendix 2 - Copy of the online questionnaire

Purpose of the Questionnaire

The purpose of this questionnaire is to collect information about supply chain uncertainty in logistics triads in the UK and their impact on economic, environmental and societal sustainability. Supply chain uncertainty refers to decision making situations in the supply chain in which the decision maker does not know definitely what to decide. In practical terms, the main causes of supply chain uncertainty can be classified as followed:

- The decision maker does not have enough and/or reliable information, e.g. stock level, lead time, customer satisfaction, supplier performance, and so on.
- ICT systems available to the decision maker do not have the capacity to process sufficiently disaggregated information.
- The forecasting and planning tools available to support decision making are not sufficient accurate, and as a result the decision maker is misled.
- Throughout the different supply chain stages, disruptions can occur that can ultimately have an adverse effect on the subsequent processes.
(van der Vorst and Beulens 2002)

This questionnaire forms part of the research for the Green Logistics project sponsored by the Engineering and Physical Science Engineering Council (EPSRC). The questions are based upon the findings of eight focus groups. Therefore, this survey is a confirmatory tool of previous research and informs future research within the project.

The results of this survey will be published on the Green Logistics website, www.greenlogistics.org, and they will be available to all the practitioners that take part.

Please, avoid using the Back button in your Internet Explorer browser while you are answering the questionnaire, since that could disrupt the flow of the questionnaire. If you have any queries with a question, please click on the question mark provided, this will open a pop-up window. In order to test whether you have pop-up blocker enable, please click on this question mark (?). The survey works best with pop-up blocker disable.

Part 1- Background information

Information sought within this section included:

- The type of company (Shipper, carrier, customer, other)
- The size of company by number of employees
- Annual turnover in the UK (£m)
- Logistics costs as percentage of turnover in the UK
- Industrial sector

Part 2- Sources of pains within the logistics triad

Question Number	Wording	Response mode
1	List what you consider to be the 4 most common sources of disruption/uncertainty in the day-to-day logistics operation of your business. A definition of each term is available including exemplar causes of uncertainty.	Tick box against list of uncertainty causes
2	Rank the 4 sources of disruption identified above, with the most serious ranked as 1.	Ranking scale (only the 4 selected in Q1 were presented)
3	For each of the 4 sources identified above, what is their impact on economic and environmental sustainability? (The scale is between 1 and 5, 1 is a significantly low impact and 5 is significantly high impact)	Likert scale
4	How frequently are your logistics operations disrupted by each of the 4 main sources identified above?	Frequency scale

Part 3 - Logistics triad uncertainty mitigation

Question 5 - List the five analysis and design tools that your company uses to improve the efficiency of logistics operations [a definition of tools was provided]

Part 4 - Acknowledgement and benefits

We thank you for taking part in this survey, and will send you a final report with the results of this research early in 2008. You will receive update information while the project evolves, such as new published academic papers, executive reports of all the research streams and user-level access in the Green Logistics webpage, developments up to June 2010. If you would like further information on the Green Logistics project including regular updates on forthcoming activities, please provide your details below. This information will be kept confidential.

13.3 Appendix 3 - Pro-forma used in the data collection

Incident Detail	
Date	
Incident Number	
Identified Time	
Departure Time	
Planned Kilometres	
Actual Kilometres	

Consignment Details	
Customer	
Unit load	
Owned Vehicle or Subcontractor	
One or Two-way Route	
Subcontracted Operator	

Actual Route	Actual Kilometres

Planned Route (or how route would have been planned with sufficient notice)	Planned Kilometres

Problem in the Network	Underlying Cause

13.4 Appendix 4 – Excel spreadsheet used to calculate the ‘extra distance’ gathered due to extra trips in the first case study

Date	Km		Extra Km	Time		Description			Cause-and-effect 'Extra distance'		Volume increase		Depot (Km)	Delay
	Plan	Actual		Depart	Id	Plan	Actual/ Alternative	Unit load	Type	Visible cause	Km	Source		Supplier
						Route	Route							
06-Jul	434	834	400	14:00	12:00	Manchester to Supplier A	Manchester to Supplier A to Manchester	50	Load more than advised	Supplier notified late	400	Supplier		
04-Jul	349	698	349	22:00	14:00	Depot A to Depot B	Two trips from Depot A to Depot B	43	Product not loaded	Depot operational failure			349	
01-Jul	349	698	349	22:00	22:00	Supplier B to Depot B	Two trips from Supplier B to Depot B	43	Delay	Supplier operational failure				349

13.5 Appendix 5 – Excel spreadsheet used to calculate the 'extra distance' gathered due to extra trips in the second case study

Date	Km		Extra Km	Description				Cause-and-effect 'Extra distance'		Volume increase		Depot (Km)	Delay
	Plan	Actual		Time		Plan	Actual/ Alternative	Type	Visible cause	Km	Source		Supplier
				Depart	Id	Route	Route						
06-Jan	434	834	03-Feb	14:00	12:00		Depot to Outlet 1	Load more than advised	Outlet 1 notified late	400	Outlet 1		
08-Jan	349	698	14-Dec	22:00	14:00		Two trips from Depot A to Depot B	Product not loaded	Depot operational failure			349	

13.6 Appendix 6 – Excel spreadsheet used to calculate the 'extra time' gathered in the second case study

Date	Extra time'		Extra Min (s)	Time	Route	Visible cause	Delays due to		
	Plan	Actual		Depart			Outlet	Supplier	Transport
06-Jan	250	300	50	14:00	Depot to Outlet 1	Supplier notified late	50		
08-Jan	400	490	90	22:00	Depot to Supplier 1	Depot operational failure		90	
09-Jan	300	350	50	22:00	Depot to Outlet 2	Supplier operational failure			50

13.7 Appendix 7 – Excel spreadsheet used to undertake the second assessment in the third case study

Date	Km		Extra Km	Description				Cause-and-effect 'Extra distance'		Volume increase		Depot (Km)	Delay	
	Plan	Actual		Time		Plan	Actual/ Alternative		Type	Visible cause	Km		Source	Supplier
				Depart	Id		Route	Route						
03-Dec	434	834	400	14:00	12:00	London to Outlet 1	Two trips from London to Outlet 1	0.312	Load more than advised	Outlet notified late	400	Outlet		
04-Dec	349	698	349	22:00	14:00	Depot A to Depot B	Two trips from Depot A to Depot B	0.305	Product not loaded	Depot operational failure			349	
29-Dec	349	698	349	22:00	22:00	Supplier B to Depot B	Two trips from Supplier B to Depot B	0.320	Delay	Supplier operational failure			349	

13.8 Appendix 8 – Excel spreadsheet used to undertake the second assessment in the third case study

Departure		Location 1	Location 2	Location 3	Fuel consumption (lt / km)	Planned Time (min)				Actual Time (min)					Net diff in vehicle running time (min)	Planned Km	Actual Km	Extra Km	Extra distance' Cause
Date	Time					Total	Location 1	Location 2	Location 3	Total	Location 1	Location 2	Location 3	Location 3					
30-Nov	10:42	Outlet 1				80	60			35	22			0		6	7	1	
02-Dec	15:19	Outlet 1				89	60			58	43			0		6	7	1	
27-Nov	19:50	Supplier 1				118	60			81	32			0		38	43	5	
02-Dec	23:07	Supplier 1	DC 1	Suplier 2		327	60	30		323	79	83		0		189	191	2	
03-Dec	21:03	Supplier 1				117	60			100	56			0		38	44	6	
03-Dec	23:08	Supplier 1	DC 1			327	60	30		350	106	79		0		189	191	2	
29-Nov	00:51	Outlet 2				180	32			173	105			0		55	56	1	
02-Dec	09:51	Outlet 3	Outlet 4			254	42	67		196	44	40		0		88	91	3	
04-Dec	10:54	Outlet 4				233	80			172	107			-5		55	55	0	
27-Nov	20:03	Outlet 5				115	46			82	27			0		52	53	1	
28-Nov	06:06	Outlet 5				172	30			157	96			0		52	53	1	

Net diff in vehicle running time = (Actual Total Time – Total Actual Location Waiting Time – Unplanned stop Time) – (Planned Total Time - Total Planned Location Waiting Time)

