MEASURING THE TIME AND DISTANCE IMPACT OF TRANSPORT UNCERTAINTY: A FMCG CASE STUDY

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Introduction

As freight transport connects companies to their customers, effective transport operations can enhance the delivery of customer value. Supply chain uncertainty, in the form of disturbances and disruptions, is an inhibitor to the effective management and control of these transport operations (Mason-Jones & Towill 1998). Some of this instability has its origin in transport infrastructure. Traffic congestion, for example, reduces the reliability of delivery schedules (Fowkes et al 2004) which can subsequently reduce the utilisation of vehicle capacity (McKinnon & Ge 2004). Factors such as delays at collection and delivery points, vehicle breakdowns and non-availability of drivers can also have a significant effect on delivery performance.

Much of the previous research on this subject has adopted a macro-level perspective. To date there have been no studies evaluating the marginal impact of external and supply chain uncertainties in terms of their knock-on effects. Similarly, whilst previous research has suggested that there is a need for a holistic perspective of the role that transport plays within supply chains (Stank and Goldsby 2000), historically transport has not been explicitly taken into account in supply chain uncertainty frameworks.

Much recent research has focused upon the causes of supply chain uncertainty. A transport-focussed uncertainty model has been developed and refined to determine the main causes of uncertainty impacting on the performance of transport operations (Sanchez-Rodrigues et al 2008). By measuring the causes of uncertainty within their operations in terms of their knock-on effects, logistics managers can take more informed decisions about which transport uncertainties should be more tightly monitored and controlled. These uncertainties generally result in vehicles travelling longer distances than would otherwise be the case. In a previous study, Sanchez-Rodrigues et al. (2009) have introduced the concept of 'extra distance' as a consequence of uncertainty. The additional vehicle-kilometres increase both the economic and environmental costs of the road delivery operation. However, uncertainty affecting a freight transport operation within a supply chain could generate 'extra time' as well as additional distance. The aim of this paper is to evaluate the consequences of different types of supply chain uncertainty on 'extra distance' and 'extra time' and how these effects translate into extra economic and environmental costs, using a combined time-and-distance assessment method.

The paper reviews the literature on transport uncertainty introducing the concept of 'extra distance' and 'extra time' associated with uncertainty. The time-and-distance assessment method is outlined and the results of its application in a case study discussed. The analysis revealed the connections between the causes of uncertainty, the case study company's efforts to prepare for and mitigate uncertainty and 'extra distance' and 'extra time' associated with uncertainty. Finally, the paper ends by highlighting the managerial implications and limitations of the research.

Concept and causes of transport uncertainty

It has been argued that "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" (Van der Vorst and Beulens 2002). It has been proposed that a manufacturer's process, their suppliers and customers are the three main sources of supply chain uncertainty (Davis 1993). Mason-Jones & Towill (1998) develop the uncertainty circle model adding an additional source of uncertainty, namely the control system (Mason-Jones & Towill 1998).

Most recently, exogenous events were added to the supply chain uncertainty literature (Peck et al 2002).

Earlier research on supply chain uncertainty has been extended with the development of a transport-focussed uncertainty model (Sanchez-Rodrigues et al 2008). The three types of organisation affected by transport uncertainty are defined as: shipper, customer, carrier, (collectively defined as the 'logistics triad', Beier 1989). A distinction is also made between two general sources of uncertainty: internal control systems and external environmental. Shipper uncertainty may arise from raw material sourcing, the production process or the activities involved in the despatch operation. Customer uncertainty can be related to the forecasting and ordering products or any delivery restrictions that the customer imposes. Carrier uncertainty can be caused by planning failures, vehicle break-downs or a lack of drivers. Control systems uncertainty is any problem caused by inadequate and fragmented ICT systems within the logistics triad, or the lack of physical monitoring systems. External uncertainty is any disruption caused by exogenous factors that are not under the control of the logistics triad, including traffic congestion, labour shortages and the volatility of fuel prices.

The original conceptual framework for transport uncertainty was refined through the application of focus groups, evaluating the different types of uncertainty affecting UK transport operations (Sanchez-Rodrigues et al 2007). The main causes of uncertainty were found to be delays within the delivery process, variable demand and/or inaccurate forecasts, insufficient supply chain coordination and delivery constraints. This early research, however, has not considered the consequences of these disruptions in terms of cost or environmental impact.

Consequences of supply chain uncertainty on transport operations

It is important to measure the impact of uncertainty on the performance of transport operations. Performance is likely to be impaired by vehicles having to run 'extra distance' and / or the delivery process suffering a delay. Both of these negative effects increase operating costs and negative environmental effects, including an increase in CO_2 emissions. The concept of 'extra distance' as a measure for assessing the efficiency of transport operations within supply chain has recently been developed Sanchez-Rodrigues et al (2009) and is defined as:

Any non value-added or unnecessary distance run within a distribution network due to 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

Strong parallels exist between the 'extra distance' measure and the concept of non-value adding transport in the lean manufacturing literature. The concept of value adding activities has its origins in the Toyota Production System, in particular the principles of identifying and eliminating waste. According to Shingo (1989), waste is any activity that does not contribute to an operation. Also, Taichi 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). In this paper, the main focus is on identifying the causes of 'extra distance' in the form of unnecessary transport movement within a distribution network due to supply chain uncertainty. Sanchez-Rodrigues et al (2010) have developed five types of 'extra distance':

- Extra distance due to route diversion generated by unplanned road congestion and/or restrictions
- Extra distance or trips due to delays within the delivery process
- Extra distance or trips due to load more than advised caused by late notifications of volume increases from customers or suppliers
- Extra distance or trips due to load more than advised caused by late notifications of volume increases from customers or suppliers
- Extra distance or trips due to inappropriate vehicle size

This 'extra distance' types will be measured in the rest of the paper.

As discussed in Sanchez-Rodrigues et al 2007, 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 requires further examination. The Transport KPI surveys sponsored by the UK Government in various sectors, including food and drink, non-food retailing, building merchants and parcel delivery, have monitored 'deviations from schedule' in the course of 'synchronised audits' of large numbers of vehicle fleets (McKinnon & Ge 2004; McKinnon, 2009). Although these surveys have also collected information about distances travelled and vehicle utilisation, no attempt has so far been made to analyse the relationship between schedule deviations and these other variables.

For the purpose of this paper, 'extra time' is defined as:
Any additional or unnecessary time consumed within a distribution network due to uncertainty, and defined as the difference between the time vehicles actually ran, and the time they would have needed to run if there had been no:

- 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

It should be noted that if an additional trip is generated (leading to 'extra distance'), then 'extra time' is only generated if this journey encounters further delays once planned.

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 'extra distance' can be generated by operational problems or errors occurred in a previous delivery cycle. Road congestion can extend the transit time and add 'extra distance' where a vehicle deviates from the optimal planned route to avoid congested sections of road. So, when road transport operations are sensitive to these two dimensions of transport performance, the assessment should include distance as well as time, particularly where archival data is available to undertake a combined time-and-distance assessment. This permits a holistic analysis of the effects that different causes of uncertainty have on road freight transport performance. The potential trade-offs between the time and distance dimensions of performance of road freight transport operations can be clarified.

Method

In this paper, the principles of the case study method recommended by Yin (2003) have been applied. The unit of analysis for this assessment is a FMCG secondary distribution operation based in the UK. Secondary distribution is defined as the movement of supplies from a retailer's distribution centre to its shops (as opposed to 'primary distribution' from factory to distribution centre).This operation was selected because there was a particular interest in identifying and assessing the importance of uncertainty in a supply chain link characterised by large volumes of product flow, high time-sensitivity, exposure to traffic conditions and close links between a retailer, its suppliers and logistics service providers.

The secondary distribution network is managed and run entirely by the FMCG company on an 'own account' basis. Within the company the sales department is a customer of the company's transport function. The retailer has a large number of distribution centres within the UK. For this research, a distribution centre located in the north of London was selected. This distribution centre served 172 locations of which 93 were the company's own retail outlets. Deliveries to these outlets represent about 85% of the outbound flows. The distribution centre also handles backloads from suppliers' premises and other distribution centres located within the East Midlands and South England areas. Although, the company manages and runs the secondary distribution network, they outsource a significant proportion of the primary distribution movements to a number of logistics providers. The case study focuses on secondary distribution, but will also include a small proportion of backhaul and primary flows in the assessment. A distribution centre location in North London was selected because within the area it serves there are a wide variety of road types, from motorways to minor roads, and traffic conditions, including congestion and urban deliveries. It also receives inbound flows from across the UK as backloads.

The transport planning process is undertaken by the company using its own modular vehicle routing and scheduling system. One of the modules optimises the network including backhaul opportunities, volume demand from stores, access restrictions at stores and suppliers and any primary volumes required from suppliers that can be transported by the secondary distribution fleet. After that, when the deliveries are executed, another module tracks and traces the vehicles to determine if the vehicles are either late or too early. This information is fed into a third module which updates the information in terms of vehicle availability and re-optimises the network. This process is repeated several times during the day.

An overall view of the research process can be found in Figure 1. In the planning stage of the research study, a presentation based on the findings from previous research was delivered in a meeting with the retailer's transport management staff. The main objectives of this presentation were to decide the scale and scope of the project and review the suitability of the 'extra distance' and 'extra time' measure to their operation.

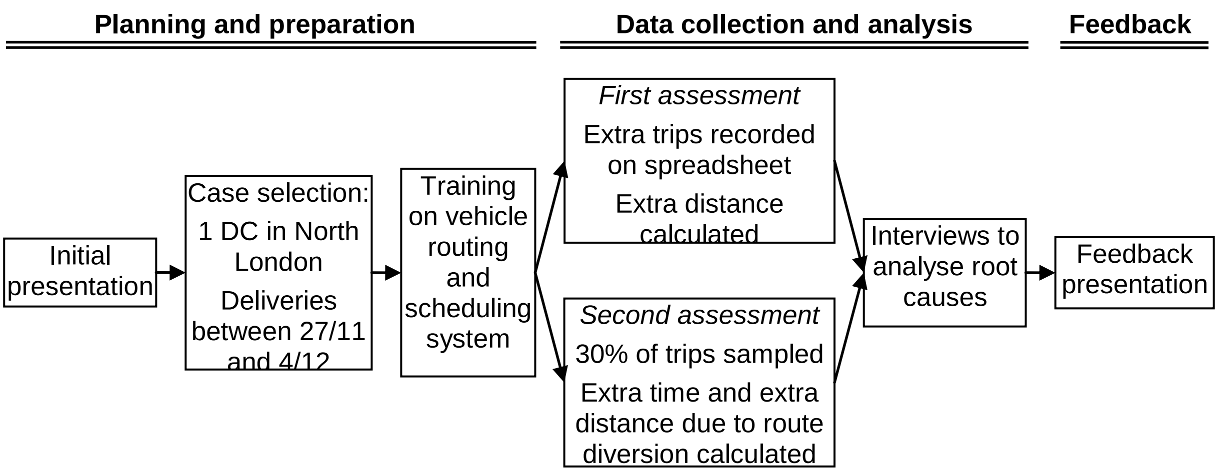

Figure 1: The research process

Before starting to collect data, one of the authors spent five days being trained to interrogate the vehicle routing and scheduling system that the company uses to optimise, track and trace and re-optimise the transport movements across the whole network. During this time in the traffic office, it was also possible to identify other data sources. Thereafter the data was collected remotely from this author's workplace. The week that was selected for the assessment was from 27th November at 19:00 to 4th December at 19:00. According to the management staff at the case study company, this week can be described as a typical week that can reflect what happens throughout the year. During the data collection, two separate sources of data were collected. The reasons for making two separate data collection exercises were: (1) to measure 'extra distance' by applying the same principles applied in the previous case studies (Sanchez Rodrigues et al 2009), (2) to measure 'extra time' in terms of additional time taken in round trips caused by delays.

The first data collection exercise was undertaken by identifying all the extra trips caused by uncertainty that occurred during the week of data collection. For all trips showing evidence of 'extra distance' being run, information was recorded on store location, total distance travelled in miles and the 'visible' causes of this 'extra distance'. All the incidences of 'extra distance' were input into an Excel spreadsheet. In this Excel spreadsheet, the amount of 'extra distance' associated with each cause of supply chain uncertainty was calculated.

The second data collection exercise was undertaken by comparing the original transport plan with the actual execution of the delivery process. 30% of the planned trips run by vehicles based at the distribution centre (DC) studied were selected for this data collection exercise. To select these trips three characteristics were considered: location, time of the day and day of the week. For every hour within the 24 hrs of every seven days of the week, 30% of the trips were selected. This degree of data sampling was chosen as 100% data gathering would have been impossible in the time constraints imposed on the data collection phase of the research. Also, according to the management staff at the case study company, 30% of the trips are a fair reflection of what happen in 100% of the trips. Moreover, for every trip identified, the planned and actual turnaround times for every unloading and / or loading point within the trips were recorded. Also, the planned and actual delivery times were collected from the system together with any unplanned stops reported by drivers.

In the second data collection exercise, two different areas were explored: the causes of delays and the causes of 'extra distance' due to route diversion within the network. In the case of delays, the reasons why vehicles were delayed were identified and categorised and the total time delayed for each cause of delay was calculated. In the case of 'extra distance' due to route diversion, the extra kilometres run within the network were categorised depending on the cause of 'extra distance' due to route diversion. This represented additional data over previous applications of this measure (Sanchez-Rodrigues et al., 2009), as the technology to capture the data was not used.

To understand more about the root causes of 'extra distance' and 'extra time', informal interviews and discussions were held with management staff within the secondary distribution operation studied. These discussions also helped to confirm the credibility of the research.

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

Results and analysis

In this section of the paper, the overall results of the data collection will be presented first. This includes the two assessments undertaken in the study. After that, the causes of 'extra distance' derived from the two assessments will be evaluated. Subsequently, the causes of 'extra time' found in the second exercise will be assessed.

Table 2 shows the types and 'causes of 'extra distances' and 'extra time' found in the case study in terms of their impacts and frequency expressed in percentages. According to the first assessment, 'extra distance' due to extra trips represents 3.05% of the total distance run in the network. On the other hand, according to the second assessment, 4.77% of the distance was run due to route diversion. Assuming that the sample in the second assessment is representative of all journeys made from this DC, it can be calculated that 'extra distance' within the distribution network accounts for 7.82% of total distance run. Moreover, 2.62% of the total hours dedicated for the deliveries were 'extra time'. A total of 276 hours of delays and 200 hours of early deliveries were found, so the gross figure is 476 extra hours, It is worth noting that delays always cause 'extra time', but they do not always cause 'extra distance'. When a delay does cause 'extra distance' to occur then it inevitably has a bigger impact on cost and the environment than 'extra time' alone. Overall, in this case study, 'extra distance' generates approximately 87.5% of the additional cost incurred due to uncertainty whereas 'extra time' generates only about 12.5% of that cost. Furthermore, 'extra distance' alone generates additional CO_2 emissions.

In the rest of this section, more in-depth insights from the analysis will be discussed based on this table. In order to calculate the percentage of 'extra time' and percentage of 'extra distance' due to route diversion have been scaled to the total number of trips run in the week of data collection The extra kilometres of the two causes of route diversion calculated from the second data collection exercise 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 by the kilometres of all of the trips gathered in the second assessment. In order to scale the 'extra time' gathered in the second data collection exercise 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 by the total number of trips gathered in the second data collection exercise.

First data collection exercise: 'extra distance' due to extra trips

As Table 2 shows, eight causes of 'extra distance' due to extra trips were found. Delays within the delivery process generated 27.2 % of the extra kilometres found in the assessment yet only 4.7% of the 'extra distance' incidents recorded during the data collection. The case study company outlets generated a greater proportion of the extra kilometres caused by delays (22.3%) in comparison to shippers (2.2%) and unplanned road congestion (2.7%). These delays occur due to the fact that the sales department wants the products to be on time at outlets and at the same time minimising the staff cost at the outlets. Also, about 20% of the outlets caused 80% of the 'extra distance' generated by generating delays at unloading bays. Customers located around Central London frequently held vehicles at their facilities. This type of issue generated two different knock-on effects. Firstly, when the delayed vehicle involved a backhaul collection from a supplier, the transport planner was forced to cancel the backhaul collection, and return the vehicle to the depot without making the collection, therefore an extra return trip is needed to collect the product at the supplier. Secondly, when the vehicle held at a store was originally scheduled to return to the depot to collect a subsequent two-store trip, at the time of the planner learning of the delay only the load for one store is ready for dispatch (and cannot wait for the delayed vehicle due to urgency of product replenishment at that store), the transport planner scheduled an extra trip to run a single return trip for the urgent store only, returning directly to the depot. Meanwhile, another less important but still considerable cause of 'extra distance' found were late notification of extra volume from outlets (7.4%) or suppliers (1.5%). This type of problems originates unnecessary trips are run. It is important to note that 29.7% of the 'extra distance' measured in the data collection originated at outlets.

'Extra distance' type	Uncertainty causes	'Extra time'		'Extra distance'	
		% of 'extra time'	Frequency (%)	% of 'extra distance'	Frequency (%)
Extra distance/time due to route diversion	Road restrictions	0	0	38.1	13.8
	Unplanned Road Congestion	0	0	22.5	79.4
Extra distance/time due to delays	Store	33.0	31.0	22.3	4.0
	Suppliers	30.0	21.0	2.2	0.4
	Unplanned stops	34.0	45.0	0	0
	Unplanned Road Congestion	3.0	3.0	2.7	0.3
Extra distance/time due to load more than advised	Late notification of extra volume from stores	0	0	7.4	1.1
	Late notification of extra volume from suppliers	0	0	1.5	0.4
Extra distance/time due to inappropriate vehicle size	Technical vehicle failure	0	0	1.5	0.3
Other	Product not load at distribution centres	0	0	1.1	0.2
	Product not loaded at suppliers	0	0	0.7	0.1

Table 1 - Types and causes of 'extra distance' found in the three case studies

The other three causes of 'extra distance' found are 'technical vehicle failure', 'product not loaded at the secondary distribution centres' and 'product not loaded at suppliers'. The first cause generates 1.5% of the total extra kilometres found while the second cause represents 1.1% of the 'extra distance' recorded. 'Product not loaded at suppliers' represents only 0.7% of the total extra kilometres. 'Technical vehicle failure' generates 'extra distance' since when a vehicle has a technical failure this means it is not available for departure, which generates a network coordination problem. Other smaller size vehicles could be available, so two smaller sized vehicles are used for the delivery instead of one larger-sized vehicle. On the other hand, when product is not loaded at the distribution centre or suppliers, a large volume accumulates for the next day and this product ultimately needs to be moved, adding extra kilometres to the original transport plan.

Second data collection exercise: comparison between plan and actual

Main causes of route diversion

Table 2 shows the findings from the data collection in terms of 'extra distance' due to route diversion of originally planned trips. Two main causes of 'extra distance' due to route diversion where found: unplanned road congestion and ad-hoc and unexpected road restrictions. For example, on Friday night, a number of roads were temporarily closed within the route between the secondary distribution depot and an outlet located in the Camden area; due to this the driver was forced to divert the vehicle from the original planned route on encountering the closure. In fact, this cause of uncertainty was only found for deliveries into London. Both of them are external uncertainty causes originated outside the logistics triad. These generated 38.1% of the total extra miles recorded but only 13.8% of the total number of incidents found.

In addition, unplanned road congestion was the other ‘extra distance’ cause found. It generated 22.5% of the extra distance within the network, but it represents 79.4% of incidents identified. Route diversion due to unplanned road congestion occurs due to the fact that deliveries need to be made on time where possible and so drivers will change their route in response to congestion so as to minimise the time impact. Because planned journey times take road conditions into account (albeit from a historical rather than real-time basis), such deviations will often not result in ‘extra time’ as the vehicle can still reach the store at the desired time.

Main causes of ‘extra time’
As Table 2 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 to take a break of 45 minutes per 4.5 hours of driving. The issue in this case is that these stops are not included in the initial transport plan. The case study company cannot mitigate this ‘extra time’ cause, since it occurs due to a government regulation, so it is a restriction that needs to be embedded into the transport plan but cannot be eliminated.

The two causes of ‘extra time’ that can be mitigated by the case study company 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. Also, ‘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 before being unloaded, so they arrive late to the distribution centre. This problem is caused primarily by the 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.

The other ‘extra time’ cause found is unplanned road congestion. It 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 extra distance due to route diversion but not delays.

Concluding remarks

This paper describes case study research evaluating the effects of different uncertainty causes on the economic and environmental performance of a road freight transport function within a secondary distribution network by measuring their occurrence and impacts in terms of ‘extra distance’ and ‘extra time’. As in research undertaken previously, 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 usages and additional fuel consumption. However, it is also vital to comparatively evaluate the impact of uncertainty in terms of ‘extra time’. In this particular case study, ‘extra distance’ represents about six times more impact than ‘extra time’. This is due to the fact that only ‘extra distance’ affects the fixed cost of transport and generates extra fuel consumption. Also, even though the vehicle routing and scheduling system re-optimises the network continuously, a more explicit and formal system to control and reduce ‘extra distance’ and ‘extra time’ is needed.

According to the results of this study, in this UK-based secondary distribution network, 7.82% of the total kilometres run are ‘extra distance’ due to extra trips and ‘extra distance’ due to route diversion The three main uncertainty causes found in the study are ‘delays due to unplanned road congestion’, ‘delays due to ad-hoc and unexpected road restrictions’ and ‘delays at unloading bays’. Jointly, they generate 87.5% of the ‘extra distance’ measured in the assessment generated due to uncertainty incidents gathered during the week of data collection, whereas only about 12.5% of ‘extra time’. In order to reduce ‘extra distance’ and ‘extra time’, the case study company needs to find mechanism to encourage the government to reduce the ad-hoc and unexpected road restrictions they uncoordinatedly imposed to commercial road transport operators.

From their perspective of the management staff at the case study company, the findings from the case study represents a starting point towards identifying the potential mitigation strategies to reduce ’extra distance' and 'extra time'. The company studied needs to concentrate first on mitigating the uncertainties generated internally in their operations or their partners' operations, e.g. delays at stores, and after working together with the government to mitigate route diversion. Since reducing 'extra distance' due to route diversion requires a change in behaviour by the London boroughs. Also, as in the case of the incidents due to road restrictions, the planned kilometres need to be revised and be made more accurate.

Finally, before embarking in any 'extra distance' and / or 'extra time' reduction programme, the company should apply the assessment for a longer period of time. The results of this study are based on data collected over a perceived 'average' week. Therefore, while the outcome of this initial assessment may inform decision making, the exercise should be repeated in order to fully validate the results. In order to do that, a robust data collection and analysis management information control system needs integrating the planning and control processes. Hence, the exercise could be repeated in other distribution networks in the FMCG sector or in other sectors.

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