



Reliability of Road Transport from the Perspective of Logistics Managers and Freight Operators

*Report prepared for the Joint Transport Research Centre of the OECD
and the International Transport Forum*

FINAL REPORT

by

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Contents

Executive Summary	3
1. Introduction	4
2. Methodology	5
3. Summary of previous study	7
4. Review of other literature	8
5. Logistics transport and congestion trends	11
4.1 Transport system	11
4.2 Logistical restructuring	14
4.3 Business trends	16
4.4 Technology	17
4.5 Working practices	17
6. Relationship between traffic volumes and transit time variability	18
7. Logistical Consequences of Delays in the Transport System	22
7.1 Impact of congestion on in-transit inventory costs	22
7.2 Impact on operational efficiency and service quality	22
8. Relative importance of congestion as a source of unreliability	25
8.1 Analysis of transport KPI data	25
8.2 Analysis of interview data	29
8.3 Case study	30
9. Adaptation of logistics systems to congested infrastructure	31
9.1 Transport	31
9.2 Warehousing	33
9.3 Inventory	36
9.4 ICT systems	37
9.5 Supply chain collaboration	39
10. Sectoral review of congestion impacts and unreliability	40
10.1 Overview	40
10.2 Automotive sector	42
10.3 Chemicals	44
10.4 Steel	45
10.5 Groceries	46
10.6 Beer	47
10.7 Forest products	48
10.8 Newspaper	48
10.9 Pallet-load networks	49
10.10 Express Parcels	50
11. Conclusions	52
12. References	53
<i>Annexes</i>	
1. Sectors represented by the surveyed companies	55
2. Questionnaire used in the interview survey	56

Executive Summary

Many of the available statistics on traffic congestion measure its impact in terms of the average delay it causes and the related 'on-the-road' costs of vehicle and driver time. Too little attention has been given to the effects of congestion on the variability of transit times and the wider consequences for logistical efficiency and performance. This study focuses on these issues, examining the relative extent to which traffic congestion impairs the reliability of logistics operations and the measures that companies are taking to minimise its adverse effects.

The study updates and extends earlier research undertaken in the UK in 1998. This previous study investigated the effects of traffic congestion on the operation of seven DCs (DCs) handling fast moving consumer goods. The present project has examined congestion impacts across nine sectors and enquired about company reactions to the significant deterioration in road traffic conditions in the UK over the past decade.

The research began with a review of relevant literature published since 1998. A total of 25 academic journals and numerous government and industry reports were scanned. This indicated that relatively little new work had been done on this topic in the intervening years. Several studies, however, have provided valuable new insights and generated more empirical data. One of the most fertile sources of this new data has been the UK government's transport KPI programme. Since 2002, this has collected data on the duration and causes of delays to around 55,000 road freight journeys across seven sectors. This consolidated data set has been analysed for the first time in this study.

The study has also explored the relationship between traffic volumes along a sample of routes and the variability of transit times. It has used a newly-developed vehicle routing software tool to analyse link- and time-specific traffic flow data obtained for the UK trunk road network from the Highways Agency. This modeling found very close correlations between the earliest and latest arrival times for freight journeys and the distance travelled, confirming the view expressed by logistics managers that most congestion is regular and predictable.

In the course of the project a total of 37 managers were interviewed in 28 companies or divisions of companies. Five visits were made to DCs, two of which were included in the 1998 survey. Detailed enquiries were made about the impact of congestion on the logistics operations, the relationship between congestion and other sources of unreliability and any measures companies were taking to mitigate the effects of congestion. Very few of the companies consulted were able to provide hard statistical data on the operational and financial impacts. Most of the data collected was therefore qualitative.

Analysis of the interview data revealed wide variations in the relative impact of congestion both within and between sectors. There was little evidence of it causing companies to restructure their logistics systems. Nor, in most cases, was it causing companies to run more vehicles, increase tractor-trailer ratios, carry more inventory or modify internal warehouse design and capacity. As most congestion is fairly regular and as congestion levels have increased gradually, companies have learned to 'work around it', altering schedules, building in extra slack, making internal processes more flexible and, in some cases, upgrading their IT systems with telematics and routing software. Some companies, however, have high exposure to congestion as a consequence of their geography, product type, scheduling constraints and customer requirements. Congestion is clearly impacting more seriously on the cost and quality of their logistics operations.

1. Introduction

Much of the research on the effects of traffic congestion has been confined to its direct, 'on-the-road' costs and relied heavily on estimates of average increases in journey time. It is now quite common to measure congestion by the number of seconds lost per vehicle-km and to convert this figure into monetary values using standard costs for driver and vehicle time. Such calculations are deficient in two respects:

1. They take no account of the variability of transit times on congested road networks.
2. They ignore the consequential, 'off-the-road' costs incurred at collection and delivery points when deliveries arrive late.

These issues were addressed in the context of freight transport and logistics in a study that the Logistics Research Centre undertook in the UK in 1998. This study has now been updated and extended for the Joint Transport Research Centre of the OECD and the International Transport Forum. Over the past decade the level of traffic congestion on the UK road network has significantly increased, making Britain's roads among the most congested in Europe. This continues to make the UK a good location for a study of this type. Although the research has focused on the UK, many of the findings can be generalised to other countries.

The study has had several objectives:

- update the 1998 study, examining relevant trends and developments in the intervening period
- review of the results of new research on the subject published since 1998
- model the relationship between traffic levels and the variability of road transit times for freight vehicles
- analyse government survey data on the relative impact of congestion on road freight transport operations
- revisit DCs (DCs) included in the earlier study to assess changes in the impact of congestion and company responses
- assess the impact of congestion-related unreliability on logistics operations in a broader range of sectors

2. Methodology

2.1 Literature review:

The previous literature review conducted in 1998 has been updated. The contents since 1998 of 25 journals on transport, logistics, supply chain management, operations management and reliability have been reviewed. We have also conducted a search for relevant reports by government departments and agencies, consultancy companies and academics. This has uncovered a substantial amount of general literature on the congestion problem, but relatively few papers / reports specifically on the effects of congestion-related unreliability on freight and logistics. Around eight of these publications, however, provide important new insights into the subject.

2.2 Analysis of Transport KPI Data

The UK government has sponsored a series of transport benchmarking surveys over the past ten years in a range of sectors. One of the Key Performance Indicators (KPIs) that they have measured is 'deviations from schedule'. These deviations have also been attributed to specific causes, including congestion. The results of these KPI surveys have been analysed to assess the relative importance of congestion as a source of unreliability in road freight operations.

2.3 Interview survey:

Four types of interview have been held with logistics managers:

1. Telephone interviews with individual managers: a total 19 interviews were held lasting between 40 and 90 minutes.
2. Telephone conferences with managers representing different functions / divisions within the company: 2 such interviews were held in each case with 3 managers. In addition to providing a broader functional perspective, these teleconferences permitted interaction between the managers which proved revealing.
3. Face-to-face interviews: a total of 4 managers were interviewed in this way.
4. Visits to DCs: five visits were made; two to DCs included in the 1998 survey, one to an express parcel depot and two to DCs operated by a large home delivery company.

A total of 37 managers were interviewed in 28 companies or divisions of companies. Details of the companies can be found in Annex 1. A total of fifteen sectors were represented. The sample included several of the largest logistics service providers in the UK which have clients in a range of sectors. As a large proportion of logistics expenditure in the UK is outsourced, it is logistics service providers (LSPs), rather than their clients, which have to deal with the problems posed by congestion on a day-to-day basis. It is for this reason that much of the primary data has been collected from LSPs.

Roughly 90% of the interviews were recorded and detailed notes were taken.

The interviews were all semi-structured. A questionnaire was used to structure the interview though not all questions were answered by all interviewees. A copy of the questionnaire can be found in Annex 2.

2.4 Transport modelling

This was undertaken to investigate the relationship between traffic volumes along a sample of routes and the variability of transit times. It employed a newly developed vehicle routing software tool which combines elements of traffic modelling and with a commercial vehicle routing algorithm. It used a road network database and standard speed-flow relationships for different classes of road. Link- and time-specific traffic flow data was obtained for the UK trunk road network from the Highways Agency.

3. Summary of the Previous Study

The main objectives of the 1998 project were:

- to assess the relative impact of congestion on internal warehouse operations
- to examine the ways in which firms are modifying these operations to minimise the effects of congestion
- to try to establish a method of quantifying the associated costs.

The study focused on the fast-moving consumer goods sector and involved detailed interviews with managers and staff in seven distribution located along the M1 motorway, one of the most congested corridors on the UK trunk road network.

The main findings of the study were as follows:

1. It was very difficult to isolate the effects of congestion from other disturbances to companies' logistical schedules. Congestion-related delays were often amplified by booking-in systems. Vehicles arriving late at a DC and missing their timetabled slots had often to queue until the next available slot. Several of the DCs were working at or near full capacity and there was little slack in their inbound schedules.
2. Only two of the DCs suffered significant disruption as a result of congestion. In the others, congestion-related delays were relatively infrequent and could generally be accommodated within normal work schedules.
3. Most congestion is regular and predictable. It can be comfortably accommodated by building extra slack into delivery schedules, usually involving the commitment of extra resource in vehicles and drivers. The study distinguished regular delays from 'major congestion incidents' (MCIs) and differentiated several degrees of disruption in terms of their resource implications and the consequences for activities further down the supply chain. The vast majority of congestion-related delays were relatively short and could be buffered within the warehouse with minimum additional resource expenditure. The most vulnerable operations were cross-docking operations carried out within a 2-3 hour time frame. Short-term redeployment of staff from other activities could usually recover the situation.
4. None of the companies consulted were unable to quantify the impact of congestion on warehouse operating costs. Most of the managers reckoned that any additional costs would be very small. Congestion appeared to be having little or no influence on inventory levels and was only marginally inflating labour costs. It had had little bearing on companies' investment decisions in the areas of materials handling and IT.
5. Senior management of two companies indicated that greater importance was being given to congestion in the strategic planning of distribution systems. As new DCs had a typical life of 20-25 years, long term trends in traffic levels and road conditions had to be considered.

4. Review of Other Literature

Several papers and reports have been published since 1998 which shed new light on the links between congestion, reliability and logistical efficiency. This research addresses five themes:

- a) assessments of the impact of congestion / transport disruptions on supply chains
- b) estimation of the value companies attach to the reliability of freight transport
- c) analyses of freight transport operators perceptions of congestion-mitigation policies
- d) surveys of company responses to declining freight transport reliability
- e) modelling city logistics systems to minimize the impact of traffic congestion

a) Assessments of the impact of congestion / transport disruptions on supply chains:

Our 1998 study fell into this category (McKinnon, 1999). Since then similar research has been undertaken at an urban scale in Auckland, New Zealand (Sankaran et al., 2005). This wide-ranging review of the effects of traffic congestion on supply chains was based on case studies of three manufacturing / trading companies and several logistics operators. It sought to '*uncover the micro-level impact of traffic congestion from a supply chain perspective*'. Several of the findings were broadly in line with those of our 1998 study. The authors concluded that:

- Congestion has a variable impact on companies' supply chains depending the nature of the market, the nature of the products, location of premises etc. This issue has been examined more systematically and in greater detail by Kuipers and Rozemeijer (2006) in research that they undertook in the Netherlands. Their work is summarized in Section 10.1.
- Congestion is '*often an amplifier of delays and costs*' caused by other factors.
- As congestion increases, '*service levels are the first casualties, with the cost of congestion felt after some time lag*'. One reason for this lag effect is much freight transport is outsourced and rates agreed periodically. Carriers therefore '*have to absorb the congestion-induced time delays at lease in the short-term*'.
- Successful management of congestion requires a collaborative effort by several organizations in the supply chain.
- Courier companies can '*blunt the impact of road traffic congestion*' by increasing the number of depots in their networks and '*shrinking*' service areas.

Another interesting observation, not discussed in other literature, is that the monthly order-invoice cycle, which is prevalent across sectors and countries, exacerbates the congestion problem by concentrating the demand for freight transport at the start of the month. This '*aggravates the impact of congestion*' partly by causing truck traffic to peak in the first week of the month, but also reducing the amount of slack in logistics systems at this time to buffer against congestion.

Wilson (2007) conducted a more general analysis of the impact of 'transportation disruptions' on the performance of two types of supply chain: a traditional supply chain and one in which vendors manage inventory for their customers (VMI system). Her work belongs to the emerging field of supply chain risk and resilience and involves simulation modeling. She models what happens '*when the material flow is interrupted between two echelons in a supply chain,*

temporarily stopping the transit of these goods, regardless of the source of the disruption'. No specific reference is made to congestion as a possible source of disruption, though as the modeling is based on a ten day interruption to transport (at four different points in the supply chain) the results are not applicable to congestion-induced delays¹. The simulation model could, however, be adapted to assess the impact of much shorter transport delays on inventory levels, product availability and costs within different types of supply chain.

Sarmiento et al (2007) provide a general review of the relationship between delivery reliability and the efficiency and performance of different types of manufacturing operation.

b) Estimation of the value companies attach to the reliability of freight transport.

Researchers in the Institute of Transport Studies at the University of Leeds employed their adaptive stated preference tool (LASP) to assess, in computerized experiments, the trade-off that a sample of 40 logistics managers made between freight transport costs and delivery reliability (Fowkes et al., 2004). Their analysis differentiated three types of delay: a 'schedule delay' at departure time; a 'predictable delay time', reflecting the regular amount of congestion on the road network, and an 'unpredictable spread of arrival times', representing the variance in transit times. By analyzing managers' responses they were able to attach average monetary values to the various forms of delay.

In a study for the Dutch government, Rand Europe examined the value of reliability (VoR) in freight transport (Hamer et al., 2005). It presented monetary values for a 10% change in reliability on six freight transport modes (road, rail, inland waterway, short / deep sea ship and air cargo). There is little commentary on the derivation of these values. The report also includes a brief summary of an expert discussion on the issue of freight VoR, but acknowledges that *'there (was) no consensus nor even a majority position within the expert group'*. The only point of agreement was that more research was required!

c) Analyses of freight transport operators' perceptions of congestion-mitigation policies

In the course of an interview survey of a large sample of for-hire and private trucking companies in California in 1998, Golob and Regan (2000) examined around 1200 managers' views of a range of *'congestion relief policies'*. These policies were classified using an exploratory factor analysis. Some of the policies related to the internal management of logistics operations while others required intervention by governmental agencies. Six classes of congestion mitigation measure were identified:

- New dedicated truck facilities
- Improved operational efficiency
- Better traffic management on the road network
- Greater priority for trucks on urban arterial roads
- Increase in road capacity
- Congestion tolling (with some concessions for particular types of delivery operation)

Many other papers recommend ways of easing the congestion problem for freight operators though their arguments are not substantiated by empirical research (e.g. Davies, 1999; Guy, 2002; Mansell, 2004; European Shippers Council, 2007a and 2007b)

¹ With the possible exception of delays to ships waiting to offload at severely congested ports.

d) Surveys of company responses to declining freight transport reliability .

The 1998 Golob and Regan survey also investigated the measures that companies were taking to reduce the impact of congestion on their freight transport operations. They were particularly interested in the application of advanced IT systems to ease the congestion problem, particularly ‘mobile communication devices, electronic data interchange (EDI), automatic vehicle location (AVI), an electronic clearance system ... as well as publicly available traffic information updates’ (Regan and Golob, 1999, p.58). In a subsequent ‘computer-aided interview survey’ of 700 trucking companies in California in 2001 Golob and Regan (2003) assessed the extent to which they were using computerized vehicle routing and scheduling (R/S) software to minimize the impact of traffic congestion on their operations. They found that ‘demand for R/S software is positively influenced directly by the need to re-route drivers, and indirectly by the need, generated by customers’ schedules to operate during congested periods’ (p.76). They also anticipated increasing demand for the input of ‘real-time information on traffic congestion to R/S systems’. The greatest application of R / S software to mitigate the effects of congestion was by for-hire carriers, companies working in the Los Angeles area, providers of ‘flatbed and container services’ and those serving the ports.

The main focus of the study by Kuipers and Rozemeijer (2006) in the Netherlands was the response of shippers and freight transport operators to worsening traffic congestion. In focus group discussions with these organizations they differentiated measures at the strategic, operational and tactical levels (Table 1).

	<i>Operational measures</i>	<i>Tactical measures</i>	<i>Strategic measures</i>
<i>Road transport companies</i>	Earlier departure of trucks (and later return) Delivery at an earlier time Use of more trucks Use of back up trucks	Make better agreements with shippers on delivery times Broadening of planning horizon Use of night distribution Use of planning software Use of mobile telephone	Consolidation of transport-networks with other transport companies Strategic cooperation with other transport companies Use of consolidation centers Increase the number of DC’s Move DC’s towards important customer locations Design of new and innovative logistics concepts
<i>Shippers</i>	Relax transport planning Longer opening hours of facilities Assign longer time windows per truck	Make more use of ICT control tools Adapt level of stocks Narrowing of planning horizon Allow night distribution	Increase the size of DC’s to increase the level of flexibility in stock keeping practices Increase the number of DC’s Design of new and innovative logistics concepts

Table 1: Measures taken in response to the declining reliability of road transit times

Source: Kuipers and Rozemeijer, 2006

e) Modelling city logistics systems to minimize the impact of traffic congestion

D’Este (2000) acknowledges the importance of incorporating congestion into the modeling of freight movements in urban areas, particularly as that is where congestion delays are concentrated. It has been suggested that the development of ‘public logistics terminals’ could help to reduce the contribution of freight traffic to urban congestion and allow freight operators to improve the efficiency and reliability of their ‘city logistics’. Taniguchi et al (1999) developed a model for determining the optimal size and location of these public logistics terminals which incorporates a ‘travel time performance function’ on ordinary urban roads and expressways.

5. Logistics, Transport and Congestion Trends

This section will review a series of trends which have affected the exposure of companies' logistical systems to traffic congestion over the past decade. These trends can be divided into five categories:

- Transport system
- Logistical restructuring
- Business trends
- Technology
- Working practices

5.1 Transport system:

Growth of road traffic and congestion levels:

Between 1998 and 2006, the total amount of motorized traffic on the UK road network increased by 10.1%. Heavy goods vehicle traffic grew by just over half this rate (5.4%). Despite this traffic growth the average speed on major roads in England (for all categories of traffic) increased slightly between 1998 and 2003, though dropped significantly in the West Midlands region (Figure 1).

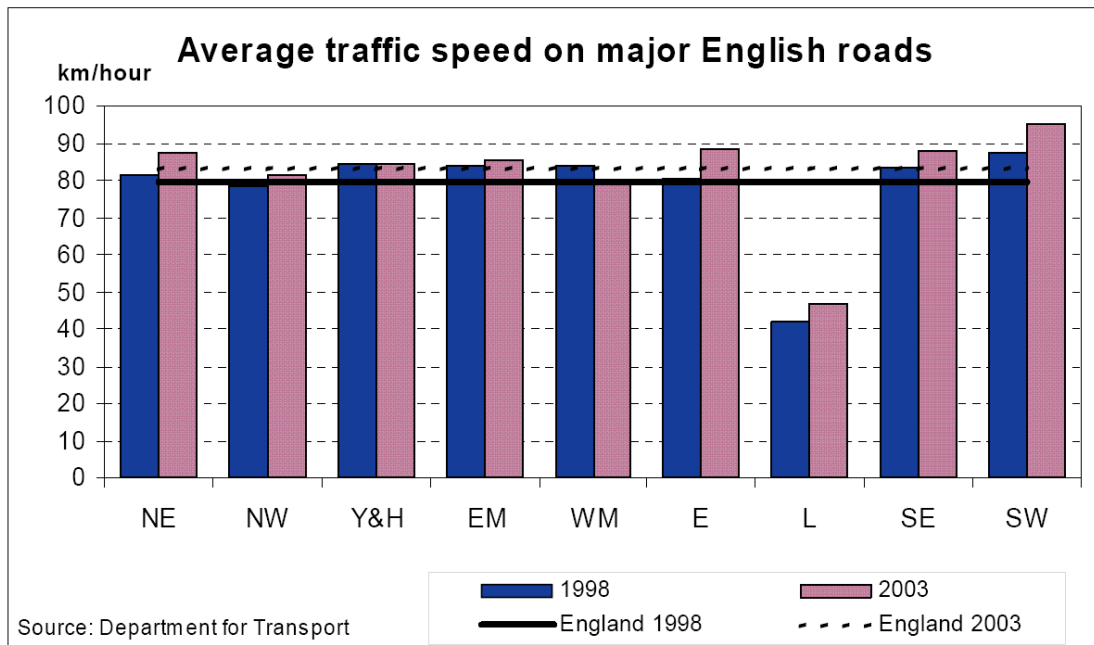


Figure 1: Trend in average traffic speeds 1998-2003.

The average speeds in English urban areas, on the other hand, steadily declined during both the peak and off-peak periods between 1999 and 2006. It is noticeable that the reduction in average speed during off-peak period has been greater than that in peak periods (Figure 2).

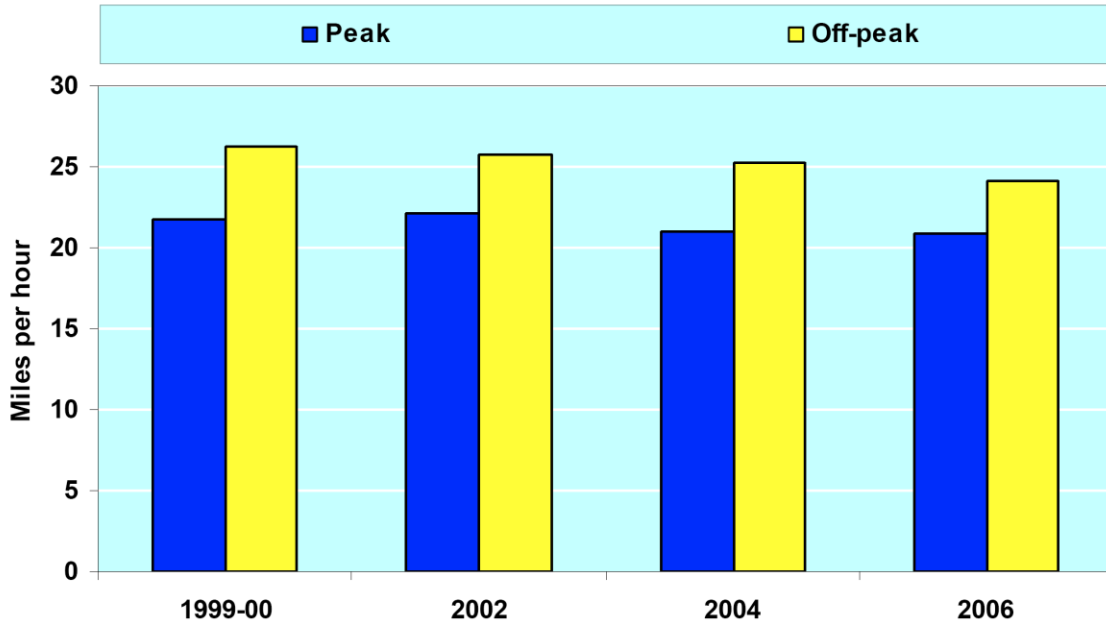
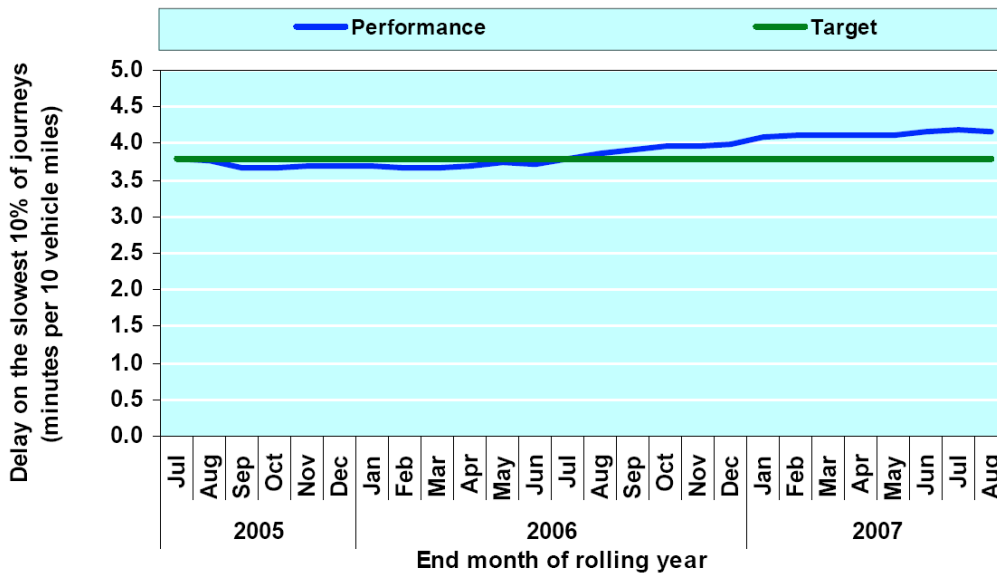


Figure 2: Average traffic speeds in English urban areas: 1999- 2006

In recent years the Dept for Transport has developed a new method of measuring the reliability of transit times on the trunk road network. This estimates the average delay (in minutes per ten miles (16 kms)) experienced on the slowest 10% of journeys on particular roads. Available data suggests that across the English trunk road network the congestion index has significantly increased over the past three years, rising above the target performance figure for the network (Figure 3).



Source: Department for Transport

Figure 3: Trend in Congestion Index for English trunk road network against target

Other data sources also confirm that traffic congestion on the UK road network has markedly worsened over the past decade. Trafficmaster, which continuously monitors traffic flow on the motorway network, has reported increases in the number of congestion alerts issued to drivers (Trafficmaster / RAC Foundation, 2005). Quarterly surveys of members conducted by the Freight Transport Association also show a gradual deterioration in road 'network reliability' (Figure 4) (FTA, 2005).

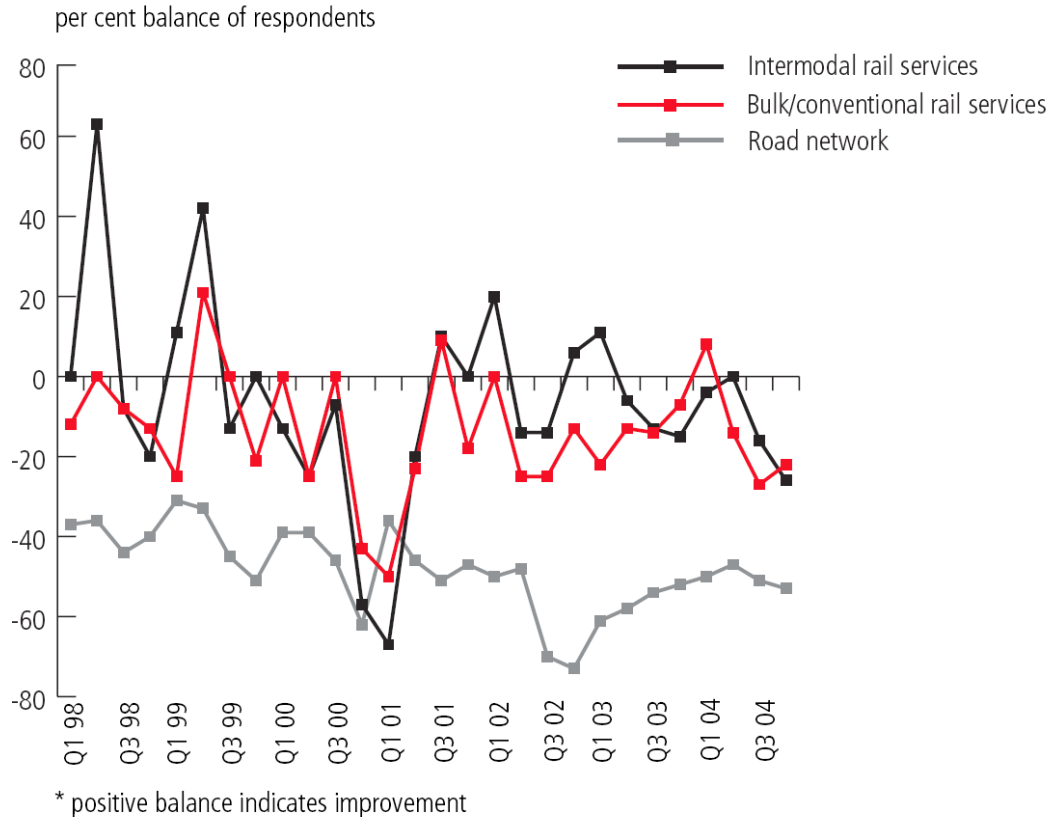


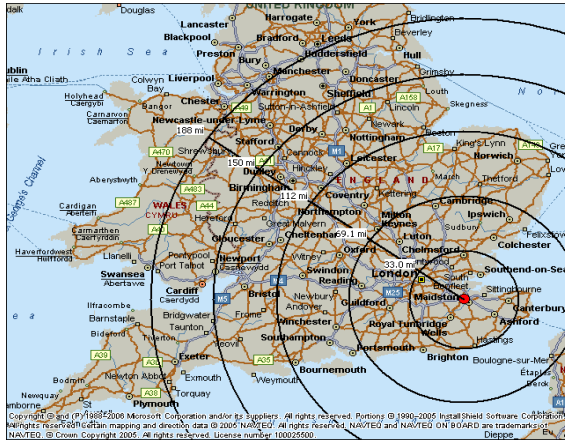
Figure 4: Distribution Managers Assessment of Network Reliability
Source: Freight Transport Association

Data provided by one of the participants in the interview survey also shows how average road speeds for lorries have declined over the past three years as result of congestion in the southern half of the UK. The maps in Figure 5 show how the isochrones delimiting the distances that can be travelled over 1 – 5 hours from the town of Maidstone in Kent have converged since 2005.

Modal Shift to Rail and Waterborne Services

Between 1998 and 2006, rail and waterborne services (mainly coastal shipping) combined increased their share of the UK freight market from 30 to 32%. Many of the companies that have transferred traffic to these modes, particularly rail, have claimed that this was done partly to escape congestion on the road network.

2005



2007

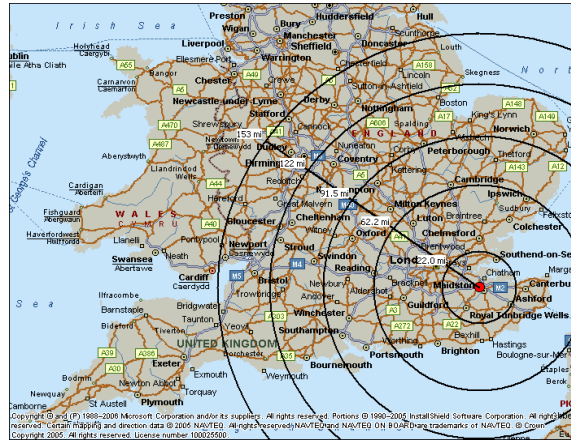


Figure 5: Delivery Ranges for Trucks within 1-5 hours of Maidstone, Kent.

Growth in Night-time Delivery.

The proportion of truck-kms run between 8pm and 6am increased from 16% to almost 20% between 1995 and 2005. This has been facilitated by several trends, including:

- Extension of opening hours at industrial and commercial premises
- Some relaxation of night delivery curfews imposed on these premises
- Increased use of reception boxes to permit unattended out-of-hours delivery

The growth of day-time congestion has been one of the main drivers of this move to night-time delivery though it has also been motivated by a desire to improve the utilization both of vehicles and fixed assets.

Active Traffic Management

The Highways Agency, which is responsible for the English trunk road network, has introduced ‘active traffic management’ on some motorway links (such as the M25 orbital motorway around London and M42 in the West Midlands). This scheme ‘aims to help keep the traffic moving by making the best possible use of the space available on our existing motorways, rather than building more new roads’. It involves varying speed limits in relation to the volume of traffic in an effort to smooth vehicle flow and minimise transit time variability.

5.2 Logistical restructuring:

Centralisation of production and inventory.

Although at a fairly advanced stage, this process of centralization has continued over the past decade. It has been quite pronounced in the brewing sector, for example. One larger brewer reduced its number of primary stock locations from 13 to 4 in the early 2000s while another has cut the number of local depots serving pubs and restaurants (the so-called ‘on-trade’) from 45 to 32 over the past few years. This has expanded the areas served by these facilities at a time when worsening congestion on large parts of the road network is increasing the

average length and variance of transit times. Companies centralizing their operations have not been deterred by forecasts of deteriorating congestion. This is partly because the economic benefits of centralization, in scale economies, lower inventories and a reduction in fixed costs, can far exceed the additional transport costs, even allowing for a congestion cost penalty. Companies have also been able to minimize transport cost and service penalties associated with congestion by operating satellite depots or vehicle out-bases. Much of the new warehouse investment has been concentrated in the West Midlands region and along the main motorway corridors serving this region, many of which are seriously congested.

Increased use of hub-and-spoke networks

These networks, which have grown substantially over the past decade, cater for less-than-truckload (LTL) movements in the form of parcels and pallet-loads. Regional hauliers collect consignments and consolidate them into larger loads for overnight trunking to sortation hubs, most of which are located in the English Midlands. Pallets collected from the hub are trunked back to the regional depot for distribution to local customers, as illustrated in Figure 6. It is estimated that in the UK around 70,000 pallets per night are handled through these networks.

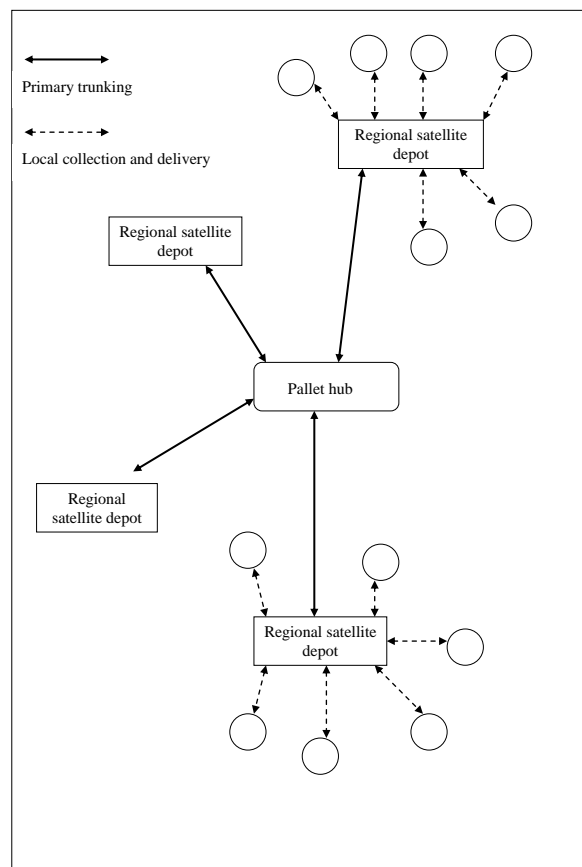


Figure 6: Hub-and-spoke structure of pallet-load and express parcel carriers.

This switch from 'echelon-type' distribution channels to hub-and-spoke networks is fundamentally changing the pattern of freight flow. As almost all the long distance trunking between local depots and central hubs is done at night, it has minimal exposure to traffic congestion. Consolidating loads on the radial trunking network also improves average vehicle

utilisation and cuts vehicle-kms travelled (relative to the amount of truck movement generated by the traditional inter-depot network). Overall, therefore, the move to 'hub-and-spoke' networks may have eased congestion pressures, though this would require further investigation.

Development of 'port-centric' logistics:

In response to the huge increase in imported goods, mainly in containers, many companies have reconfigured their inbound supply chains. Many companies have set up separate 'import centres' where containers are 'de-stuffed' and their contents stored and handled. It is common for these centres to be at or near the major ports. Basing these facilities at the ports can effectively remove a link from the supply chain and permit more direct delivery to shops / industrial customers. On the other hand, road and rail routes to the ports have become quite heavily congested reducing the reliability of direct deliveries to and from port-based DCs.

5.3 Business Trends

Offshoring of production to lower-cost countries

Over the past decade there has been a large shift of industrial capacity from the UK to the low labour cost countries of the Far East and Eastern Europe. When a manufacturing plant is relocated to another country or its output is replaced by imports, the upstream and downstream supply networks can be dramatically altered. Many of the upper links in the supply chain also transfer to the foreign country as new overseas vendors are found. Partly as a result the freight-transport intensity of the UK economy (i.e. ratio of tonne-kms to GDP) has declined. This has reduced the rate of truck traffic growth in the UK, though as trucks only represent around 7% of total vehicle-kms the net effect on the congestion trend is likely to have been modest. This trend, like the previous one, has also exacerbated congestion on 'trade-routes' to and from the ports (FTA).

Growth of factory gate pricing:

In some sectors, most notably grocery, major retailers have increased the proportion of supplies that they buy at 'factory gate prices' thereby assuming control of the inbound transport operation back to the point of production. This has enabled them co-ordinate transport operations more effectively across their supply chains and improve vehicle utilization. The resulting multi-tripping of vehicles (between DC and shop, shop and factory, factory and DC, DC and DC) requires a high degree of confidence in the delivery schedule. Traffic congestion makes it harder to secure the full operational benefits.

Reduction in order lead times:

In some sectors, there has been a further compression of order lead times as companies endeavour to cut inventory levels. Survey data is available for the retail grocery sector to confirm this trend (IGD, 1999 and 2007). Lead times have shortened despite the lengthening of average road transit times and increase in their variability as a result of traffic congestion.

Increased interest in supply chain risk and resilience:

Following major supply chain disruptions in the UK in the early 2000s and partly in response to corporate pressures to develop 'business continuity plans', many companies have been subjecting their supply chains to supply chain risk audits. Worsening traffic congestion has been identified as a supply chain risk factor, though no research has been done to assess the extent to which this has influenced corporate decision-making behaviour.

Growth of home deliveries

Over the past decade the proportion of retail sales delivered to the home has increased from around 3% to 9%, mainly as a result of the growth of online retailing. This has transferred more of the responsibility for home delivery from the consumer to the retailer / carrier, converting a personal shopping trip to a freight movement by truck or van. This has intensified delivery operations in urban areas where traffic congestion problems are concentrated.

5.4 Technology

Information and Communication Technology

Over the past decade mobile phones have become widely diffused across the road freight sector, establishing direct communication between vehicles, their traffic offices and customer locations. There has also been extensive development of vehicle tracking and alerting systems, though, according to a survey in 2005, traffic congestion has not been a major motivating factor in the adoption of telematics by road freight operators (McClelland and McKinnon, 2005).

5.5 Working Practices

Working Time Directive

In 2006, the Working Time Directive was applied to road haulage operations, imposing tighter restrictions on working hours particularly during the night. It was predicted that this would reduce the degree of flexibility in delivery scheduling and, among other things, make it more difficult to adapt transport operations to worsening traffic congestion. Feedback from industry, however, suggests that the WTD has had much less impact than expected. This is partly because the definition of 'periods of availability' within the WTD regulations is quite liberal, but also because many companies have been able to alter working practices and shift patterns to accommodate it.

6. Relationship between Traffic Volumes and Transit Time Variability

Data provided by the Highways Agency has been used to assess the minimum and maximum arrival times for a number of routes varying in length between 7km and 773km. This analysis has combined information from various sources on:

- Traffic volumes
- Digitised road network of England
- Speed flow functionality
- Road freight movements

The Highways Agency has over 4,500 detector loops embedded in the major roads throughout England as shown in Figure 7. These loops collect information on the flow of traffic passing over the sensors. Hourly totals of traffic volume throughout each day, and for every day of the year, are stored on a database called TRADS (TRAffic and Accidnt Data Statistics). Also recorded are incidents such as accidents, road works, sporting events and weather delays. There is a huge amount of data stored by TRADS. Given the limited time and resources available for this study, sub-set of the data was extracted showing, for the year 2007, the hourly traffic volumes for an average weekday (excluding public holidays) and standard deviations indicating of variability of the traffic volumes.



Figure 7: Locations of Highway Agency loop detectors

The congestion analysis used a digitised road network of England consisting of nodes corresponding to a location on the road network such as a motorway exit, junction, roundabout, traffic lights, or a change in road category, and links which contain information about a stretch of road between pairs of nodes, such as distance and road category. The traffic volumes and standard deviations from the TRADS database were mapped onto this digitised network by matching the sensor locations with appropriate links. Certain roads did not have any road sensors so traffic volumes and standard deviations had to be estimated based on the road category. By applying an appropriate speed-flow formula it was possible to use the traffic volume to estimate the speed on each link. This made it possible to derive travel times for vehicles on each link.

The Highways Agency's "The Design Manual for Roads and Bridges" contains speed-flow formulae for different types of road. A speed-flow function estimates the speed of a vehicle depending on the volume of traffic on a road. The speed of vehicles decreases as the flow, or volume of traffic, increases. There are 13 speed-flow formulae depending on the type of road being used,. Each formula has the traffic volume as a variable, but it is possible to add many other variables to allow for hills, bends, intersecting side roads in rural areas, visibility and verges or hard strips at the sides of roads. Data on these additional variables is not available for the links in the road network, and therefore default values, as defined in the COBA manual, have been used and kept constant throughout the analyses. An assessment was made of the effects of taking account of these other variables. This showed that they would only have a small impact on the calculated speeds, ranging between plus and minus 5kph.

The main source of road freight data is the Continuing Survey of Road Goods Transport (CSRGT), which samples around 17,000 trucks (with gross weights over 3.5 tonnes) and records their activities over a period of one week (journeys made, weight of vehicle, types of goods moved and fuel used, together with some related documentation). From a total sample in excess of 140,000 journeys, a sample of 21 was selected based on a range of distances from the origin to the destination.

Using a shortest path algorithm a quickest route was found for each of the 21 journeys using the average traffic volumes and speed-flow formulae. The route lengths ranged from 7km which had 11 road links to 773km which had 188 links. A series of 100 simulations were undertaken for each of the 21 routes. These simulations applied a random traffic volume to each link in the route based on the average traffic volume plus or minus twice the standard deviation (this equates to approximately a 95% confidence interval). The simulations stored minimum and maximum time taken to travel the route. The routes were kept constant for each of the simulations. The results are summarised in Table 2.

The results show that as the route distances increase so does the difference between the earliest and latest arrival times. In the case of the shortest trip the difference was only 2.6 minutes but for the longest it was 70 minutes. When this range is expressed as a percentage of the average arrival time, the results show that the highest percentage differences in travel time occur on the shortest routes. For example on routes of 7, 32 and 47kms the % differences were, respectively, 14,19 and 18. For routes of 259, 455 and 773 kms the corresponding values were, respectively, 5, 7 and 4. Clearly, over greater distances, a vehicle has greater opportunity to make up time lost on the more congested stretches of the route. The relative impact of congestion can be much more severe in the case of short journeys across busy sections of the road network.

Figure 8 plots the maximum and minimum trip times against route length, with each of the 21 routes shown as a point on the graph. These initial results clearly show the variability of potential arrival times for routes ranging from 7km to 773km. The correlations between the between earliest and latest arrival times and distance traveled are reasonably strong at 0.92 and 0.88 respectively. This confirms the view expressed by the logistics managers surveyed that most congestion is regular and predictable. An analysis of this type yields results that could be factored into companies' logistics modeling to ensure that allowance is made for worsening traffic in the strategic planning of logistics systems. Further research would be required to validate these results and to explore a wider range of delivery options.

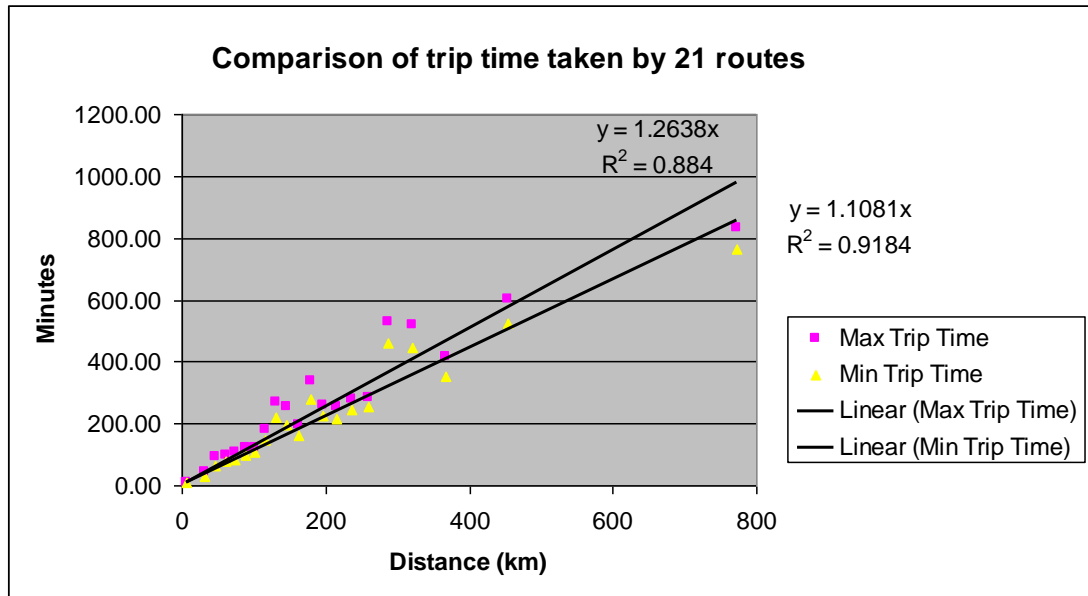


Figure 8: Relationship between max and min transit times over varying distances

Route	From Node	To Node	Route	Distances (km)						Max Trip Time (mins)	Min Trip Time (mins)	Average	+ or - as a % of	
				Motorway	Dual Carriage way	Primary Road	Regional Road	Local Road	Total Kms				(mins)	(mins)
1	6648	6928	6648-7084-6638	0.0	0.0	2.9	4.1	0.0	7.0	10.4	7.9	9.1	1.3	14%
2	6017	6207	6017-6364-6018	15.3	11.6	0.0	4.6	0.0	31.5	46.0	31.5	38.8	7.3	19%
3	5738	9189	5738-5766-9002	0.0	24.4	20.6	0.8	1.2	47.0	93.6	64.5	79.1	14.5	18%
4	7146	7292	7146-6787-6800	24.8	25.6	5.0	5.3	0.0	60.7	97.9	77.2	87.5	10.3	12%
5	3537	5439	3537-3687-3567	20.1	2.4	43.4	8.3	0.0	74.2	108.0	81.2	94.6	13.4	14%
6	3148	3843	3148-3579-3157	48.1	20.9	18.9	0.0	0.0	87.9	124.3	96.5	110.4	13.9	13%
7	4586	5652	4586-4929-4570	70.8	16.6	11.3	3.5	0.0	102.2	124.4	106.3	115.3	9.1	8%
8	2488	3988	2488-2822-2870	43.8	40.6	24.6	7.8	0.0	116.8	181.1	149.0	165.1	16.0	10%
9	1767	6335	1767-2137-1770	2.8	94.4	31.0	3.0	0.0	131.2	269.8	219.6	244.7	25.1	10%
10	453	8359	453-556-570-530	56.6	89.6	0.4	0.0	0.0	146.6	256.1	196.4	226.2	29.9	13%
11	3291	8571	3291-3298-3314	123.1	31.8	7.2	0.0	0.0	162.1	193.8	163.9	178.8	15.0	8%
12	4517	5782	4517-4730-4603	36.4	126.9	1.3	14.9	0.0	179.5	335.7	280.6	308.2	27.6	9%
13	835	3291	835-953-8006-700	105.4	20.2	70.6	0.5	0.0	196.7	257.5	224.1	240.8	16.7	7%
14	2950	4473	2950-2861-3753	162.9	42.7	0.0	9.7	0.0	215.3	252.8	216.0	234.4	18.4	8%
15	4055	7126	4055-3832-4322	180.6	50.5	4.7	0.0	0.0	235.8	281.5	244.8	263.2	18.3	7%
16	2079	5995	2079-1862-2097	191.1	26.7	26.9	14.7	0.0	259.4	285.7	256.4	271.1	14.6	5%
17	5204	9126	5204-5282-5274	33.8	157.1	78.4	17.8	0.0	287.1	530.1	461.6	495.8	34.2	7%
18	6721	8571	6721-6712-6827	122.3	140.9	54.5	2.6	0.0	320.3	517.0	445.2	481.1	35.9	7%
19	1244	7135	1244-1347-1240	293.5	56.2	14.4	3.6	0.0	367.7	414.4	352.5	383.4	31.0	8%
20	2140	7844	2140-1680-2180	290.9	130.6	26.5	6.5	0.0	454.5	600.4	521.7	561.0	39.3	7%
21	555	8854	555-596-578-610	643.8	124.1	5.4	0.0	0.0	773.3	834.3	764.1	799.2	35.1	4%

Table 2: Results of simulation

7. Logistical Consequences of Delays in the Transport System

7.1 Impact of Congestion on In-transit Inventory Costs

When traffic congestion lengthens the average transit time, the quantity of inventory in the transport system increases. This inventory represents an investment of working capital which must be financed at prevailing interest rates. It is difficult to estimate the total value of in-transit inventory, as official surveys measure freight only in weight terms. On the basis of previous research and applying a price inflation index it has been estimated that the average tonne of road freight in the UK in 2006 was worth around £1470. The average journey speed and average length of haul for road freight in that year were, respectively, 83 km per hour and 86 kms. This suggests that there would have been an average of £313 million of in-transit inventory on the road (in trucks with a gross weight of 3.5 tonnes or more) at any given time. The annual interest payable on this amount of inventory, at commercial interest rates prevailing at the time, would have been £22 million. Using government traffic figures, it is estimated that the average truck journey is delayed by 7.6 minutes by congestion on the strategic road network. No comparable data is available for delays on other types of road. As congestion is generally more severe in urban areas, it is likely that the average delay will be higher than 7.6 minutes. If assumes that the average delay is 12 minutes, the cost of financing the extra in-transit inventory would be only £4.2 million per annum. Allowing for the fact that these are merely 'order-of-magnitude' calculations, the latter figure is fairly negligible when set against estimates of the effects of congestion on vehicle operating costs. It can also be argued that if inventory spends more time in-transit it may simply spend less time at the warehouse, factory or shop. There may, therefore, be no increase in total inventory carrying costs.

7.2 Impact on Operational Efficiency and Service Quality

The 1998 study differentiated several degrees of disruption that could result when inbound deliveries were delayed:

- 1) delay accommodated within normal operating procedures:
- 2) temporary redeployment of resources at minimal cost: e.g. staff and equipment temporarily redirected from less time-sensitive to more time-sensitive activities
- 3) temporary deployment of additional resources: eg. staff overtime: late deliveries can make it necessary to extend the shifts of warehouse operatives.

In stages 1-3 the effects of the delay are contained within the DC with no disruption to outbound deliveries. Where much of the warehouse throughput is cross-docked within a few hours, contingency measures within the DC may not be sufficient to 'buffer' the inbound delay, in which case the outbound delivery will be affected. This, too, can happen to differing degrees:

- 4) delay to the outbound departure, possibly transmitting the problem to premises further down the supply chain.

- 5) departure of the outbound vehicle without the product that was delivered late, possibly resulting in stockouts and lost sales downstream and under-utilisation of the outbound transport.

In most of the DCs surveyed in 1998, congestion-related delays were accommodated at levels 1 and 2. Only where deliveries were severely affected by a major traffic jam, and /or where serious congestion coincided with other operational delays, did the disruption reach levels 4 and 5. This situation does not seem to have changed much over the past decade, despite the increase in congestion levels. The impact of congestion-related unreliability has now been assessed across a much broader range of sectors. The general response has been that almost all inbound delays can be contained within DCs and very seldom 'cascade' down the supply chain. Little additional cost has to be incurred in warehouses to cope with late inbound deliveries. There is also little evidence of the utilization of outbound vehicles being adversely affected.

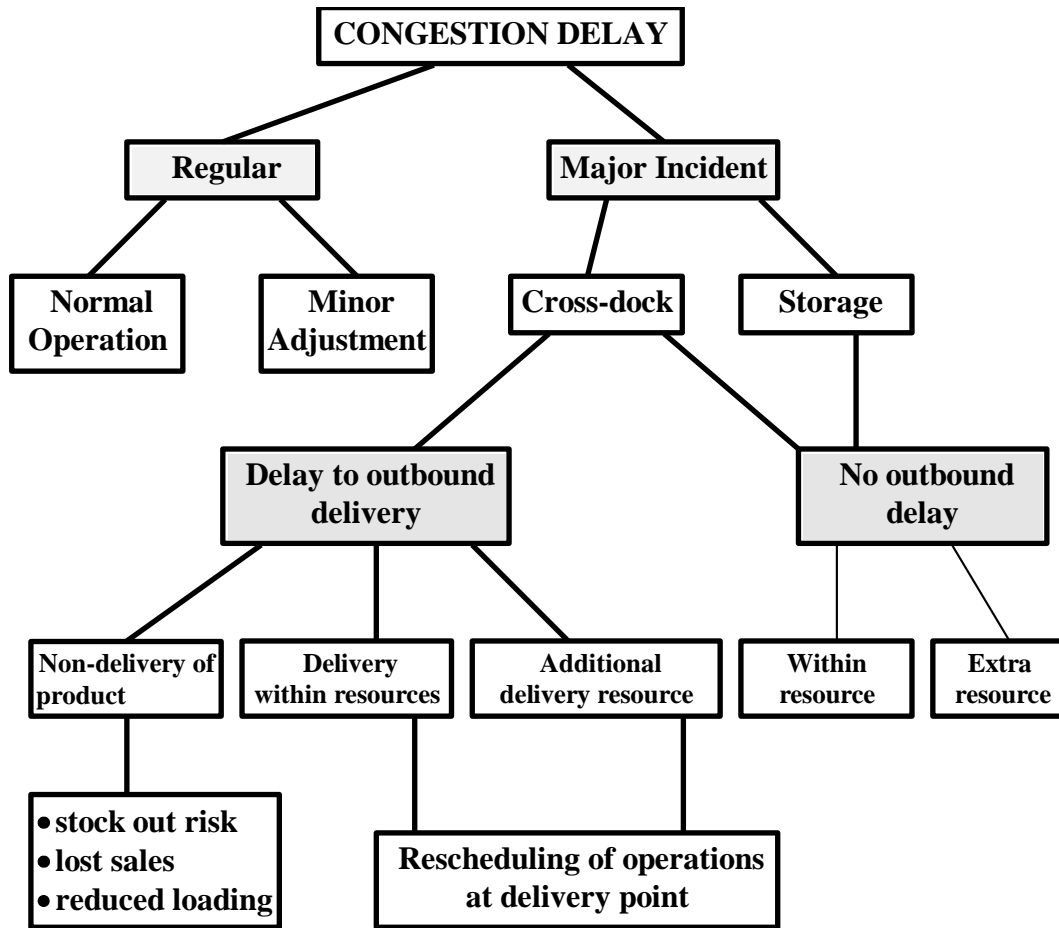
The ability to contain the impact of congestion-related delays at levels 1 - 3 is largely attributable to three factors:

- most delays are short relative to internal process times, providing adequate buffering.
- the degree of flexibility in the redeployment of resources.
- the regularity with which congestion-related delays occur.

There was unanimous agreement across the 2008 interviewees that most congestion is regular and predictable. There was disagreement, however, over the extent to which the frequency of major congestion incidents had changed over the past five years. The majority of managers believed that it had increased, a significant minority disputed this. Data collected from the transport information company Trafficmaster appears to confirm the former view. It measures the degree of congestion by the number of alerts that it has to send out to drivers when serious traffic jams occur. The number of alerts has increased significantly in recent years

One of the outputs of the 1998 study was a hierarchical classification of congestion-related delays (Figure 9). The primary distinction in this classification was between short delays which occur regularly and can be accommodated with little or no modification to warehouse operations and 'major congestion incidents' which are much more disruptive. These two general types of delay can be further subdivided in terms of their resource implications and consequences for activities further down the supply chain. Major congestion incidents that seriously disrupt warehouse operations occurred with a frequency of once per annum for the non-food national DC and once per month for the most time-sensitive of the DCs which cross-docked and distributed chilled food within the south east of England.

Figure 9: Classification of the Logistical Consequences of a Congestion Delay



8. Relative Importance of Congestion as a Source of Unreliability

Previous research has established that traffic congestion is only one of many factors that disturb logistical schedules. These other factors can be broadly divided into two categories: (i) factors directly related to the transport operation (ii) factors affecting other aspects of the logistics activity. Information on the former category has been collected over the past decade in the UK government's Transport KPI surveys, while our interview survey has provided new insights into the latter category. One of the companies participating in the survey has also provided the results of a survey of delivery failures. These form the basis of a short case study.

8.1 Analysis of Transport KPI Survey Data

Since 1997 the UK government has commissioned eleven key performance measurement (KPI) surveys of road freight operations across eight sectors. These surveys take the form of 'synchronised audits' in which large numbers of vehicle fleets are simultaneously measured against a standard set of criteria over a 24-48 hour period. One of the key criteria is 'deviations from schedule'. This requires companies to indicate if a journey leg was significantly delayed, by how many minutes it was delayed and the main cause of the delay. Traffic congestion is listed as one of six possible causes of delay. The others are:

- Problem at collection point
- Problem at delivery point
- Own company actions (internal problems)
- Lack of driver
- Vehicle breakdown

In the case pallet-load networks, problems at the sortation hub were separately identified. Companies could also indicate if the cause was simply 'unknown'.

This data has been recorded for KPI surveys in seven sectors: food, drink, automotive, non-food retailing, express parcels, pallet-load networks and builders merchants.. In the case of food products, three surveys have been undertaken, in 1998, 2002 and 2007, making it possible to conduct a time-series analysis for this sector. It has also been possible to separate food retailers from food suppliers in the case of the 2002 survey.

Across the seven sectors surveyed since 2002, data is available on 55,820 journey legs. 26% of these legs were subject to a delay and 35% of these delays (i.e. 9% of the total) were attributed mainly to traffic congestion. The incident of delays varied widely among the sectors (Figure 10). In the express parcels sector, where a premium is attached to rapid and reliable delivery, no delays were reported. At the other extreme, 44% of the trunk movement of pallets between local collection / delivery depots and the central hubs were delayed, though only 14% of these delays were blamed on congestion. Three-quarters were due to problems at the hubs. Food retailers, drinks suppliers, automotive companies and the local collection / delivery of pallet-loads also experienced a relatively high frequency of delays. In these sectors congestion delayed 10-12% of all journey legs. Its absolute and relative contribution to delays was significantly lower in the case of builders merchants. The transport operations of non-food retailers, on the hand, recorded a relatively low proportion of total delays, but over half of them (57%) were

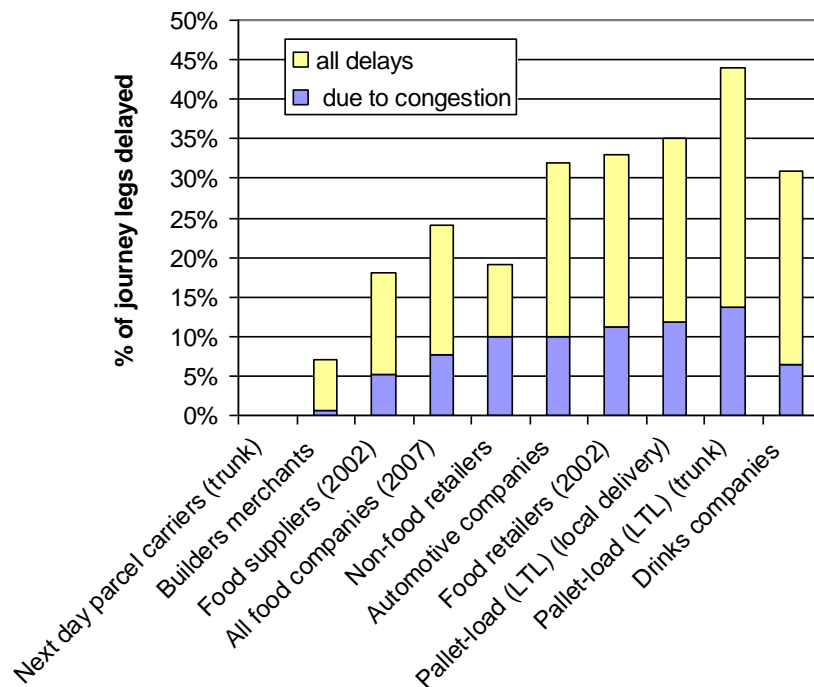


Figure 10 : Sectoral Variation in the Frequency of Total and Congestion-related Delays

blamed on congestion. Table 3 shows the relative contribution of all the main causes of delay.

	<i>Food</i>	<i>Drink</i>	<i>Pallet-load C&D</i>	<i>Pallet-load trunk</i>	<i>Non-food retailers</i>	<i>Automotive</i>	<i>Builder's Merchants</i>
Traffic congestion	35%	21%	34%	31%	57%	10%	34%
Problem at delivery point	28%	26%	41%		17%	4%	37%
Problem at collection point	8%	6%	16%		6%	6%	
Own company action	24%	8%	8%	11%	26%	4%	20%
Lack of driver	4%	2%	1%	1%		5%	
Vehicle breakdown	1%	1%	0%		2%	4%	9%
Hub operation				57%			

Table 3: % of journey legs delayed disaggregated by cause and sector.

The average length of the delay caused by traffic congestion was relatively short. It averaged 24 minutes, by comparison with an unweighted average delay time for all causes of 41 minutes. Problems at sortation hubs for pallet-load distribution and vehicle break-downs causes the longest delays, respectively, 58 and 52 minutes. When the frequency and duration of delays are combined and the results weighted by the number of journey legs surveyed in each of the sectors, 'own company actions' emerges as the most important source of delays, followed by problems at delivery points (Figure 11). Traffic congestion comes third, being responsible for 23% of total delay time.

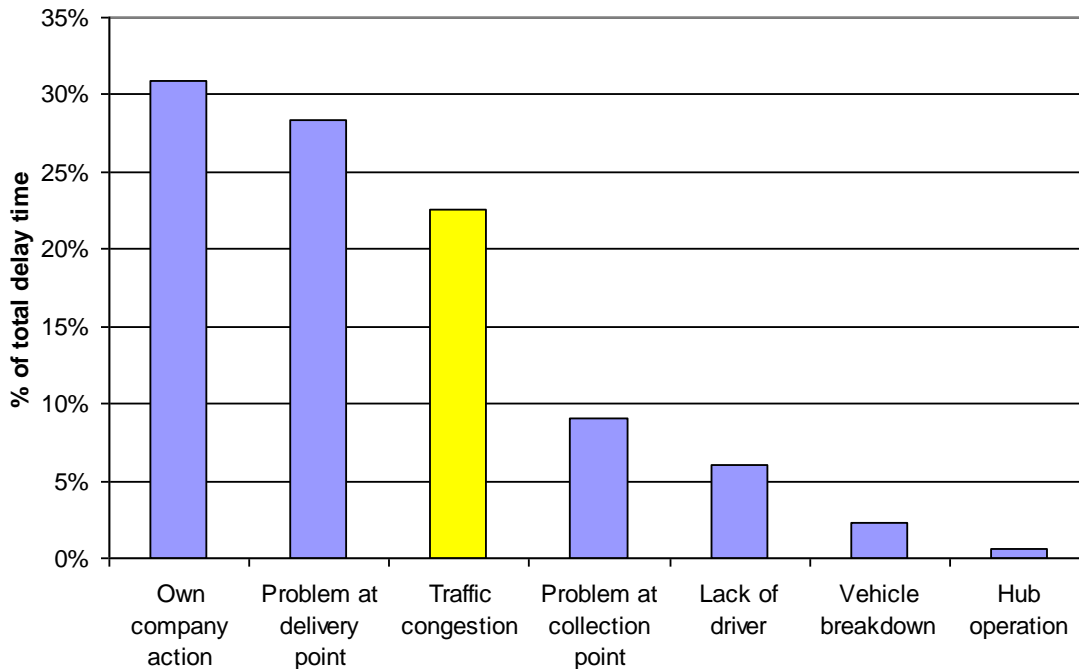


Figure 11: % of total delay time attributable to different causes (all sectors)

According to the time-series analysis of KPI data for the food sector, it appears that the relative importance of these sources of delay has been changing through time. In terms of its share of total delays, its average duration and overall contribution to delay time, traffic congestion remain fairly constant between 1998 and 2007. Its share of total delay time in the food supply chain rose from 20% to 22% over the period. Problems at delivery points, on the other hand, declined from 44% to 26% over this period (Figure 12). This can be largely ascribed to improvements in the reception of goods at retailers' DCs. In 2002, there was a 32% chance that an inbound delivery to an RDC would be delayed and these delays averaged 40 minutes. This was partly due to 'backdoor congestion' at many of these premises. Recent improvements in the reliability of these inbound operations can be attributed to:

- Substantial investment in new food DCs with greater goods reception capacity.
- Growth of primary consolidation, where supplies, mainly of chilled and frozen food, are consolidated at upstream warehouses prior to delivery to retailers' DCs. This reduces the number of RDC deliveries and allows them to be more tightly scheduled.
- Move to factory gate pricing, giving retailers full control of transport operations from the point of production.
- Growth of 'green-laning' where some inbound deliveries from some suppliers are subject to less load checking and paperwork.

Delays due to 'own company actions' has followed the opposite trend, with its share of total delay time rising from 20% to 34%. This requires an admission by the company responsible for transport, mainly the logistics provider but also suppliers with own-

account transport operations, that the delay occurred because of some failure in their internal processes. The proportion of delays due to the lack of driver climbed fourfold from 2% to 8%, probably reflecting the worsening lorry driver shortage in the UK and increasing reliance on agency-drivers, often brought in at short notice to cover for absenteeism.

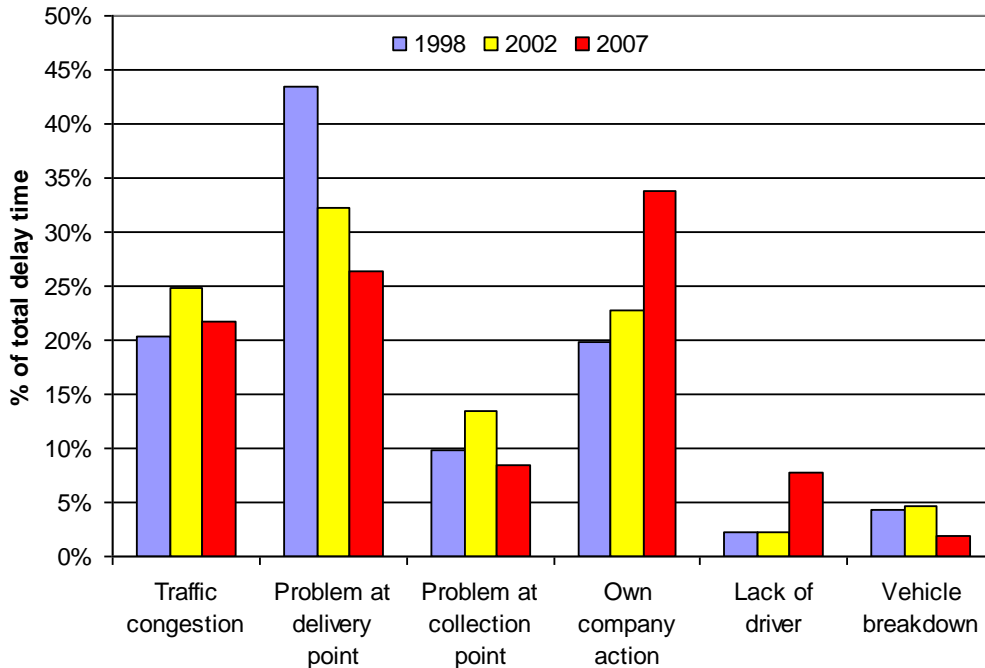


Figure 12 : % of total delay time in the food supply chain attributable to different causes

In summary, the transport KPI data suggests that, across the sectors surveyed, traffic congestion is not the main cause of unreliability in delivery operations. It is the most frequently occurring source of delay but has the shortest average duration. When frequency and duration are factored together, congestion is found to account for 22% of delay time, making it less important than internal problems in companies' logistics operations and delays at delivery points.

These transport KPI survey results require two qualifications. First, as companies will already have allowed for congestion-related delays in their scheduling, the figures are likely to under-estimate the true magnitude of the congestion problem. The focus here, however, is on reliability (i.e. deviations from schedule) and so this analysis is very pertinent. Second, the various causes of schedule deviations are inter-related. Companies were asked to identify the main cause of a delay, but a delay due to one factor can be reinforced by another. For example, a vehicle delayed by congestion may miss its booking-in slot at a DC and have to wait until the next available off-loading slot. If it is making multiple deliveries, delays will then accumulate, being amplified by the booking-in systems at each customer location. In the 1998 food KPI survey, respondents were given the opportunity to stating if a delay had 'no single cause'. 19% of the delays were assigned to this category.

8.2 Analysis of the Interview Data

In the course of the interviews managers were asked unprompted about the other factors disrupting logistical schedules. Figure 13 summarises the responses from 22 managers in twenty-two companies. The three most important factors were deemed to be vehicle / equipment break-downs, staffing problems and delays in the production operation, each accounting for 16% of all the factors mentioned. Equipment failures almost always related to vehicles, though a couple of references were made to production and handling equipment failing. By the far the most frequently mentioned staffing problem was drivers failing to turn up, particularly agency drivers. Problems with production operations invariably involved vehicles arriving to collect products and having to wait to until they are ready for despatch. Deficiencies in the planning process and poor forecasting, each accounting for 9% of mentions, are inter-related. The key to successful logistics management lies in managing variability in the levels and pattern of demand from day to day. The fact that most managers did not mention this fundamental source of variability was probably because they regard it as being intrinsic to the logistics process. They have certain expectations of the extent to which this variability can be managed. Errors in forecasting and planning, however, can cause unnecessarily large fluctuations destabilising logistics operations. Another source of unreliability identified by a few managers lay at the modal interface with rail, shipping and airfreight operations. In the case of intermodal operations, delays could transfer from one mode to another. The remaining factors received few mentions, though were considered important in particular sectors. For example, logistics operations in the forest products sector were particularly sensitive to bad weather, while variations in the enforcement of local access restrictions in urban areas frustrated deliveries to shops, pubs and offices in inner urban locations.

Only around a quarter of the managers interviewed considered traffic congestion to be the most important of source of unreliability in their logistics operations.

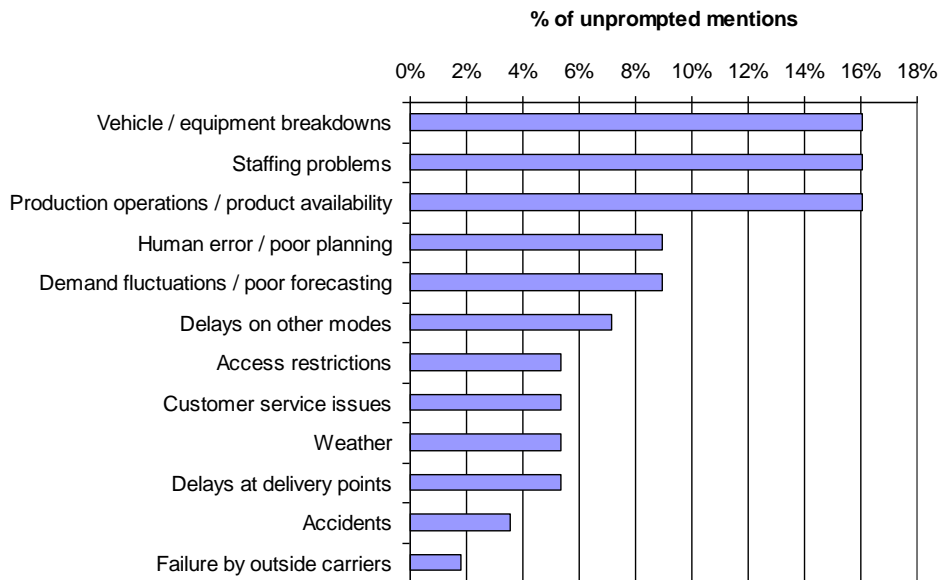
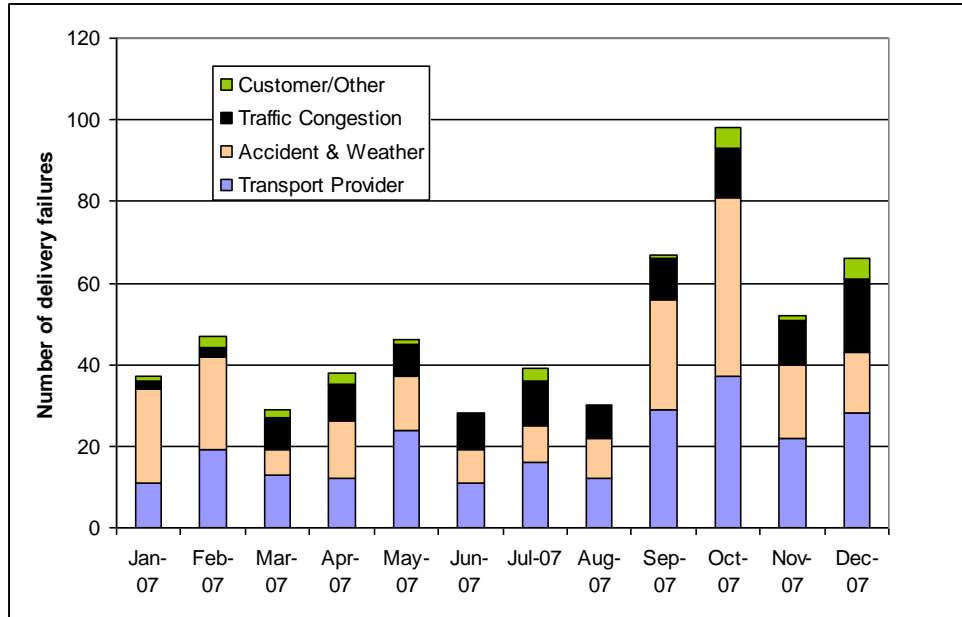


Figure 13: Other sources of unreliability mentioned by interviewees

8.3 Case study: the effects of congestion on the distribution of paper products

The company concerned distributes paper products from a plant in the south east of England and is forced by customer requirements to deliver during the morning peak period. The company closely monitored delivery failures (i.e. late deliveries) during 2007 and attributed them to five possible causes, one of which was traffic congestion (Figure 14).

Figure 14: Number and causes of delivery failures in paper delivery operation



This revealed wide monthly variations in both the number of failures and the relative importance of the different causes. The number of delivery failures was 3.5 times greater in October than in June, while the proportion of failures due to congestion fluctuated between 4% in February and 32% in June. There would also be some inter-relationship between congestion, weather and accidents. It is not known if this degree of variability in the incidence and composition of delivery failures is typical.

The company also monitored changes in a series of congestion-related KPI between 2005 and 2007. This values show a significant decline in delivery performance over this period, most of which the company attributes to worsening traffic congestion (Table 4).

Table 4: Delivery KPIs for paper delivery operation.

	2005	2007
Hours per delivery	4.83	5.16
Trips per day	1.8	1.74
Trips per driver day	1.45	1.40
Miles traveled per vehicle day	280	275
Average revenue per vehicle per day (indexed)	100	97.2
Average vehicle speed (miles per hour)	38.6	35.2

The company has estimated that congestion adds approximately 6% to its distribution costs.

9. Adaptation of Logistics Systems to Congested Infrastructure

On the basis of earlier research, a list of possible methods of adapting logistics to congestion was compiled. During the course the interviews companies were asked if they had applied these methods or were planning to implement them. Interviewees were also given the opportunity to mention other congestion-related initiatives that they had undertaken. The broadening of the range of sectors surveyed revealed new methods of adaptation that were not applied by the FMCG companies investigated in 1998. It has also made it possible to assess the relative importance of the various methods. They can be divided into five general categories: (i) transport (ii) warehousing (iii) inventory (iv) information and communication technology (ICT) (v) supply chain collaboration.

9.1 Transport

9.1.1 Increase fleet size

This can take two forms:

Increase in the number of powered units (i.e. rigid vehicles or tractor units on articulated vehicles):

The majority of the companies interviewed argued that there had been little or no increase in the number of vehicles as a result of congestion. With more careful planning of the delivery operation or some of the other adaptation measures listed below they had minimised the effect of congestion on vehicle numbers. Several respondents conceded, however, that it was difficult to assess the effects of congestion on vehicle numbers for several reasons. First, freight volumes fluctuated over different periods and were often subject to longer term underlying growth. There could, therefore, be a significant amount of excess capacity in the fleet to accommodate peak volumes. This added flexibility. Second, companies would often make more use of sub-contractors during peak times rather than expand their own fleet. One company (in the paper industry), which was able to quantify the impact of congestion on delivery costs (6% increase), could partly do so because much of the extra expense went on employing sub-contractors to help deal with congestion-related delays.

Increase in the ratio of trailers to tractors (i.e. the 'articulation ratio'):

Where the ratio is greater than one companies can effectively decouple the transport operation from the loading / unloading activities. These activities can then proceed even if inbound vehicles are delayed. One might, therefore, expect the average articulation ratio to increase as congestion increases and delivery reliability deteriorates. Across the sample of companies interviewed this ratio varied from 1 to 3.5 and averaged around 1.6. It reflected fundamental differences in the nature of logistics operations. The main reasons offered for having high ratios were the desire to maximise internal warehouse or factory productivity and lack of storage space in these premises (with trailers being portrayed as 'warehousing with wheels'). Most companies reported a marginal reduction in the ratio of tractors to trailers in recent years, presenting this as evidence of improved transport efficiency. The few companies that had seen their articulation ratios increase attributed this mainly to factors other than congestion, though most conceded that it made it easier to accommodate traffic delays.

9.1.2 Adjustments to journey planning

Vehicle routing software which is now widely used across UK industry incorporates average speeds for different classes of roads. Any reduction in these average speeds

would be an obvious indicator of the impact of congestion on delivery operations. The main application of this software is for multiple drop / collection operations. Only three of the companies which used it for this purpose claimed to have revised average speeds downwards in recent years. These software packages tend to assist rather than replace manual route planning. The results of the computerised routeing and scheduling are often overlain by a large amount of human judgement by traffic clerks and drivers who have a good knowledge of traffic conditions. In the local delivery parcels to homes, vehicles typically make 130-140 deliveries in an eight hour shift, while to business customers an average of 70-80 drops are made. Many of these deliveries are made in urban areas and therefore exposed to significant day-time congestion. Very little use is made of routeing software in these operations. There is heavy reliance on the drivers' knowledge of the delivery area. As they visit the same zone every day they build up a detailed awareness of traffic conditions and routing options. Two of the main parcel carriers in the UK, which employed this system, had not detected a reduction in the average number of drops per trip in recent years, despite worsening urban traffic congestion.

9.1.3 Reschedule deliveries to off-peak periods

A distinction can be made between the rescheduling of day-time deliveries to avoid the morning and afternoon peaks and the rescheduling of deliveries into the evening and night.

(i) Avoiding peak periods

Where possible most companies try to avoid delivering at peak times, but this is often constrained by the following factors:

- Need to deliver fresh produce to shops before 8-9pm opening times
- In the construction industry, building sites typically need supplies between 7 and 10 am.
- Urban access restrictions can prohibit deliver vehicles from entering shopping streets after 9 or 10am
- Industrial customers insist on receiving deliveries at particular times which requires peak hour running
- Vehicles making longer distance deliveries before or after the rush hours are inevitably on the road at peak times
- Train or ferry timetables may require road feeder movements to be made at peak times
- Industries with continuous 24 hour assembly / processing operations and JIT supply systems need a constant inflow of products, even during peak periods.

Opportunities for off-peak delivery have been increasing as opening hours and good reception windows at factories, warehouses and shops have been extended. The width of the am and pm rush hours have also been widening, however, as peak traffic flow spreads over longer periods. Early morning deliveries which used to be completed before the morning peak can now be subject to a congestion delay.

(ii) Evening and night-time delivery:

The proportion of truck-kms run between 8pm and 6am in the UK has more than doubled over the past twenty years. Roughly half the companies consulted had increased night-time running over the past 5-10 years. This switch is only partly motivated by a desire to avoid congestion. It is also done to improve the utilisation of vehicle assets and to meet

the growing demand for overnight delivery in the express parcels and pallet-load sectors. A large steel distributor had raised its proportion of night-time running from 20% to 50% over the past ten years. 50% was considered the maximum because vehicles were run around 20 hours per day and need balanced scheduling between day and night. Some companies incentivised customers to receive supplies through the night by offering discounted delivery rates. One major supplier of car components in the automotive 'after-market' had invested in 'drop-boxes' at its 300 branches around the country to permit secure, unattended delivery during the night.

There are, nevertheless, several constraints on night delivery. The main constraint is the need to synchronise road transport operations with production and distribution operations most of which still take place during the working day. The widespread application of the JIT principle has more closely integrated the scheduling of inbound deliveries with these operations. Local planning authorities also impose curfews on night deliveries to industrial and commercial premises near residential areas. Trade bodies, such as the Freight Transport Association and British Retail Consortium, have campaigned to have many of these curfews lifted in recognition of the fact that lorries are now much quieter and can be equipped with many noise-abatement systems. A recent trial in London over a five month period demonstrated how night-time deliveries could be made to inner urban supermarket without a single resident complaining. When compared with the previous day-time deliveries, average transit times were reduced by a third, fuel consumption cut by 25,000 litres per annum and CO₂ emissions by 68 tonnes per annum (Freight, March 2008).

9.1.4 Alter Working Practices

It had been predicted that the imposing of the Working Time Directive in April 2006 would make it harder for companies to reschedule delivery operations to accommodate worsening traffic congestion. The responses of interviewees suggests that this has not been the case. As discussed earlier, the definition of 'periods of availability' that the UK government adopted has given companies greater flexibility than expected and companies have found ways to reorganising work schedules to accommodate the new regulations. As one logistics manager explained, the WTD has forced companies to be more 'creative' in the way in which they allocate tasks and manage their staff. A common tactic has been to shift non-transport duties (such as goods handling and paperwork) from drivers to warehouse staff to maximise the proportion of the driver's shift actually spent driving the vehicle. Some companies have done the opposite and built extra flexibility into their systems by training staff to drive both trucks and fork-lift trucks.

9.2 Warehousing

In assessing adaptive measures affecting warehousing it is important to distinguish strategic from operational changes.

9.2.1 Strategic Decisions

In theory, there are six ways in which, at a strategic level, warehousing might be adapted to worsening traffic congestion

(i) Warehouse design:

The main design features relevant congestion are the configuration of the cross-docking area and the separation of loading and off-loading bays. As cross-docking is the most time-sensitive activity in a warehouse, the internal layout needs to be designed in a way that

maximizes the speed of this operation. This is something that companies want to do anyway, however, and appears not to have been specially influenced by congestion concerns. The sharing of reception bays between inbound and outbound deliveries was highlighted by a couple of the companies interviewed as congestion risk factor. If several inbound vehicles arrived late they either had to be rejected or the start of the outbound loading had to be postponed. Many new DCs, particularly in the FMCG sector, have a 'through-flow' design with inbound reception bays on one side of the building and outbound bays on the other. This largely eliminates the risk of inbound delays physically impacting on outbound loading and delivery, though to be economically viable often requires a large and continuous throughput.

(ii) Internal warehouse operating system:

Building more slack into internal handling systems should enhance the flexibility of warehousing operations and thus improve their ability to cope with congestion-related delays. If congestion were having a major impact on warehouse performance, therefore, one might expect to see companies investing in additional handling equipment. When managers of DCs in the FMCG sector which questioned about this in 1998, their unanimous response was that they 'give little or no consideration to congestion-related delays when deciding on the provision of handling equipment'. When asked to rate the degree of consideration on a scale of 1 - 5 (5 denoting the lowest degree), their average rating was 4.9. The much larger sample of managers from more diverse sectors were asked the same question in 2008 and the response was almost exactly the same. There is no evidence that congestion is causing companies to incur additional capital cost in internal warehouse handling systems. One logistics manager noted, however, that the capacity of these systems is often geared to peak volumes offering sufficient slack to accommodate a congestion-related surge at other times. When a severe congestion problem arose at peak time, handling systems could be put under strain. It should be noted too that most of the cross-docking operations / short-term picking operations that were examined are labour-intensive and involve minimal use of capital equipment.

(iii) Demand for warehouse space:

One determinant of a DC's ability to cope with unreliability in the delivery system is the amount of space available. In the 1998 study, two of the seven DCs visited were space-constrained and this reduced their ability to divert staff and equipment away from the less time-sensitive 'put-away' operation (i.e. putting goods for storage into the racking) to much more time-sensitive cross-docking and picking operations. They simply did not have enough space to accommodate a build-up of inbound supplies awaiting put-away. The unanimous response of the managers surveyed in 2007, including those at one of the two DCs with a space problem in 1998, was that, when considering their response to traffic congestion, warehouse space was not an issue.

(iv) Allocation of throughput to DCs:

As traffic congestion is concentrated in particular corridors and areas, it distorts the pattern of accessibility across the road network. It can affect the average length and variance of transit times more on some routes than others. This might cause companies to redraw the boundaries around DC service area, and hence reallocate volumes between DCs, in a way that reduced the overall efficiency of the distribution. No evidence of this congestion-induced sub-optimality could be found in the 1998 survey. This was not mentioned as a significant issue by the 2007 sample of companies. This may simply be because congestion is factored into logistics planning as a 'fact of life' and its effects on DC zoning are not separately assessed. In the intervening decade, there has been a

major shift away from the delineation of rigid boundaries around DC service areas to integrated fleet planning where transport operations are managed across a network of DCs. Some companies describe this as 'flexing boundaries' around DCs. This had added greater flexibility to delivery planning and made it easier to adjust to short-term variations in congestion levels. Two of the companies responding to the present study acknowledged that from time to time, partly in response to congestion, they might switch the sourcing of some products from one DC or factory to another.

(v) Number of Distribution Centres

Some commentators have speculated that if road congestion in the UK gets much worse, the process of warehouse centralisation, which has been one of the dominant logistical trends of the past 30 years, may go into reverse as companies find it increasingly difficult to service customers within the required lead times from their existing DCs. When the MVA Consultancy asked a sample of 50 companies in 1995 how they would be likely to react to increases in average journey time, only a small proportion indicated that they would increase the '*number of sites/depots/outlets*'. Approximately 6% would do so if transit times increased by over 50%, 3% if the increase was between 11 and 50% and none if it was below 10%. As noted earlier, average traffic speeds actually increased on the major roads between 1998 and 2003, though speeds on urban road during off-peak period declined by around 10%. According to the MVA 'elasticities' these changes in average transit times would be likely to induce any decentralization of warehousing. Indeed, over the past decade, there has been further centralization of warehousing, particularly in the brewing sector.

The present study did, however, find some examples of companies planning to decentralize their operations partly because of traffic congestion. One major supplier of building materials with a factory in the Midlands was considering setting up a DC in the London area, partly in an effort to build up sales there but also partly because congestion was making it increasingly difficult to hit narrow time-windows at building sites and builders' merchants in the South East of England directly from its plant. A logistics service provider was also planning to set up two new regional DCs but this was in response to the growth and diversification of its business rather than to congestion. The additional facilities would make it easier for the company to deal with congestion, but this would be a minor spin-off benefit.

Several other producers of industrial commodities such as paper and glass which have centralized their production over the past 15-20 years are also finding it hard to serve peripheral areas directly from their factories as a result of congestion. Initially they may simply develop 'out-bases' for vehicles and drivers to ensure longer deliveries can be made within the drivers' hours regulations on more congested roads. In the longer term, however, if traffic conditions continue to worsen these may be converted into stockholding depots.

A large food distributor operated 2 depots and 4 out-based in 2005. It had recently added a third depot and plans to add another out-based within the next year. Congestion has been significant factor in the decision to expand the number of both depots and out-bases.

(vi) Location of Distribution Centres:

Several of the companies surveyed reported having localized congestion problems in the vicinity of some DCs. In three cases the DCs had been built over twenty years ago on the outskirts of towns, but the towns had expanded and new shopping centres or/and

business parks had been constructed nearby. As a consequence local access roads were seriously congested at peak times. This not only affected freight deliveries; it could also cause staff to arrive late for work. None of the company consulted, however, had plans to relocate DCs because of congestion at local, regional or national levels.

9.2.2 Operational Decisions

Traffic congestion can destabilise internal warehouse operations and as consequence reducing overall productivity. Staff and equipment are under-employed when inbound deliveries are delayed and over-stretched when several late deliveries are bunched. By increasing the flexibility of these operations companies should be able to minimize the impact of congestion on the cost and performance of warehousing. One obvious source of flexibility is the switching of staff between activities at short notice. Evidence of this was found in the 1998 study in two grocery DCs. In the most time-sensitive of their operations, grids of discrete product lines were laid out on the warehouse floor from which items were picked by store into roll cages. Where supplies of a particular product arrived late these were 'line-picked', particularly for those shops that were most distant and required an early despatch. If, because of congestion, an increasing proportion of supplies were to arrive late, more line-picking would have to be done before the grid was complete. It was noted that 'In extreme situations, this could quickly degenerate into a 'shambles'' though in practice this very rarely occurred.

The FMCG companies surveyed in the 2008 study indicated that this practice of switching from store- to line- picking still occurs in response to any late inbound delivery. It can be fairly routine and simply a part of standard warehouse management. There was little evidence that it had increased in importance as a result of traffic congestion. In other sectors, given the nature of their handling and sorting operations, this practice is much less common. Through time there has been a greater 'multi-skilling' of warehouse staff and adoption of more flexible shift patterns. This had been done to improve general labour efficiency and not specifically in response to traffic congestion. It has, nevertheless, helped firms to minimise the effects of traffic congestion on internal warehouse operations and costs.

Other operational decisions relate to warehouse opening hours and staff over-time. In theory, one might expect worsening day-time congestion to encourage warehouses to stay open longer in the evening / night. In practice almost all the DCs operated by the companies surveyed opened 24 hours, indeed many of them were at their busiest during the night. Some, particularly in the primary industrial sectors, close at the weekend. One senior manager argued that by delivering more at the weekend companies would reduce their exposure to the congestion peak experienced on Monday mornings. Across the companies surveyed, little staff over-time is attributable to traffic congestion. In the 1998 survey, overtime payments were identified as one warehouse cost element that might be linked to traffic congestion. None of the companies in the present survey were able say how much, if any, of their warehouse overtime costs were due to late inbound deliveries

9.3 Inventory

A recent US study has asserted that, '*Manufacturers must devote more plant space to storing inventory because they cannot be as sure of the delivery schedule*' (Cambridge Systematics Inc., 2004). Little evidence has emerged in either the 1998 or 2008 UK studies, however, to suggest that inventory levels are being significantly affected by traffic congestion.

The 1998 study concluded that:

'There was almost unanimous agreement among the managers consulted that traffic congestion was not affecting inventory levels within their DCs. In the case of 'storage' items, even the most severe congestion delays were insignificant relative to the average length of time spent in the warehouse, which ranged from a few days to several weeks. The only example that could be found of inventory increasing was where an inbound order (of non-perishable product) arrived too late to be cross-docked and had to be held back for delivery the following day. This was an infrequent occurrence, however, and so had a negligible effect on the average inventory level. Combining this evidence with the earlier analysis of in-transit inventory suggests that traffic congestion has very little effect on inventory costs.'

The results of the 2008 survey could be summarized in exactly the same way, despite the fact that it covered a larger and much more diverse range of companies and that the level of congestion on the UK road network is much higher today than in 1998.

According to UK government statistics (Dept for Transport, 2007) there was an average of 4.4 weeks of inventory in the manufacturing, wholesaling and retailing sectors in 2005. The average length of haul for all domestic freight movements by all modes in the UK is 140 kms. If one assumes that these movements run at an average speed of 70 kms per hour and allow an hour for loading and unloading at either end of the journey, the average transit time will be only 4 hours. As explained in Section 3, even on the 10% of journeys most seriously delayed on the strategic road network, the average delay during the morning peak is only 26.6 minutes. Congestion delays are, therefore, extremely short relative to the average amount of time that products spend in the supply chain.

While these calculations help to explain why traffic congestion has minimal effect on inventory levels, it would be wrong to use them to dismiss congestion as a business issue. In judging the relative significance of congestion, one must consider the time-scales over which businesses operate. Relative to the total amount of time products spend in the production and distribution system, delays caused by traffic congestion can pale into insignificance, but they can represent a significant proportion of the customer order lead time. Most freight transport, after all, is 'transaction-driven'. As one logistics manager has explained, 'the clock starts ticking when the order arrives. It is against that delivery time to customer that we are judged, not how many days or weeks the item previously spent in manufacturing and storage'. If customer order lead times continue to shorten and congestion deteriorates, the importance of congestion-related delays will be magnified.

9.4 ICT Systems

The small sample of companies surveyed in 1998 were making very little use of ICT to reduce the impact of congestion on their logistics operations and attaching very little or no impact to congestion in IT investment decisions.

Over the past decade, there has been wide diffusion of ICT across the UK logistics sector. This has taken various forms. At its most basic, it involves driver communication by mobile phone. This is almost universal across the fleets operated by companies in the survey. At a higher level, companies can install GPS tracking of vehicles. Only a small

minority of trucks, probably less than 10% are currently equipped with this technology. This can be supplemented with satellite navigation systems (SATNAV) which provides the driver with live route guidance. More advanced forms of SATNAV can route vehicles around congested sections of road. Some trucks also have Trafficmaster systems installed which provide advanced warning of congestion ahead, giving drivers time to take evasive action. A logistics service provider with one of the largest truck fleets in the country (over 5000 vehicles) indicated that 85% of its vehicles had mobile phone communication, 20% had tracking systems and 6% full SATNAV.

A survey of 32 road haulage / logistics companies using vehicle telematics / tracking systems in 2005 found that the main reason for acquiring them was to ‘improve reliability’ (Figure 15). The majority of users also expected to obtain six other benefits from them, including better driver control, establishing electronic POD and achieving fuel savings. Across the sample of managers interviewed for the present survey, the main benefit of ICT (both tracking and mobile phones) was seen to be the alerting capability. The ability to notify delivery points in advance of arrival times and / or delays led to improved management of reception facilities and contingency planning. Informing customers of delivery delays has become a standard requirement in many sectors. By improving the ‘visibility’ of road freight transport, ICT was making it easier for companies to adapt their the logistics (and production) operations to worsening congestion.

There is still limited use being made of ICT to ‘dynamically reroute’ vehicles around bottlenecks. When alerted to a congestion problem by, for example, Trafficmaster or a mobile phone call from base, drivers can either use their knowledge of the road network to deviate onto an alternative route or get rerouting advice from the traffic clerk. Very often, however, there are no suitable routes and, if so, these routes will already have filled with diverting traffic. Several managers expressed the fear that SATNAV systems would merely displace congestion problems onto alternative routes rather than spread the traffic.

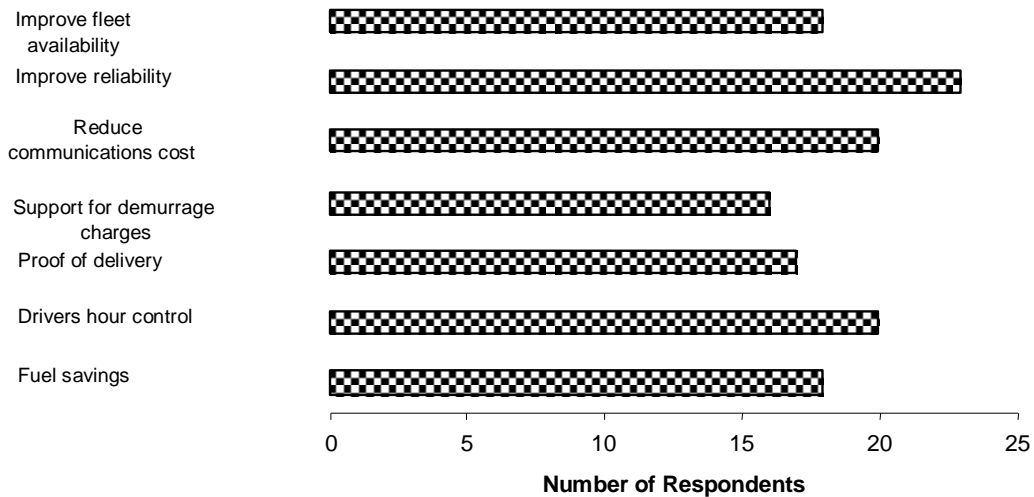


Figure 15: Main reasons for acquiring vehicle tracking system

9.5 Supply Chain Collaboration

There is a limited amount that each company can do in isolation to mitigate the effects of congestion-related unreliability on logistical efficiency and performance. Each company, after all, is partly constrained by the activities of upstream suppliers and downstream distributors and customers. This applies to both in-house and outsourced logistics operations. Of the companies surveyed, those whose scheduling was tightly constrained by customer requirements and forced a large proportion of deliveries to be made at peak times were among the most seriously affected by congestion. Different tactics have been used to try to get customers to relax these requirements. One logistics provider has undertaken a detailed analysis of congestion impacts and presented the client and their customers with hard data on the cost and service implications. Two other companies, in the chemical and steel sectors, have used the price mechanism to discourage requests for deliveries at peak times and promote off-peak delivery. Getting customers to change their replenishment cycles and inbound scheduling can be difficult, however, particularly when they occupy a dominant position in the supply chain and are more concerned about the efficiency and convenience of their internal processes. There is also a widely-held view that congestion is the supplier's or their logistics provider's problem and that they should have adequate systems in place to deal with it.

As one senior logistics executive from the steel sector pointed out, effective management of the congestion can only be conducted 'holistically at a supply chain level'. It requires companies at different levels in the chain to explore opportunities for rescheduling operations to minimize the proportion of deliveries exposure to congestion at peak periods. During the survey, several examples were quoted of collaboration between supply chain partners resulting in such rescheduling. A large logistics provider in the grocery sector also organized a daily conference call with major suppliers to pool information about any anticipated delivery problems, including those resulting from traffic congestion. A general feeling was expressed by many of the managers that more could be done, at a supply chain level, to 'work around' the congestion problem. A similar point was made by Sankaran et al (2005) in their New Zealand. They concluded that *'Successful management of the impact of congestion by freight transport service providers will entail flexibility on the part of clients and their customers' receiving and dispatching processes i.e. having clients and their suppliers / resellers think in terms of the overall supply chain process'* (p.178).

10. Sectoral Review of Congestion Impacts and Unreliability

10.1 Sensitivity of Logistics Operations to Congestion

The 1998 study, which focused on DCs in the FMCG sector identified five factors that are largely determining the sensitivity of a warehousing operation to traffic congestion.

- relative importance of cross-docking and storage ('put-away') operations
- internal process times for cross-docking, vehicle loading and unloading, paperwork etc.
- scheduling of deliveries over the 24 hour cycle
- dependence on vehicle pre-loading
- stringency of booking-in times

These factors were inter-related. For example, it was found that the more rapid cross-docking operations, which were particularly vulnerable to congestion, occurred late in the evening or in the early hours of the morning when traffic on the road network was relatively light. This sensitivity of a cross-docking operation to congestion is not simply a function of the speed with which it is performed: it is also affected by its timing relative to periods of peak traffic flow on the road network.

The 2008 survey conducted across a broader range of sectors has identified several other factors which affect sensitivity to congestion:

- geographical location, with respect to motorway access and local bottlenecks
- direct links to other transport modes
- warehouse layout, particularly the sharing of reception bays and nature of the crossdocking area
- flexibility of shift patterns and working practices.
- use of delivery alerting systems

The importance of these various factors varies widely both between and within industrial sectors. Accordingly, some sectors are more sensitive to congestion-related unreliability than others.

Research conducted in the Netherlands (Kuipers and Rozemeijer, 2006) has attempted to measure the sectoral variation in sensitivity to the reliability of travel times. From focus group discussions with panels of experts it identified a set of eight factors which affected this sensitivity:

1. Rapid depreciation of the products
2. Rapid depreciation of the process
3. Stock-keeping strategy
4. Stringent customer service requirements
5. Irrationality
6. Supply chain-power
7. Direct influence of the end-customer / agility
8. Width of time-windows / continued disruption down the supply chain

The list of factors differs from ours partly because it relates to the whole logistics operation rather than simply the warehousing operation. It attaches more importance to

the distribution of power in the supply chain and customer expectations. There is, nevertheless, some overlap between the two classifications (e.g. stock-keeping strategy and width of time-windows).

The Dutch researchers then invited their expert panel to indicate for each of 13 product groups whether each of these factors had ‘a decisive influence on the distribution strategy giving priority to reliability of travel time’. On this basis, these groups had their ‘sensitivity to reliability of travel times’ graded on a three-point scale: very strong sensitivity, average sensitivity and insensitive. Table 5 shows the results of this exercise. Only two sectors were deemed to be insensitivity to transport-related unreliability, waste and dry / bulk liquids. Consumer products and car components were all rated as very sensitive. These sensitivity ratings were then combined with tonne-km data for the various product groups to make an overall assessment of the amount of freight movement in the Netherlands sensitive to unreliability in the transport system. This suggested the proportions of total tonne-kms with strong sensitivity, average sensitivity and no sensitivity were, respectively, 25%, 35% and 41%.

Table 5: Sensitivity of thirteen product-groups to travel time reliability

<i>Product-group</i>	<i>Rapid depreciation product</i>	<i>Rapid depreciation process</i>	<i>Stock-keeping strategy</i>	<i>Stringent customer service requirements</i>	<i>Irrationality</i>	<i>Supply-chain power</i>	<i>Direct influence end-consumer/agility</i>	<i>Time windows/continuation of disruption in supply ch.</i>	<i>Total sensitivity assumed</i>
1. Consumer goods slow/fast		*	*	*	*	*	*	*	++
2. Food (fresh)	*	*	*	*	*	*	*	*	++
3. Clothing	*		*				*	*	++
4. Other durable consumer goods	*		*			*	*	*	++
5. Paper/printed matter	*	*	*				*		++
6. Parts/semimanufactured products						*		*	+
7. Instruments/tools/equipment/machinery	*		*			*			+
8. Car-parts/trucks/cars etc. (automotive)	*	*	*	*	*	*	*	*	++
9. Waste matter						*		*	0
10. Building material		*						*	+
11. Dangerous goods		*			*	*		*	+
12. Dry/liquid bulk		*				*			0
13. Products sold via internet (b2c)			*	*	*		*	*	++

Source: Kuipers & Rozemeijer (2005)

* = factor is of decisive influence in the distribution strategy giving priority to reliability of travel time. / ++ = very strong sensitivity to reliability of travel times, + = average sensitivity, 0 = insensitive.

One important implication of this, and other, research is that the same amount of delay, measured in minutes or hours, can differ in the amount of disruption that it causes to logistical operations in different sectors.

It is partly for this reason that Rand Europe and the Dutch Transport Research centre (Hamer et al., 2005) found it so difficult to attach a monetary value to reliability in the case

of freight transport. This valuation hinges on the 'definition of too late', but this definition is highly variable within and between industrial sectors and commodity groups. The concept of a delivery being 'too late' is also rather simplistic as it fails to capture the different degrees of impact that unreliability can have on a logistical system (as discussed in Section 6.2).

No attempt has been made to quantify the sensitivity of different commodity groups / sectors in the UK to congestion-related unreliability. In the remainder of this section, however, we examine key logistical characteristics and trends in various sectors and show how companies in these sectors have tried to adapt their operations to congestion.

10.2 Automotive sector

(i) Inbound supply of components to assembly operations

This is the sector in which just-in-time replenishment and lean production developed. The typical car plant has only 3-4 hours stock of many components. If production has to be suspended because of lack of inventory, expenses of £300,000 per hour can be incurred. Given the vulnerability of this sector to inbound delays, one might have expected to find companies relaxing JIT schedules and building more inventory into their systems. There was no evidence of this, however. On the contrary, it appears that inventory levels have continued to decline in recent years, despite worsening traffic congestion. The commitment to lean production principles seems to be as strong as ever, with car manufacturers and their logistics providers undertaking ever more complex planning to 'work their way around' reliability problems such as traffic congestion. JIT is 'engineered' into the automotive production system, as car plants have very small holding areas for components and sub-assemblies. On-site vehicle movements are also very tightly controlled. Trucks often visit several reception bays at different stages in the production line within narrow time-windows. Traffic congestion seldom disrupts this operation, despite the fact that some inbound deliveries arrive at peak times. Inbound transport follows the same rhythm as the assembly operation with work spread fairly evenly over the 24 hour cycle.

This planning task has been made even more challenging by two other major developments in the automotive sector in recent years.

1. Off-shoring of component sourcing: One of the main logistics service providers responsible for deliveries into major UK car plants reported that in 2002, 75% of vendors were UK based and located within 75 miles of Birmingham. Today around three-quarters of the vendors are located an average 600 miles away in Central and Eastern Europe. Despite this lengthening of inbound supply lines, the main congestion problem remains in the UK. Ironically, the LSP now has more flexibility to deal with delays on the UK road network. The 10 day order lead time from Eastern Europe (which includes the manufacturing time) comprises several days of transit time which can be 'flexed' to buffer against delays in the UK.

2. Customisation of vehicles: an increasing proportion of cars are customised to customer requirements. This requires the assembly of particular combinations of parts at particular times in the production schedule. Achieving this degree of precision in a minimal-inventory production operation requires very careful inbound

scheduling. Some of the components are delivered directly to the plant, with the remainder channelled through 'cross-dock' depots where combinations of parts are picked for direct feed onto the production line. Both operations are highly time-sensitive. Despite the relatively high levels of traffic congestion on the road network of central England where most of the car plants are located, these exacting standards are almost always met.

There is a minimum of 2 hours of 'stock' for the most time-sensitive parts both in the car plant and at the cross-dock depot. The planning of inbound logistics takes account of typical road speeds on routes into the plants at different times of day. Once a quarter, actual speeds are compared with the 'benchmark' speeds factored into the vehicle routing software and the latter are adjusted as necessary. As most congestion is regular and predictable it can be accommodated in the delivery schedule. This is not separately costed and simply treated as an integral part of the transport operation. When major congestion incidents occur, causing 'unplanned congestion', 'event management' is deployed to minimise their impact. In extreme cases, this can involve rescheduling deliveries of particular components and altering the sequence in which parts are assembled. It can also be necessary to use an express courier to rush parts into a production line, though this only happens a few times per year. On one occasion urgent plants were actually airfreighted from Southampton to Birmingham because of problems on the road network.

A more serious potential source of unreliability is a vehicle not carrying the exact assortment of parts required by the production operation. Problems in the upstream supply and order picking system can cause shortages of individual parts which can disrupt the assembly operation. The introduction of ICT systems has been motivated more by a desire to monitor the inflow of individual parts than to manage congestion-related delays more effectively.

(ii) Delivery of spare parts in the automotive 'after-market'

Spare parts are stored at a national distribution centre (NDC) and distributed from there overnight by outside carriers to 300 branches around the country. These branches provide a guaranteed 2-hour delivery to customers (mainly garages / vehicle repair centres) during the day. Outbound deliveries to branch network start leaving around 3pm though most of the delivery takes place during the evening and night. Drop boxes have been installed in the branches to permit secure, out-of-hours unattended delivery.

There are two ways in which congestion can adversely affect this operation:

1. Disruption of transport operation at the NDC: This DC has only one set of reception bays for inbound and outbound deliveries. Inbound deliveries are made mainly in the morning and must be completed by lunchtime to permit loading of the outbound vehicles. Serious congestion related delays to inbound vehicles (of 1-2 hours) would delay the outbound loading and despatch. Many deliveries of parts from the NDC are day 1 for day 2 and so it important that the outbound deliveries are not disrupted.

2. Delays to outbound deliveries from branches to customers: The company sets a very high customer service standard in assuring delivery within 2 hours during the working day. A large proportion of deliveries are in urban areas and therefore subject to significant day-time congestion. With 300 branches, the company is able to keep

service areas reasonably small, while enough vehicles and drivers are provided to achieve the 2 hour deliveries, many of which are single drop.

Although congestion levels have increased in recent years, the company has not increased its numbers of vehicles and drivers. The proportion of primary movements to branches run during the night has increased slightly increasing transport costs. Congestion has had no impact on the warehousing operation. All parts are 'put-away' in racking and stored. Product throughput times are therefore relatively long and not affected by congestion. Nor has it been necessary for the company to acquire additional materials handling equipment or employees to buffer its warehousing operation against congestion. The entire local delivery fleet of 1500 vans have onboard telematics systems though this was justified more on the grounds of improved customer service, reduced fuel costs and most efficient routing than easing the effects of traffic congestion. Their ability to notify customers of a congestion-related delay is, nevertheless, beneficial.

The company is now planning to insert a new tier of around 18 regional DCs between the national DC and the local branches to 'hold greater depth of stock' locally and be able to provide better service to customers. This will make it easier to deal with congestion, though this has not been a major factor in this logistics restructuring exercise.

10.3 Chemicals

The company consulted is one of the UK's largest chemical companies producing a range of plastics, 80% of which go into consumer packaging. The inbound flow of feedstock (mainly natural gas) into the plant is by pipeline and unaffected by congestion. Outbound deliveries have been significantly affected by congestion, partly because the main plant is located in a peripheral area and the trunk roads into the heart of its market area are seriously congested. This is a highly competitive market, with logistics costs representing around 10% of product value and high importance attached to the standard of delivery service. Many customers operate on a JIT basis. Although the commodity is relatively low value, it is bulky and customers lack storage space. Many require next day delivery often within 3-4 hour time windows. For example, the downstream manufacture of plastic bottles (e.g. for milk) and sandwich containers can follow a strict daily cycle, with plastic pellets delivered in the morning, processing and moulding of the plastic in the afternoon, despatch of the finished containers in the evening, filling with product during the night and delivery to supermarket the following morning. Around a third of the customers have only 6-8 hours stock. While it is unlikely that a congestion delay on its own would be of this duration, the superimposition of congestion on other disruptions could be critical.

Within the chemical industry it is quite common for companies to have 'vendor managed inventory' (VMI) agreements with their customers. The supplier then assumes responsibility for maintaining an adequate level of inventory at the customer's premises and retains ownership of the inventory until it is 'called off'. This gives the chemical supplier more control over the distribution channel. It can schedule deliveries during off-peak periods and, if necessary, hold larger inventories at customer premises to buffer against transport delays.

The case study company had adopted several measures to reduce the impact of congestion on its operations:

1. *Modal shift:* in 1999 at the time when production volumes rose sharply, the company began to use rail. Today 60% of sales to the UK market (mainly bulk plastics) go by rail, with the remainder (mainly palletised) sent by road. The decision to use rail was motivated, in roughly equal measure, by concerns about worsening road congestion and environmental impacts. The railfreight services trunks bulk products around 300 kms to a DC from which they are transported by road to customers. These road deliveries can also be 200-300 km long and traverse sections of heavily congested motorway network. The switch to rail has, therefore, only partly eased the congestion problem. The rail service can also be unreliable, with approximately one train a month being up to a day late. As the DC holds an average of 3 days of inventory, an occasional inbound disruption of this magnitude can be absorbed.

2. *Use of the price mechanism to discourage deliveries at peak times and promote greater use of night-time delivery.* This has helped the company to increase the proportion of deliveries made between 8pm and 6am from 10% ten years ago to 80% today. (The switch to night-time delivery has also been facilitated by customers moving to 24 hour operation.)

3. *Outsourcing the transport operation:* the logistics service provider responsible for road deliveries is expected to manage the transport operation in a manner that minimises the impact of congestion on cost and service. It is reckoned that they have, nevertheless, had to increase the number of vehicles and drivers to accommodate worsening congestion. It is not known by how much or at what additional cost. The LSP has introduced telematics into the vehicle fleet and provides an alerting service for customers partly in response to traffic congestion.

The movement of hazardous chemicals is typically confined to a restricted road network. This limits opportunities for diverting vehicles onto less congested routes in the event of serious traffic jams.

10.4 Steel

There has been an increase in the proportion of steel moved from mills to distribution hubs by rail. This modal shift has been partly induced by worsening traffic congestion on the road network. Some of the railhead hubs, however, are in areas seriously affected by traffic congestion. Scheduling of steel trains to arrive during off-peak periods can minimise the exposure of the road feeder movements to congestion. Late running of the trains, carrying up to 1500 tonnes, can result in feeder trucks leaving the hubs at peak periods. Collections of steel by road require a steady inward flow of trucks as the 'steel manufacturers main priority is to free up their storage space to be able to produce more steel'. There is normally sufficient storage space at a mill to buffer against congestion-related delays to the inward flow of empty vehicles.

The main industrial customers for steel products typically operate booking-in systems with 3-4 hour time windows. Some specialist steels are distributed to sectors characterised by tight JIT regimes, most notably the automotive industry. Delays in excess of an hour or two can cause production stoppages in these sectors, though they rarely occur as a result of traffic congestion. In the opinion of one of the largest steel

distributors, widening and rescheduling delivery windows to non-peak periods could significantly cut congestion costs in the steel industry. This company has attempted to charge clients more for delivery at peak times and to offer a discount for deliveries outside peak periods. This has helped it to increase the proportion of night-time deliveries to roughly 50%, maximising the double-shifting of its vehicles and sharply reducing congestion costs.

10.5 Groceries

Grocery products can be divided in several categories which differ in their speed of distribution and sensitivity to delays. The main distinction is between ambient-temperature and frozen products which are stored in DCs (i.e. 'put-away' in the racking) and chilled products / 'produce' which are cross-docked in the DC and not stored. As ambient products are typically stored for an average of 4-5 days in a retailer's DC there is a substantial inventory buffer against congestion-related inbound delays. The cross-docking of fresh produce, on the other hand, usually occurs over a period of 2-3 hours. An inbound delay of an hour or more can seriously disrupt this cross-docking operations and require short term alterations to internal handling procedures or result in the late products missing the 'cut-off' time for the outbound delivery. As fresh produce is replenished daily, a missed outbound delivery will normally result in an 'out-of-stock' and lost sales in the shop. The product will also lose a day of shelf-life.

95% of the supermarket supplies in the UK are channelled through retailer-controlled DCs. One senior manager in this sector estimated that approximately 80% of all supermarket grocery sales now pass through around 70 DCs. The exposure of the UK grocery distribution system to traffic congestion is, therefore, affected by the location of a relatively small number of DCs relative to the pattern of road traffic flow.

The following description is based on the experience of a major grocery DC serving serving shops in and around London. The DC operates a booking-in system for inbound deliveries with vehicles expected to arrive within +/- 15 minutes of a specified time. Over one month (February 2008) an average of 46 out of 530 (8.7%) inbound deliveries were late. 27% of these delayed were recorded as being due to traffic congestion (2.3% of all inbound trips). Other major sources of delays were the poor reliability of agency drivers, vehicle break-downs and hold-up at previous delivery points on multiple-drop rounds. Cross-docked products spend an average of only 2.5 hours in the DC. The company indicated that inbound delays 'very often' caused the late despatch of outbound vehicles and the failure of inbound produce to be transferred in time onto the scheduled outbound vehicle. The retail client insisted that 99% of outbound deliveries arrived at its shops on time, a KPI which was closely monitored. It was estimated that to meet this target given the current levels of traffic congestion the delivery fleet had to be around 5% larger than would otherwise be necessary. In the absence of traffic congestion, a larger proportion of trucks could make second trips during the day. Despite congestion, however, the company managed to operate an extensive backloading operation, with 26% of the inbound supplies being collected from suppliers in returning shop delivery vehicles. It was very rare for these vehicles to return so late that the outbound distribution operation was disrupted.

The company had not calculated the additional costs incurred as a result of congestion, though managers estimated that the distribution cost penalty would be around 10%. 80% of the additional cost would be borne by the transport operation and 20% by the

warehousing. The additional warehousing costs were almost all labour-related and associated with over-time payments to staff. Management indicated that the warehousing costs could have been increased by as much as 10% because of traffic congestion (roughly £1.5 million per annum). Congestion had not increased the requirements for warehouse space, mechanical handling equipment or inventory. It had, however, been an important factor in the decision to invest in vehicle routing software and a vehicle telematics system.

10.6 Beer

The beer market is split between the 'on-trade' to licensed premises such as pubs and restaurants and the 'off-trade' to retail outlets such as supermarket in the market from on-trade to off-trade sales as the supermarket chains have expanded their share of this market and people have consumed a higher proportion of beer at home. This has had a major effect on the logistics of beer distribution in the UK. It has shifted volume away from the traditional networks of local depots supplying beer in small consignments to pubs and restaurants to the more centralised distribution systems which serve the retailers' DCs. Arguably this has reduced the overall exposure of beer logistics in the UK to congestion. The section of the beer supply chain most affected by congestion has been deliveries to 'on-trade' licensed premises most of which are located in urban areas. Most of these deliveries are made during the day, as staff are too busy in the evening or early hours of the night to receive the orders. The alternative, off-trade distribution channel for beer is much less exposed to congestion. It involved trunking full articulated loads from large regional warehouses, or some cases directly from breweries, to retailers DCs. Beer is then consolidated with other FMCG products for delivery to stores. Many of these deliveries of ambient product are made during off-peak period.

Before the liberalisation of the beer market in the early 1990s, the vast majority of pubs were controlled by larger brewing companies. They were then forced to sell off much of their 'pub estates', with the result that most pubs now operate independently of the brewers and are free to source beer from various suppliers. This has also given them control over the replenishment process and the freedom to specify when they want deliveries made. This often involves running local delivery vehicles (called 'drays' in the beer sector) at peak times. As these drays require two men to handle the heavy beer kegs, delivery costs per hour, and hence the cost of congestion-related delays, are high. An increasing number of on-trade customers are accepting early morning deliveries allowing vehicles to arrive before the morning rush hour. Access restrictions on town centre streets, which often take effect from 8.30 or 9am, have also encouraged this trend.

The sensitivity of upstream distribution operations in the drinks industry to congestion-related unreliability has also been reduced by the change in the product mix. Beer sales have been in long term decline as consumers have switched to wine and spirits, products which typically spend longer in storage. One of the largest distributors of drinks in the UK has 1.75 days of inventory in its depots and can therefore comfortably accommodate congestion delays. At peak times, however, when inventory levels are sometimes reduced by production problems and inaccurate sales forecasting, even short congestion delays can be critical.

The decline in the beer market and shift to off-trade distribution has made it necessary to rationalise the networks of local depots which have traditionally served the on-trade. One large logistics provider serving the drinks industry has reduced its number of depots from 45 to 32 in recent years. This has had the effect of increasing the average distance to customers and required replanning of delivery routes. As depots are now serving wider areas, exposure to traffic congestion has increased.

10.7 Forest Products

The movement of timber from forests to saw or pulp mills is marginally affected by traffic congestion at particular times of year. This occurs in areas where the rural road network experiences a growth of tourist traffic. The limited capacity of these roads and lack of alternative routes in areas of low population density can make transit times sensitive to seasonal increases in traffic volumes. This can cause problems for timber haulage as journeys can be relatively long and much of their mileage run on unpaved forest roads with tight speed limits. If delayed, drivers can have difficulty completing return journeys within the legal driving day, especially as they typically spend much of their working time operating cranes at the timber collection points. Opportunities for running vehicles during the night when roads are uncongested are very limited partly because of operational constraints on night working in the forests but also because of curfews on timber movements through rural villages. Mills typically hold around 2-3 day stock of timber and so are well buffered against any congestion-related delays. They tend not to operate booking-in systems for timber deliveries and so vehicles do not have to hit narrow time-windows. Queuing, however, can be a problem at bigger mills at particular times of day. The other major source of unreliability in the upper reaches of the forest product supply chain is bad weather. Remote rural roads are very exposed to snow, ice, flooding and blockage by fallen trees. In the winter months this is a much more serious problem than congestion.

10.8 Newspapers

It has been possible to chart this supply chain from a plant supplying paper ('newsprint') to the printing plant to the shops selling the finished product. This is a highly time-sensitive supply chain. The final product, after all, is extremely 'perishable' as nobody wants to buy old news. Even the upper links in the chain, however, are subject to tight time pressures and were found to be more adversely affected by traffic congestion. Three links in the chain will be examined:

Delivery from paper plant to newspaper print sites:

The paper plant is located in the south east of England and supplies most of its output to print sites in and around London. Around 60% of its deliveries have to be made between 6am and 9am, forcing trucks onto the road during the morning peak. This schedule is largely dictated by working practices in the printing industry. The print / publishing environment is highly unionised and staff work on a 'job and finish' basis. Staff who have been working part of the night are responsible for off-loading inbound deliveries and insist on finishing by 9-10am. In theory, inbound deliveries could be received up to 2pm, but it is very difficult to obtain a 'booking-in' slot after 11am. The printing plants carry little inventory, for a combination of reasons including space restrictions, security concerns and simply tradition. Disruption of inbound supplies can affect that day's print run.

This schedule exposes inbound deliveries to serious congestion. Data presented earlier in the report showed how the impact of congestion on this operation has increased over the past three years. Congestion-related delivery failures rose from 74 in 2005 to 120 in 2007, representing roughly 1% of all inbound deliveries. These failures occurred despite the inclusion of extra slack into delivery schedules. Additional vehicle and driver resources committed to this operation to buffer against congestion is estimated to add 6% to delivery costs. Delays on morning deliveries to print sites can also impair the utilisation of vehicles later in the day as follow-on trips are disrupted. Several vehicles that used to be able to make three trips per day can now only make two and the average distance travelled per vehicle has declined from 280 to 275 miles over two years.

The obvious way of easing this congestion problem would be to reschedule the deliveries. The newsprint supply chain, however, tends to be dominated by the newspaper publishers and printers and they dictate the schedule. The work practices also appear deeply entrenched and difficult to alter. The analysis of the congestion impacts and costs (by far the most detailed that we have encountered in this study) was undertaken by the logistics provider to expose the gravity of the problem and try to influence the behaviour of the supplier and customer. To date, however, this has had little effect.

Delivery of newspapers from printing plants to local wholesale depots:

These deliveries are made during the night and therefore have only minimal exposure to traffic congestion. They are despatched from print sites between 11pm and 2am and generally arrive at depots by 4 am. A very 'pick and pack' operation is then undertaken in the depots and fleets of vans sent out to deliver the newspapers to shops. The main cause of delay to inbound deliveries is late completion of the newspaper and print-run. The final edition may be held back to cover a late news story. There has also been heavy investment in new high-technology print plants in recent years and they have suffered technical 'teething problems'. This too has become a source of unreliability, though probably only temporarily. As the picking operation in the depots requires a full range of papers and is undertaken manually at high speed, there is little buffering for inbound delays. The regionalisation of newspaper printing in recent years has also reduced the average length and transit time of inbound deliveries. This has allowed publishers to gain more editorial and production time. As deliveries are made through the night, however, this geographical restructuring has little relevance to the congestion issue.

Delivery of newspapers to shops:

Most van deliveries to shops are made before 7.30 am i.e. before the main morning peak. If outbound deliveries from the depots has to be delayed, usually because of late inbound arrivals, some vehicles may get caught up in the rush hour traffic. Given the high % of sales early in the morning and 'perishability' of the product, late deliveries to newsagents can have a significant impact on sales and increase the amount of returned product later in the day. It can also have knock-on effects for the use of vans on other types of delivery later in the day.

10.9 Pallet-load Network

These are hub-and-spoke networks for the overnight delivery of pallet-loads across the UK. They cater for less-than-truckload (LTL) movements, usually of time-sensitive products. Regional hauliers collect pallets and consolidate them into larger loads for

overnight trunking to sortation hubs, most of which are located in the English Midlands. Pallets collected from the hub are trunked back to the regional depot for distribution to local customers. It is estimated that in the UK around 70,000 pallets per night are handled through these networks. Express parcel carriers operate similar hub-and-spoke networks.

The case study company has one national hub in the Midlands and two regional hubs. The focus here will be on the activities of the regional hub in the London area which also serves as a local collection and delivery (C&D) depot.

The overnight trunking operations between the hubs and the C&D depots are largely immune to traffic congestion. Congestion solely impacts on the local collection and delivery operations which take place during the day. Deliveries are made during the morning and early afternoon with most of the collections made in the afternoon. Most of these deliveries and collections are made in the Greater London area and many are made during the am and pm rush hour. Only around 10% of the delivery points require arrival within booking-in slots – typically a 1 hour window. For inbound pallets the sorting operation at the regional hub takes place between 8.30 pm and 1 pm. If collections / inbound deliveries are seriously delayed they might miss the overnight connection, but this seldom happens because of congestion. Extra slack has had to be built into the local transport operation to accommodate congestion, but this has not been quantified or costed. ‘Delivery on time’ performance is monitored but the causes of delivery failures are not recorded. As congestion is quite regular and ‘persistent’ they have adapted to it. A more serious source of unreliability for the company is the ‘human element’ when staff absenteeism and sickness disrupt operations.

Several measures have been introduced which are relevant to the congestion problem:

1. Imposing a supplementary charge per pallet for deliveries in Central London to cover the congestion charge, Low Emission Zone costs and general congestion costs, though the latter have not been quantified. The company claims that the imposition of the congestion charge has not had a noticeable effect on the average speed or reliability of deliveries in Central London.
2. Training drivers to operate both lorries and fork-lift trucks. This enables them to switch roles and increase operational flexibility. This can be advantageous when inbound vehicles arriving in the late afternoon / early evening are late.
3. The establishment of regional hubs to supplement the main national hub has shortened average trunking distances. As most trunking is undertaken at night, however, any congestion benefit is very marginal.

10.10 Express Parcels

The collection and delivery of express parcels is not simply time-sensitive. Companies in this sector often offer ‘time-definite’ deliveries on a guaranteed basis. Their logistics systems must therefore fully internalise any unreliability associated with congestion. The structure of these systems is very similar to that of pallet-load networks, with parcels collected during the day and assembled at a local depot for overnight trunking to a national or regional sortation hub. Parcels sorted for a particular zone are they trunked

out to the appropriate depot and delivered from there the following day. As trunking operations take place during the night they are little affected by congestion. This was confirmed by the analysis of transport KPI data in Section 7. Only in the case of peripheral depots, is it possible that inbound trunk movements get caught up in the morning rush hour, but this seldom happens.

The main exposure to congestion is the local delivery and collection of parcels in urban areas during the day. Much of this delivery work is done during the inter-peak period. It also relies heavily on the local knowledge and experience of delivery drivers who load their own vehicles in sequence and adjust the routing of the vehicle to local traffic conditions. Partly as a result of drivers' skill, but also as a result of periodic revisions to delivery zones and rounds, parcel carriers have been able largely to maintain the productivity of their delivery operations. Vans typically make 120-140 drops per day and this figure has remained fairly constant in recent years despite growing congestion.

The most time critical part of the operation is the return to the depot of local delivery vans with collected parcels. If their return is delayed by serious congestion during the afternoon peak, cut-off times for onward trunking may be missed. These cut-off times are particularly rigid for airfreighted consignments. According to the managers consulted, both at head office and local depot, the probability of parcels missing the overnight trunk is extremely low.

11. Conclusions

This study updates and extends research originally undertaken in the UK in 1998 on the effects of traffic congestion on the efficiency and performance of logistics systems. It began with a review of literature on the subject published over the past decade. Despite the huge expansion of the logistics literature and growth in concern about the congestion problem over this period, relative little new research has been undertaken on this topic. Several papers have provided new insights and added to the limited body of empirical data. There remains, however, a dearth of published information about the impact of congestion on logistics practices across a range of industrial and commercial sectors. The relationship between congestion-related delays and other sources of unreliability are alluded to in the literature but not, as yet, adequately modelled. Nor has there been much progress in the monetary valuation of freight transport reliability in recent years.

The UK government transport KPI surveys have proved a valuable source of empirical data on schedule deviations in different types of supply chain. They permit calculations of the relative importance of traffic congestion as a source of unreliability. They suggest, for example, that approximately a quarter of road freight journeys are subject to a delay and that traffic congestion accounts for roughly a third of these delays. Other factors, such as equipment breakdowns, poor production planning and staffing problems, can occur more frequently and cause longer average delays. When account is taken of the average duration of different types of delay, it is found that congestion is responsible for roughly 23% of total delay time in road freight transport. The limited amount of time-series data available indicates that the proportion of deliveries delayed by congestion increased only marginally in the UK between 2002 and 2007. As no comparable data were found for other countries, it is not known to what extent similar patterns and trends are exhibited elsewhere.

In the course of the research, 37 logistics managers were interviewed across nine industrial sectors. Only a quarter of them regarded traffic congestion as the main source of unreliability. There is, however, a complex interaction between congestion and other causes of schedule deviation. There were also variations in the absolute and relative importance of congestion-related delays in different sectors. Individual companies reported that the reliability of their logistics operations has been markedly deteriorating in recent years mainly as a result of traffic congestion. Some provided hard data to back up these claims.

Overall the interview survey found little evidence of traffic congestion causing companies to restructure their manufacturing and / or logistical systems. Fleet sizes, tractor-trailer articulation ratios, the speed calibration of vehicle routing software, inventory levels and internal warehouse design and working practices have also been largely unaffected by the deterioration in transit time reliability. There has, however, been a growth of evening / night-time delivery and some instances of companies making greater use of regional depots and outbased vehicles / drivers. Overall, companies have been able to adapt their logistics operations to traffic congestion gradually over a long period, particularly as much congestion is regular and predictable and being made more so, along particular corridors, by active traffic management schemes. The increasing use of vehicle telematics, routeing software and fleet management packages has assisted the adjustment to more congested infrastructure. Credit must also be given to the skill and resourcefulness of freight and logistics managers for whom minimising the impact of congestion on the cost and quality of logistics has become a core skill.

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Annex 1: Sectors represented by the surveyed companies

LSP - construction
LSP deep-sea containers to / from ports
LSP industrial + FMCG sectors
LSP - paper
LSP – retail grocery
LSP - FMCG
LSP- industrial
LSP industrial /automotive sector
LSP industrial + FMCG sectors
LSP mixed - mainly automotive
LSP beer
Building products
Chemicals
Defence electronics
Electronics
Express parcels delivery
Food manufacturer
Food manufacturer / distributor
Forest products
Grocery retailing
Grocery retailing
Home delivery company
Newspaper wholesaler
Non-food retailer
Pallet-load network
Steel distributor
Steel producer
Trade Association

LPS = Logistics Service Provider

Annex 2: Questionnaire used in the interviews.



Congestion, Reliability and Logistics

PART 1: GENERAL QUESTIONS:

1. Perception of the current effect of traffic congestion on logistics operations:

Inbound: not a problem 0 1 2 3 4 5 very serious

Outbound: not a problem 0 1 2 3 4 5 very serious

2. Forecast of future effect of traffic congestion on operations (in 5 years):

Inbound: not a problem 0 1 2 3 4 5 very serious

Outbound: not a problem 0 1 2 3 4 5 very serious

3. Extent to which operations have had to be modified as a result of congestion:

Inbound: not at all 0 1 2 3 4 5 major change

Outbound: not at all 0 1 2 3 4 5 major change

4. How does the company currently monitor late deliveries?

Does this monitoring system attribute delays to traffic congestion / other causes?

If so how?

5. Has the company attempted to measure the additional cost imposed by congestion-related unreliability? If so, how?

6. To what extent is traffic congestion regular and predictable, allowing it to be accommodated by building some extra slack in logistical schedules:

Very regular 1 2 3 4 5 very irregular

13. The Highways Agency is increasingly using 'Active Traffic Management' to improve network reliability even if this means that average speeds are reduced:

Has this, as yet, had an observable effect on your companies' logistics operations?

Do you support this initiative?

14. Typically how long does an inbound delay have to be to cause significant disruption?

15. To what extent is it the 'superimposition' of congestion on other delays that causes the problem?

PART 2: INBOUND MOVEMENTS

Nature of the inbound operation:

16. What proportion of the inbound deliveries does your company directly control?

17. What is the nature of the booking-in system at DCs / hubs?

I. Length of the booking-in slots?

II. Has the booking system been modified in recent years in response to congestion?

18. What proportion of inbound deliveries are so late that they cause an operational problem / incur additional costs in the DC?

Internal Cross-docking operation:

19. How much time elapses between arrival and despatch on cross-docked / sorted products:

Maximum

Average

Minimum

How have these times changed over the past five years?

20. What opportunities are there for switching between activities within the DC in response to late arrival?

how often does switching occur

what problems does it create

what are the implications for:

staffing

equipment

space requirements

DC operating costs

Additional resources required:

21. Warehousing opening hours:

- How have these changed over the past five years?
- To what extent has traffic congestion influenced opening hours?

22. Warehouse working practices and staff numbers:

- how have working practices changed over the past 5 years?
- have staffing / working practices increased flexibility / made it easier to absorb congestion effects?

Much less flexibility 1 2 3 4 5 Much more flexibility

- does congestion increase the level of overtime payments?
(if so, how much does this add to the wage bill?)

23. Handling equipment

- To what extent has congestion-related unreliability increased the requirement for materials handling equipment (eg. pallet loaders, fork lifts)?

large amount 1 2 3 4 5 not at all

24. Information and Communication Systems:

- To what extent have ICT developments been able to reduce the impact of traffic congestion?

Large amount 1 2 3 4 5 Not at all

Which ICT developments have had the greatest effect in easing congestion impacts:

⇒ warehouse management / stock replenishment system

⇒ loading dock management system

⇒ in-cab data communication

⇒ mobile phones in cab

⇒ vehicle tracking system / early warning system

- How much importance was attached congestion in the decision to undertake these ICT developments?

none 0 2 3 4 5 great importance

- How good are suppliers / carriers at notifying DCs of late inbound deliveries?

very poor 1 2 3 4 5 excellent

Is this situation improving
 remaining the same
 deteriorating?

- What procedures does the DC have for receiving and acting upon advance notification about inbound delays.

25. Inventory:

- To what extent are inventory levels in the warehouse affected by traffic congestion?

not at all 1 2 3 4 5 to a large extent

In what ways are inventory levels affected?

26. Short term adjustments

How frequently do the following situations arise and what is the typical chain of consequences?

(i) missed booking-in time:

- I. rejection of load / repeat delivery
- II. delay in unloading / cumulative delay on later drops/collections
 - (ii) missed opportunities for backloading
 - (iii) delay warehouse 'put-away' (for warehouse with storage function)
- III. allow stock to accumulate in holding area
- IV. is there adequate space available for this?
 - (iv) extend warehouse opening time
 - (v) have staff work overtime.

27. Knock-on effects for outbound transport operation

How frequently are outbound deliveries delayed because of inbound delays?

Never 0 1 2 3 4 5 very often

How often are outbound vehicles despatched with part-loads because of inbound delays?

Never 0 1 2 3 4 5 very often

Is there much pre-loading of drop trailers at the DCs?

What is the ratio of tractors to trailers ('articulation ratio')?

How has this been changing?

How has it been affected by increasing traffic congestion?

PART 3: OUTBOUND DELIVERIES

28 Details of the distribution operation: indicating which parts are most affected by traffic congestion:

Nature of premises served (shops, RDCs etc):

Nature of the outbound distribution operation:

I. Types of vehicle:

II. No. of drops per delivery:

29. Transport operation

Extent to which outbound delivery operation has been adjusted for congestion:

- general reduction in average speed (factored into routing software?)
- route-specific / time-specific scheduling
- earlier departure time / extra slack in the delivery schedule
- extent to which drivers are given discretion to vary routes to avoid congestion
- has congestion resulted in a reduction in the number of drops per trip
- dynamic rerouting of vehicles using tracking / telematics systems

30. Additional resources required:

Has it been necessary to increase in the number of vehicles / drivers because of traffic congestion? If so, by how much? Has the additional cost been assessed?

31. ICT systems

What types of ICT systems are used?

- mobile phone
- automatic early warning system
- in-cab data link
- is there direct vehicle - customer communication or is it via the depot

- None of the above

To what extent has investment in these systems been a response to worsening traffic congestion?

32. Delivery constraints at customer premises

What proportion of customers have booking-in systems for deliveries?

Typical length of delivery windows?

How has this been changing?

Consequences of late delivery?

Any data on the proportion of late deliveries to customers attributable to traffic congestion?

33. Other constraints imposed on vehicle access:

To what extent is the congestion problem compounded by access restrictions in urban areas?

Not at all 0 1 2 3 4 5 Not at all

34. Drivers' shifts / rosters

How often does congestion make it difficult for drivers to complete their delivery rounds with the drivers' hours limits / daily shift?

Never 0 1 2 3 4 5 Very frequently

To what extent have restrictions by the Working Time Directive made it more difficult to adapt logistics operations to traffic congestion?

35. Any other points / issues?

