Environmental Impact of Road Freight Transport in 2020

Full Report of a Delphi Survey

M.I. Piecyk and A.C. McKinnon

Logistics Research Centre
School of Management and Languages
Heriot-Watt University
Edinburgh
EH14 4AS

M.Piecyk@hw.ac.uk
A.C.McKinnon@hw.ac.uk

www.sml.hw.ac.uk/logistics
www.greenlogistics.org

August 2009

Executive Summary

This report summarises the results of a Delphi survey of 100 logistics specialists which sought their views on future freight transport and environmental trends in the UK up to 2020. According to this panel of experts, over 50% of companies involved in road freight transport operation are likely to see their activities affected by climate change concerns to a significant or large extent by 2015. This proportion is expected to rise to over 80% by 2020.

Some long-established production and logistics trends which exert a strong influence on road freight demand, such as the centralisation of manufacturing and inventory, the adoption of JIT replenishment and the outsourcing of non-core activities, cannot continue indefinitely. The results of the Delphi survey reported in this paper suggest that these trends are likely to continue at least until 2020. The following trends were identified as most likely to occur up to 2020:

- Further relocation of production capacity to other countries.
- Increase in primary consolidation of inbound loads to manufacturing plants and / or distribution centres.
- Significant growth in online retailing.
- Reverse logistics is likely to gain in importance with more products re-entering the supply chains for recycling, refurbishment and resale.
- More frequent 'out-of-hours' operation, especially increase in proportion of night-time deliveries.
- Growth in the use of advanced IT systems for transport planning and management (telematics, computerised vehicle routing and scheduling, etc).
- Increase in logistical collaboration initiatives between companies.
- Greater use of online freight exchanges online and load matching services.
- Fuel prices and availability of drivers were identified as major threats to the road freight industry.

The inter-relationships between this broad range of business trends, freight traffic levels and related CO_2 emissions are very complex. While some of the trends predicted by the panel of experts will increase the environmental footprint of road freight operations, others will have the opposite effect. Generally speaking, many of the trends anticipated at the upper strategic, commercial and operational levels in the decision-making hierarchy are likely to increase their environmental impact, while those projected to occur at a functional level in the management of transport resources will have an offsetting effect. The actual net impact of all these changes on freight-related energy consumption and emissions is difficult to quantify. Nevertheless, an attempt has been made to construct three possible road-freight CO_2 scenarios for 2020 using the experts' opinions to calibrate the spreadsheet-based forecasting model. The mid-range BAU scenario indicates that the most likely outcome is a marginal reduction in CO_2 emissions from road freight transport of around 10% to 17.4 million tonnes per annum. This would occur despite an increase of 21% in the amount of road freight movement above the 2007 level. Substantial improvements in vehicle utilisation and fuel efficiency and shifts to alternative transport modes and lower carbon fuels would more than offset the effect of this growth in road tonne-kms on CO_2 emissions.

The optimistic and pessimistic scenarios, defined by a one standard deviation range on either side of the mean Delphi scores, envisage road-freight-related CO_2 emissions falling by 47% or rising by 56%. If the optimistic projection proved accurate, the GB road freight sector would be on a trajectory that would comfortably meet the 80% CO_2 reduction that the UK government has set for the economy as a whole by 2050. If, however, the mid-range BAU forecast is adopted, as it reflects the majority opinion of the Delphi panellists, the road freight sector will fall well short of the necessary 'carbon pathway' to an 80% CO_2 reduction by 2050. Government and business will then have to intensify their efforts to decarbonise the movement of freight by road.

Contents

Acknowledgement

The authors would like to thank all the members of the Delphi panel who contributed to this research. Without their support the study would not have been possible. They are also grateful to the Engineering and Physical Sciences Research Council which is funding the work as part of the Green Logistics project. Responsibility for the rigour and accuracy of the research rests with the authors.

Introduction

This report summarises the results of a study undertaken as a part of an EPSRC-funded project called Green Logistics. The objective of this research was to produce a forecast of business-as-usual (BAU) trends in key logistics and supply chain variables and associated environmental effects of road freight transport up to 2020. It employed the Delphi method to survey the opinions of a large and varied sample of experts on these trends.

1. The Delphi method

The Delphi method is a systematic, iterative procedure for "structuring a group communication process so that the process is effective in allowing a group of individuals, as a whole, to deal with a complex problem" (Linstone and Turoff, 2002, p.3). A Delphi survey usually involves sending a first-round questionnaire to a number of respondents, collating and analysing the data and then re-circulating the questionnaire accompanied by a summary of results. The experts are asked to confirm or modify their previous responses. This procedure is repeated for a pre-determined number of rounds or until a desired degree of consensus has been reached or response rates dwindle (Rowe and Wright, 1999, Hasson et al., 2000, Linstone and Turoff, 2002, Mullen, 2003, Okoli and Pawlowski, 2004, Hsu and Sandford, 2007a).

The three main characteristics of the Delphi method are as follows (Woudenberg, 1991, Gupta and Clarke, 1996, Rowe and Wright, 1999, Linstone and Turoff, 2002, Loo, 2002, Landeta, 2006):

- **Anonymity of participants –** typically experts are approached by mail or computer and they remain anonymous to the other members of the panel. The anonymity of participants eliminates the problems associated with group decision making.
- **Iteration –** there are several rounds of consultation and thus a narrowing of the initial range of opinion.
- **Feedback –** in the second or subsequent round, the results of the whole group on the previous round are analysed and fed back to the experts in a statistical format.

The Delphi method is a popular forecasting technique that can be applied to a wide range of research problems and disciplines. In the 1950s it was used by the RAND corporation as a means of expert-supported military decision-making, particularly with reference to planning and developing new technology (Rieger, 1986, Loo, 2002). Since then the Delphi technique has been widely recognised as a means of supporting decision-making processes through the development of more reliable forecasts (Landeta, 2006). It has been applied across disciplines and extensively used in planning and policy-making, long- range forecasting and decision support in both private and public sectors.

The Delphi method has been relatively widely applied in the field of logistics and supply chain management, mainly to the forecasting of future logistics trends, at different geographical, industrial and operational levels. To date it has been used to predict changes in the physical distribution of food products in the UK (Walters, 1975, 1976), project future directions in distribution systems, logistics and supply chain management at a national and European level (Cranfield School of Management, 1984, Cooper, 1994, McKinnon and Forster, 2000, Runhaar et al., 2002, Ogden et al., 2005), as well as to investigate factors affecting location decisions in international operations (MacCarthy and Atthirawong, 2003). In the most recent studies the Delphi method was used to investigate factors crucial for supply chain flexibility (Lummus et al., 2005) and to project the future of supply chain management up to 2011 (Melnyk et al., 2008).

As the main objective of the current research is to construct a baseline BAU scenario of freight transport futures, forecasting based on expert opinion has been identified as the most suitable approach. It has the major advantage of rooting the forecasts in a detailed understanding of the underlying causes of freight traffic growth and its environmental impact. A Delphi questionnaire survey was chosen as a formal means of capturing and consolidating expert judgment. In order to increase the reliability of the forecast a large panel of experts has been consulted. A structured questionnaire has been used to enable statistical analysis of the responses. The results have been used to construct future scenarios of developments in the road freight transport system. An advantage of using scenarios is that it assesses possible future trajectories for a range of variables and attempts to determine their likely consequences (Firth, 1977). It can take account of the interrelationship between the variables. It is believed that a real-world expert outlook on future developments in logistics and supply chain trends and analysis of their underlying causes will help to maximise the credibility and accuracy of the forecasts produced by this research.

The Delphi method has been selected as the most appropriate means of achieving the purpose of this study for a number of reasons. Firstly, due to the recent breaks in the statistical data series, extrapolatory forecasting methods could not be applied without a great deal of uncertainty about the accuracy of results. Qualitative forecasting was considered as a more reliable alternative. The opinions expressed by specialists directly involved in distribution and supply chain activities and, hence, contributing to the future direction of the key logistics variables, were regarded as the best available indicators of prospective developments in road freight transport operation. In order to maximise accuracy of the forecast and to get a broad spectrum of perspectives a large and diverse panel of experts was consulted. The survey was used to collect quantitative estimates of the strength and directions of the trends in the series of key logistics ratios. It also permitted statistical analysis of panellists' projections. The aim was to build the best available forecast based on the available expert evidence. The Delphi survey dataset permits not only the estimation of an average projected value for each variable but also, based on differences in opinion, the construction of a number of scenarios to reflect alternative future changes in the key ratios.

2. Research design and analysis

The survey was organised by the Logistics Research Centre at Heriot-Watt University between January and August 2008. A web-based questionnaire was designed for the purpose of the study. Within the time allocated for the survey, it was possible to achieve one iteration of results.

2.1. Sample

A sampling frame of approximately 600 specialists was constructed on the basis of previous surveys, participation in workshops and networking with professional and trade bodies. From this 'population', a stratified sample was drawn to reflect the shares of seven different types of organisation involved in logistics: producers, retailers, logistics service providers, public policy-makers, trade organisations, consultants and researchers. As the main objective of the Delphi study was to produce a reliable forecast based on expert judgement, only those specialists considered to have sufficient knowledge and experience of the subject were selected. An invitation to join the Delphi panel was emailed to 347 potential participants. In the first round 100 invitees filled in the questionnaire giving an overall response rate of 29%. Figures 2.1 and 2.2 show the composition of the sample by type of organisation and industry. In the second round, the participants were sent the questionnaire again but this time annotated with a mean panel response from the first round and their previous responses. They were offered an option to modify their answers in the light of the first-round results. They were also informed that if they did not fill in the questionnaire again it would be assumed that they did not wish to alter their first round responses. 66 participants filled in the questionnaire again, 59 of whom changed at least one answer in almost all cases increasing the degree of consensus. The average standard deviation of the responses declined between the rounds by 9%.

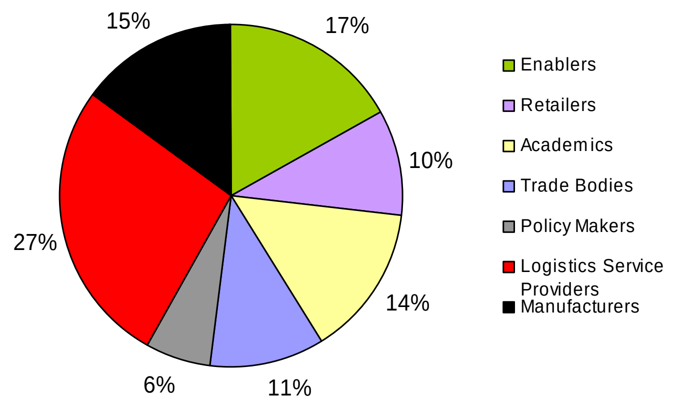

Figure 2.1. Sample composition by type of organisation

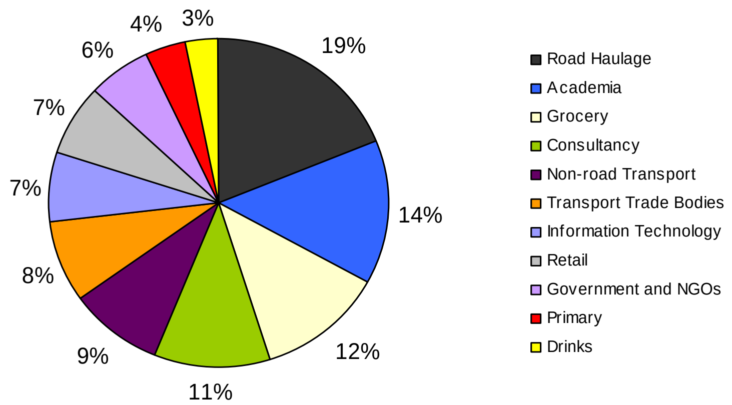

Figure 2.2. Sample composition by industry type

The vast majority of participants occupied senior positions within their organisations (83%). Age and gender of participants were not considered as selection criteria. Age is typically positively correlated with years of experience and the later criterion was regarded as more important. 96% of those who responded to the survey were male. This is a higher proportion than the industry average where almost 80% of people holding logistics-related positions are male (Figure 2.3). The impact of gender on logistics performance is still being discussed (Tatham and Kovacs, 2008) and there is some evidence that sex of a logistician may have an impact on performance in some areas, for instance in purchasing negotiations (Min et al., 1995). The particular characteristics of female logistics executives have already been investigated (Cooper et al., 2007) as yet there has been no attempt to compare them with those of male logistics professionals. Given the lack of evidence that gender is a significant differentiation factor in the logistics profession, the gender criterion was not considered to be relevant for this research.

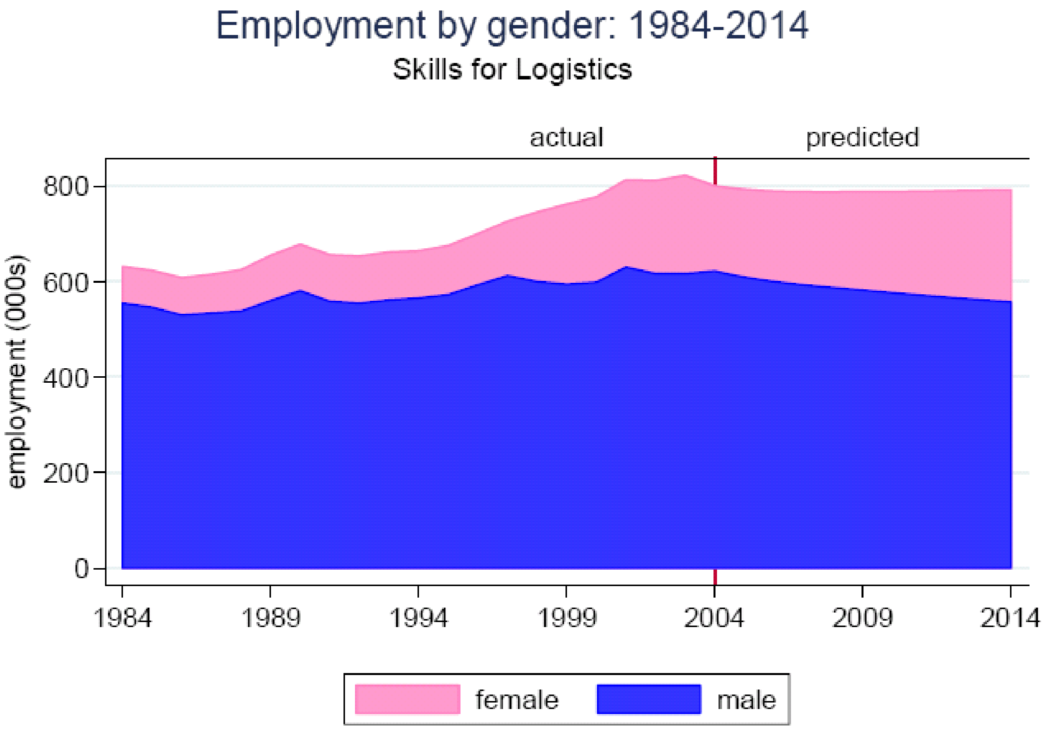

Figure 2.3. Employment in logistics-related jobs, by gender.
Source: (Dickerson et al., 2008).

2.2. Non-response bias

The data from both rounds was entered into a statistical software package (SPSS 16.0) for analysis. It was first tested for the non-response bias which may arise when the characteristics of the respondents vary significantly from those of the non-respondents. Most of the literature focuses on non-response to mail surveys. However, Hudson et al. (2004) could find no evidence that the incidence of non-response bias was significantly different in mail or Internet surveys. Non-response bias may occur even in research with relatively high response rates (Carter and Jennings, 2002). This is of a particular importance in case of a Delphi study where there is a need not only to achieve a desirable response rate in the first round but also to maintain a high level of response in the following iterations (Hsu and Sandford, 2007b). Lambert and

Harrington (1990) suggest that non-response bias can be a problem where response rates are lower than 40%. The most common protection against this bias is to increase response rates. This was done in the Delphi survey by sending out a follow-up emails in each round. Additionally, in the second round a personalised questionnaire was prepared, summarising their responses in the previous round. This helped to stimulate their interest in the study and maintain a high level of expert involvement. The panellists were also informed that they would be sent a report summarising the research findings once the study was completed.

Having collected the data, one way of testing for non-response bias is to compare the answers of early and late respondents to the survey (Diaz de Rada, 2005). Participants who respond in later waves of the survey (e.g. after a follow-up letter) may only have responded because of the additional stimulus and, thus, be similar to non-respondents (Armstrong and Overton, 1977). In this study the first and last quartile of respondents in both rounds were compared to assess the potential non-response bias. The data collected for all survey questions was first tested for normality within the early and late respondent groups (using normal Q-Q probability plots and Shapiro-Wilk test). A t-test or a Mann-Whitney test was then used to compare the differences in responses, depending on whether the distribution has proven to be normal or not. The results suggested that the responses of the last quartile participants did not display statistically significant differences from the responses of the first quartile participants in both rounds. It was therefore concluded that no significant non-response bias was present.

2.3. Data analysis

In the next stage of the analysis, the spread of data for each variable was assessed visually by constructing histograms to detect cases with non-normal distributions (for instance a binominal spread of responses). None of such cases were identified. Statistical measures of central tendency and variability were calculated to summarise the experts' speculations. This analysis was conducted on the whole sample and then repeated for individual respondent groups. For the purpose of inter-group comparisons (by type of supply chain member and by industry sector) the data was tested for normality within groups (using normal Q-Q probability plots and Shapiro-Wilk test). Where the data was shown to be normally distributed a test for homogeneity of variance was carried out (Levene's test). In the case of questions where data within groups was normal and of homogeneous variance, a one-way analysis of variance (ANOVA) was carried out to detect whether there are significant differences in opinion between different participant groups. Where data were not normally distributed a non-parametric Kruskal-Wallis test was used instead of ANOVA.

For most of the questions no statistically significant differences in opinion were found between the various respondent groups. Reference will be made later in the report to variables on which statistically significant differences of opinion emerged.

The mean responses from the first and the second rounds were also compared to see if there were any significant changes in experts' attitudes between rounds. The analysis of what happens between rounds is an important part of the process as it shows not only whether a consensus has been reached and what the final opinion was, but also the extent to which the opinion of the panel as a whole changed between rounds (Greatorex and Dexter, 2000). For instance, changes in circumstances between rounds may result in altering experts' opinions. The survey was carried out between January and August 2008, a period during which some important changes occurred in the external business environment. Particularly notable were a 14% increase in the average price of diesel fuel (European Commission, 2008) and negative press coverage about the use of biofuel. Only very minor changes in the average opinion were detected, however, suggesting that short-term market distortions did not influence the long-term outlook of the logistics and supply chain professionals consulted.

The final analysis is based on the results of the two-round Delphi study. The mean and standard deviation values were used to project the future trends. The mean values indicate the group opinion on both the direction of trends and their relative strength. Standard deviation measures how widely spread the values in the data set are, representing the amount of disagreement within the panel. The respondents were asked what changes would occur by 2020 using the following types of questions:

- To what extent would a particular variable increase or decrease against a base index value of 100, representing the current level?

- To what extent would a particular variable change as compared to its actual value in 2006?
- What would be the intensity, importance or impact of future changes in a particular variable on a five point Lickert scale?

As was noted before, the results summarised in the next part of the report are based on the combination of the second-round responses, where participants revised their opinions (59% of the panel) and first-round responses for the remaining 41% of experts.

3. Survey results

The survey consisted of 21 questions, many of them multi-faceted. The experts were asked to express their views on a number of factors that may influence supply chain structures, modal split, vehicle management and fuel management up to 2020 and evaluate their likely impact. The results of the survey are presented below.

3.1. Importance of environmental concerns in logistical decision making

In order to investigate the impact of global warming on supply chain practice, participants were asked to assess to what extent concern about climate change had forced their companies to modify their freight transport operations over the last three years and how they expected it to affect their logistics systems in the future. The answers for the 65% of respondents belonging to companies with a freight transport operation were rated on a five-point Likert scale where 0 = not at all, 4 = large extent (Figure 3.1).

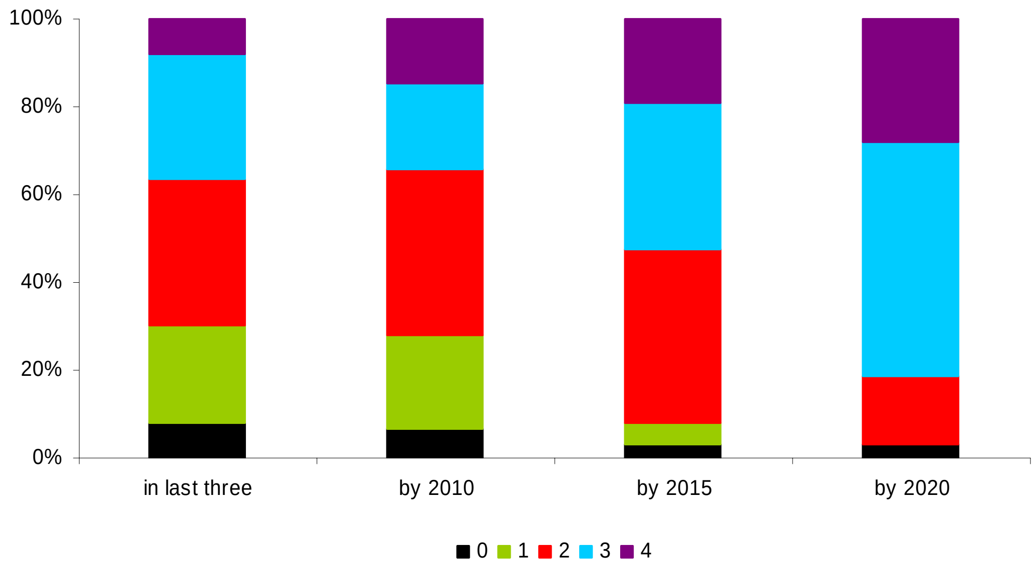

Figure 3.1. Impact of climate change concerns on companies' freight transport operations

In less than 40 percent of the businesses had concern about global warming influenced freight transport operations significantly in last three years (response 3 or 4). This percentage is expected to increase to over 80 percent by 2020. The proportion of company transport operations on which it will have no or a very limited impact (response 0 or 1) is likely to drop from 30 percent in last three years to 3 percent in 2020. This confirms that managers are aware of the growing scale and severity of the climate change problem. It also highlights the need for companies to understand how to measure and manage CO_2 emissions from their road fleets.

3.2. Future trends in key logistics variables

On a macro-level, underpinning the future trend in these CO_2 emissions will be the relationship between the volume of road freight movement and economic growth. Recent experience in the UK suggests that there has been a decoupling of economic growth and the growth in road freight movement (Figure 3.2). Between 1997 and 2007, GDP rose by 32% in real terms while road tonne-kms grew by only 7%. If this decoupling were to continue, it would indicate a long-term structural change in the UK economy, in which increasing national prosperity would not generate a proportional increase in freight traffic volumes. Stabilisation and subsequent reduction in freight-related externalities would help to promote the sustainable development policy advocated by the British Government and European Union (DETR, 1999, European Commission, 2001, European Commission, 2006). Nonetheless, it is questionable if this trend is going to endure, as recent evidence suggests that expectations of the long-term decoupling may have been premature (McKinnon et al., 2008).

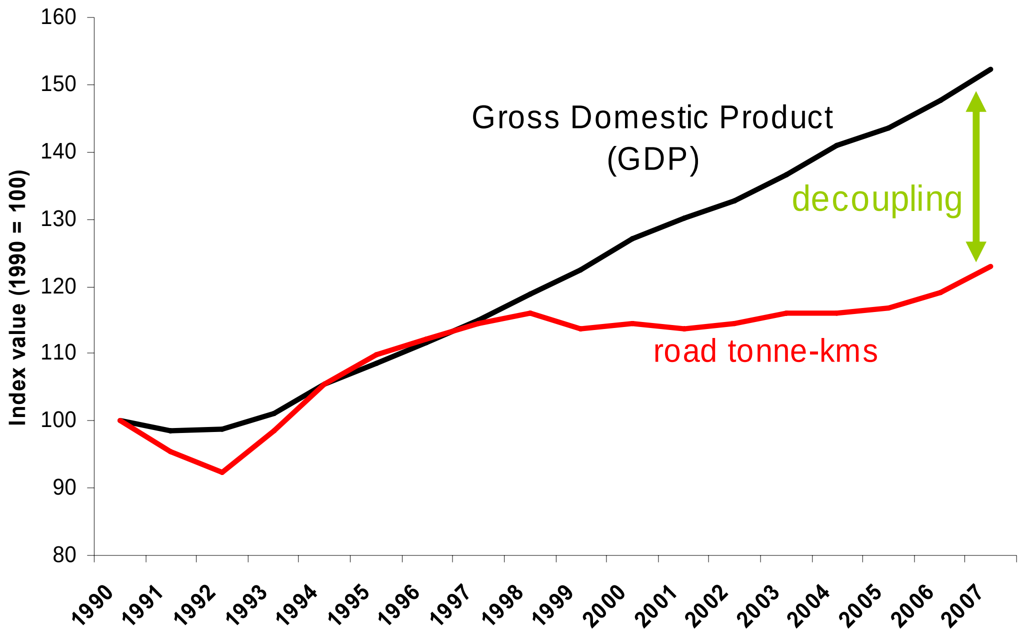

Figure 3.2. Decoupling of economic growth and road freight transport.

The Delphi panellists were asked to rate how road tonne-kms will grow relative to GDP up to 2020, where -2 = much slower, 0 = same rate, 2 = much faster. The mean response was -0.5 with a standard deviation of 0.9. This indicated that freight transport activity will continue to grow at a slower pace than economic performance. However, this decoupling may not be strong enough to achieve major reductions in the environmental impact of freight transport.

Next, experts were asked to indicate if total freight tonne-kms are going to increase or decrease by 2020 against a base index value of 100, representing the current situation. The average response was 127 with a standard deviation of 21. This suggests that total tonne-kms will rise from 255 billion in 2007, (Department for Transport, 2008a) to 325 billion tonne-kms in 2020.

How are the following road freight parameters likely to change between now and 2020?	**Now**	**2020 (Mean)**	**Standard deviation**
Average length of haul (km)	87	85.7	15.0
Handling factor	3.4	3.4	0.7
Lading factor (%)	57	64.4	5.8
Empty running (%)	27	21.9	4.3

Table 3.1. Projected changes in supply chain structure and vehicle utilisation

Supply chain structure and vehicle utilisation strongly influence the environmental performance of road freight transport sector. Supply chain structure is determined by the number of links and their average length. The number of links in the supply chain is measured crudely by handling factor which is a ratio of the tonnes-lifted to the actual weight of goods produced or consumed. However, very limited data are available on the weight of goods produced and consumed (McKinnon, 2003). An approximate handling factor was calculated by dividing the tonnes-lifted estimate for 2006 (Department for Transport, 2008b) by corresponding material flow value published in the UK National Accounts (Office for National Statistics, 2008). Vehicle utilisation is measured by the lading factor and percentage of empty running. The lading factor is a ratio of the tonne-kms that a vehicle actually carries to the tonne-kms it could have carried if it was running at its maximum gross weight. Empty running is expressed as a percentage of the total lorry kilometres run. The average length of haul, lading factor and empty running figures for 2006 were published by the Department for Transport, (2008b). Table 3.1 presents the experts' opinion on future directions in these parameters up to 2020.

The panellists did not expect any significant changes in supply chain structure. The number of links is going to remain the same and their average length will be reduced by only 1 km to 86 kms. This suggests that that supply chain links are now almost fully extended and that, within a BAU scenario, the domestic pattern of road freight movement is going to experience only modest change by 2020. There will, however, be considerable improvements in the utilisation of HGVs by this date. Lading factor is expected to increase to 64.4 percent from 57 percent and only 21.9 percent of vehicle kilometres will be run empty, down from 27 percent in 2006. If these improvements can be achieved, they will yield substantial environmental benefit.

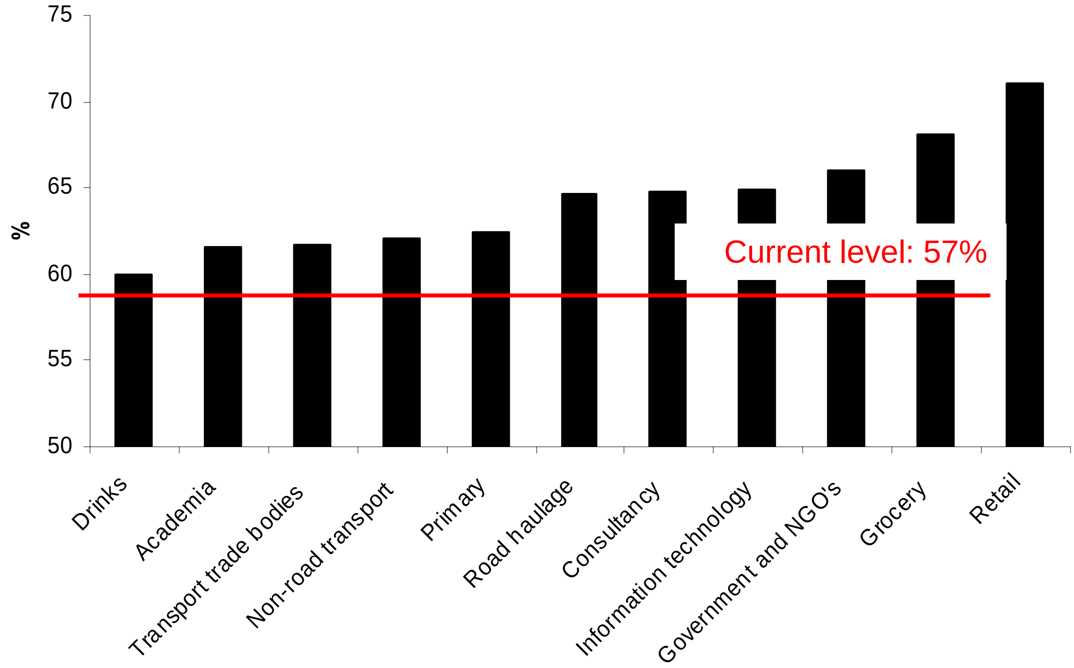

Figure 3.3. Differences in opinion on lading factor in 2020 (by industry)

It should be noted here that even though representatives of all industry sectors expected better vehicle utilisation in 2020, statistically significant differences in opinion emerged on the extent of the likely increase in lading factor and reduction in the percentage of kilometres run empty (Figures 3.3 and 3.4). Panellists from the retail sector were the most optimistic in their projections (average lading factor of 71% and drop in empty running to 19%). On the contrary, only a modest positive change was expected by the experts from the drinks industry (3% increase in lading factor and 2% reduction in empty running). A significant decrease in empty running was also anticipated by panellists involved in consultancy work (20%). However, their projections for the lading factor in 2020 were in line with the overall average (65%).

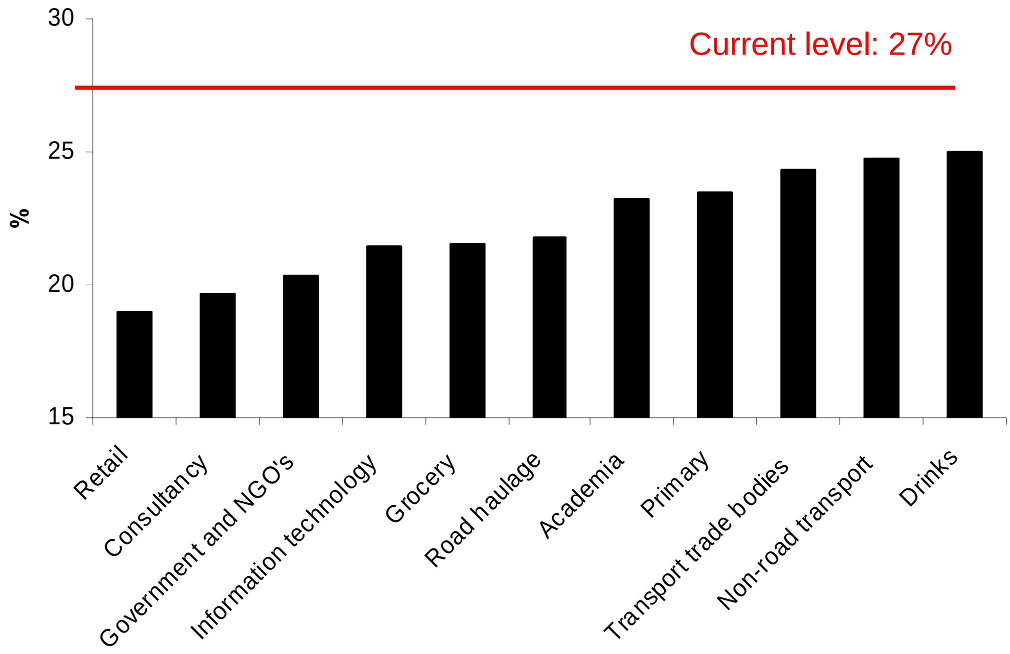

Figure 3.4. Differences in opinion on empty running in 2020 (by industry)

A summary of changes in the key logistics variables projected by the Delphi panel is presented in Figure 3.5. These changes will be a result of a number of factors occurring at company, supply chain and industry levels as well as in the wider socio-economic environment. The next section explains how logistical decisions made at different levels within a business affect key variables such as supply chain structure, modal split, vehicle utilisation and fuel management.

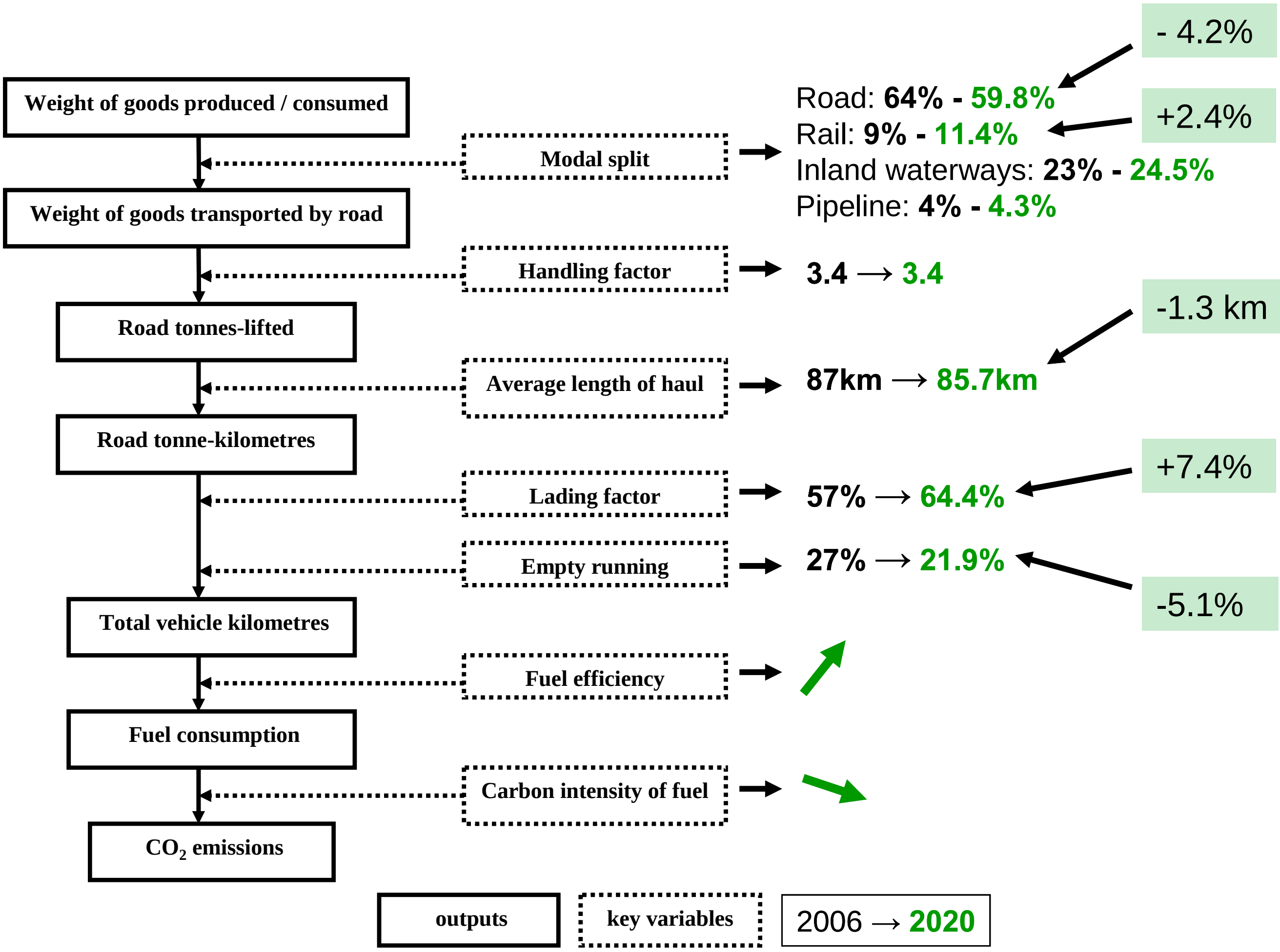

Figure 3.5. Projected changes in the key logistics variables

3.3. Factors influencing the environmental impact of road freight transport in 2020

CO_2 emissions from road freight transport are a function of the amount and type of fuel used. The amount of fuel used is closely correlated with a company's demand for road freight transport. In turn, the demand for road freight transport is the result of a series of decisions made at different levels within the corporate hierarchy. McKinnon and Woodburn (1993, 1996) differentiated four levels of logistical decision-making within a company, each of which will be influenced by a set of factors:

- **Structural factors** determining the number, location and capacity of factories, warehouses and other facilities in the logistics system;
- **Commercial factors** related to companies' sourcing and distribution strategies and policies;

- **Operational factors** affecting the scheduling of product flow;
- **Functional factors** relating to the management of transport resources – usually regarding the choice of vehicle, planning of loads and routeing of deliveries.

The complex interaction between decisions made at these four levels largely determines the amount of road freight traffic.

This framework has been extended to include two further factors:

- **Product-related factors** affecting the nature of the transport operation;
- **External factors** – such as government regulations and tax policy, wider macroeconomic trends, market dynamics and advances in technology.

The six sets of factors have a complex inter-relationship with the key freight transport variables as shown in Figure 3.6. Each set of factors exerts an influence on more than one variable, while some have a pervasive effect on most of the variables. The Delphi questions were broadly defined to elicit the opinions of the logistics specialists on the impact of this wide range of factors. There was one issue, however, about which there was a great deal of uncertainty. This was the likelihood of a major switch to alternative fuels, and particularly biodiesel. Around the time of the Delphi survey, doubts were being expressed in official reports and in the press about the net environmental benefits of biodiesel. Given this uncertainty, it was decided to focus on the overall demand for fuel and potential for improving fuel efficiency, and not speculate about future changes in its average carbon content.

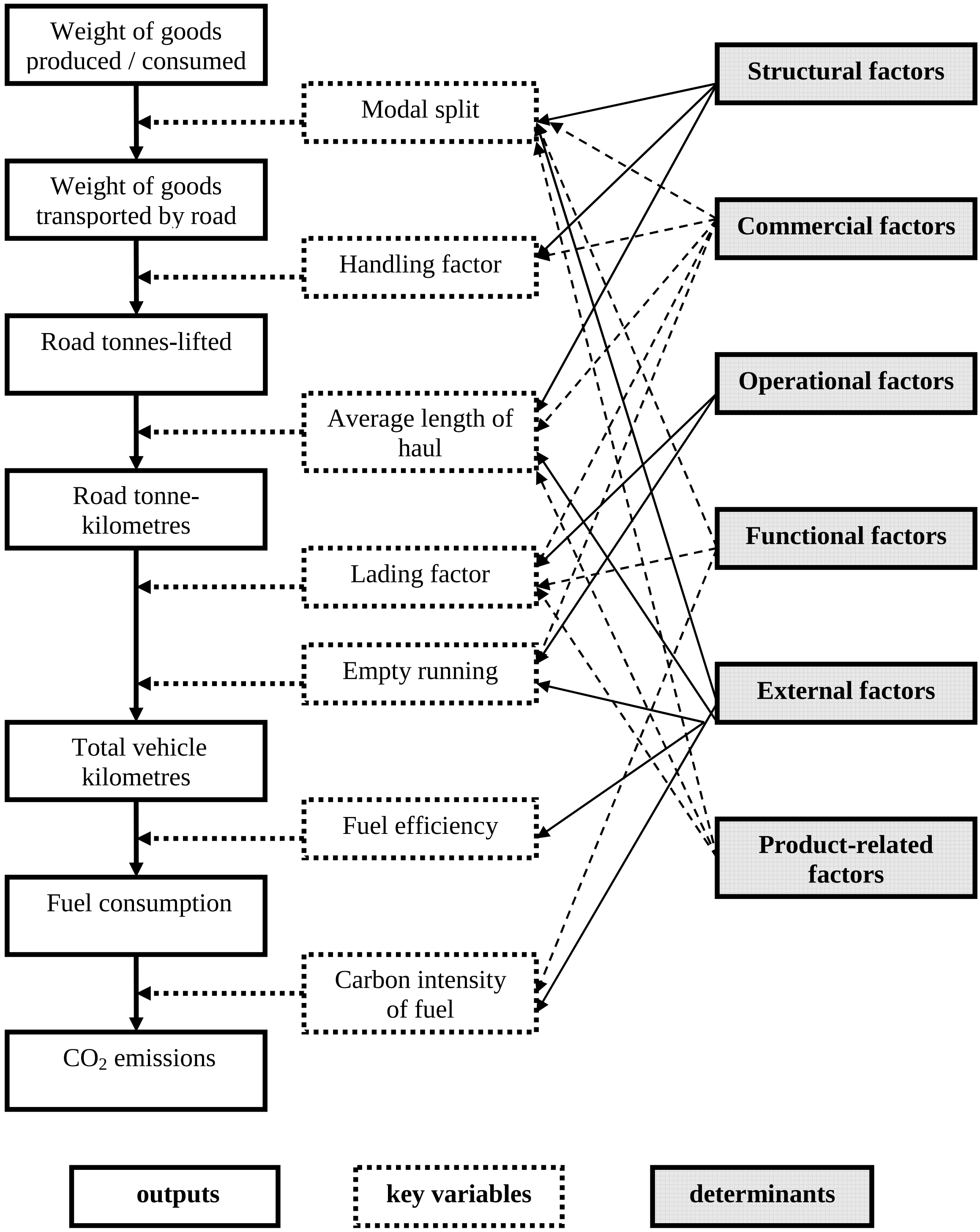

Figure 3.6. Relationship between logistical variables, determinants and environmental impacts

Structural factors

There was general agreement that in 2020 the UK market will be predominantly supplied with goods produced overseas and then distributed through centralised logistics networks within the country. The majority of respondents believed that pressures to centralise production and inventory within the UK will remain much stronger than any tendency to decentralise (Figure 3.7).

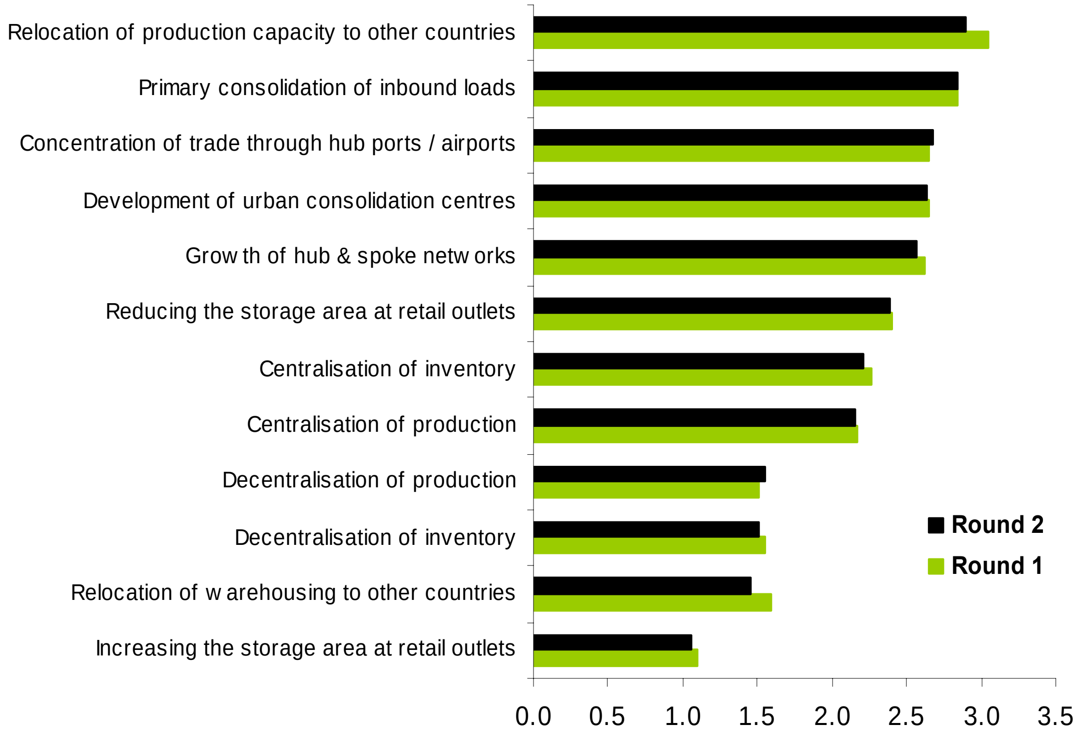

Figure 3.7. Structural factors affecting road freight demand (where 0 = no occurrence and 4 = occurrence to large extent)

However, in case of the centralisation of inventory, statistically significant differences in opinion emerged both between different types of specialist and between different sectors (Figure 3.8). For example, retail logistics managers predicted strong pressure for further centralisation (mean response of 3.4), while academics and trade body representatives anticipated only a very limited increase (mean response of 1.5).

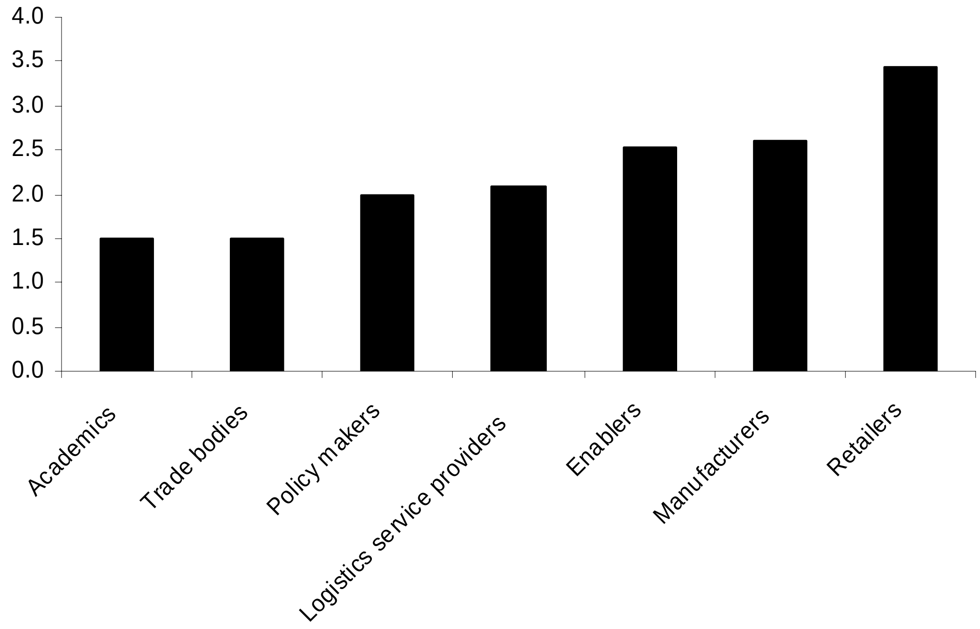

Figure 3.8. Differences in opinion on the extent of further centralisation of inventory (where 0 = no occurrence and 4 = occurrence to large extent)

There was also disagreement on the extent to which warehousing operations would relocate to other countries (Figure 3.9). Logistics service providers and manufacturers expected a significantly greater degree of relocation (1.8 and 1.7), than retailers and trade bodies (0.8 and 1.1).

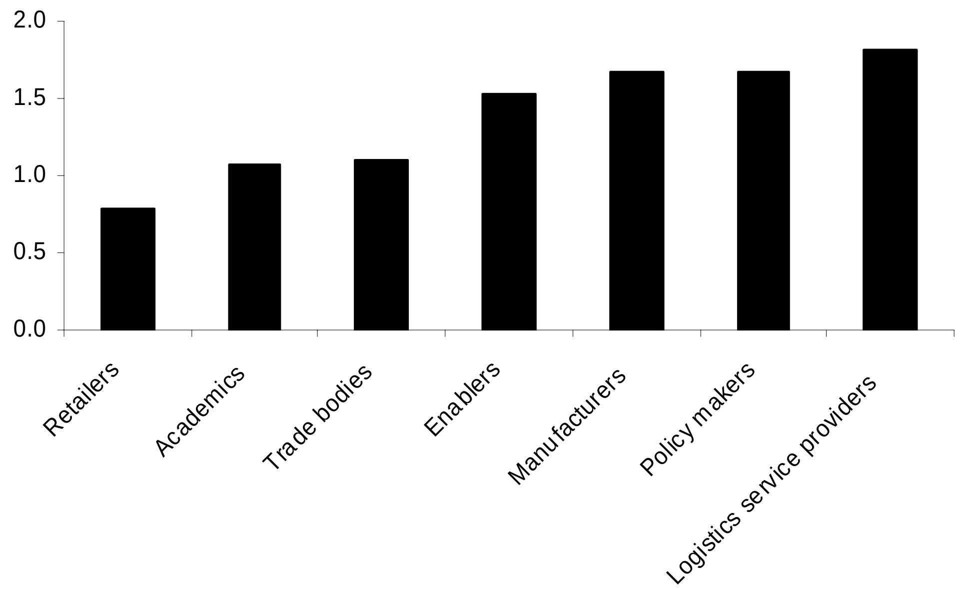

Figure 3.9. Differences in opinion on the extent of relocation of warehousing to other countries (where 0 = no occurrence and 4 = occurrence to large extent)

If, as the majority of respondents suggested, the geographical concentration of manufacturing capacity and inventory continues, average length of haul and total tonne-kms are likely to rise. It was also anticipated that an increasing proportion of freight will be channelled through the hub-and-spoke networks of parcel and pallet-load networks and through primary consolidation centres upstream of retailers' distribution centres. This typically has the effect of adding links to the supply chain and therefore generating additional tonne-kms. The forecast growth of port- and airport-centric logistics, on the other hand, has the potential to streamline distribution channels, removing links and moderating any increase in tonne-kms.

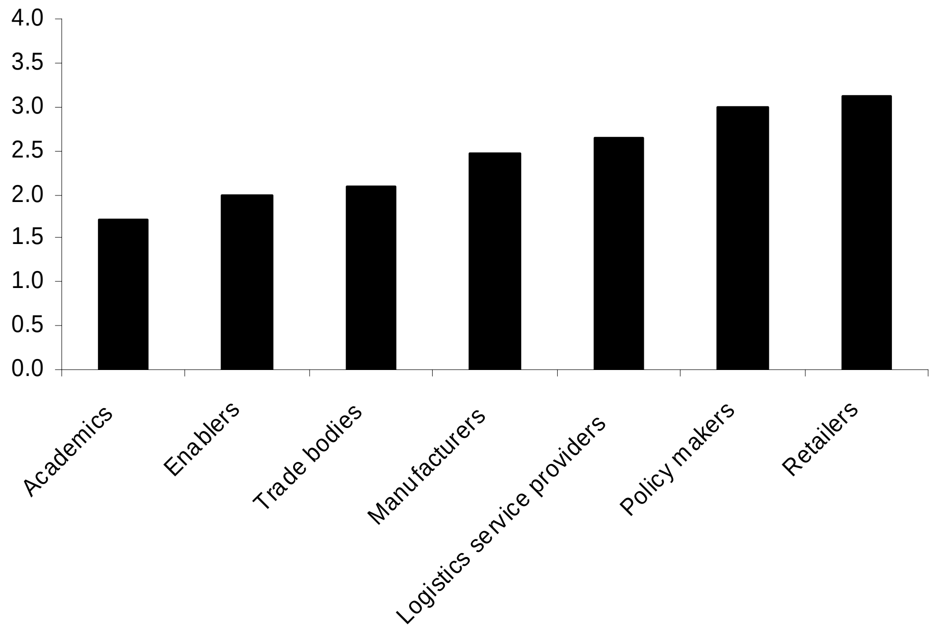

Figure 3.10. Differences in opinion on the extent of reduction of shop storage areas (where 0 = no occurrence and 4 = occurrence to large extent)

Increases in tonne-kms will not necessarily translate into a growth in vehicle traffic as vehicle loading may change. Structural factors can also influence vehicle utilisation. The centralisation of economic activity, the shift to hub-and-spoke networks and insertion of primary consolidation centres into distribution channels typically lead to greater consolidation of loads. In theory this should ensure that freight vehicle-kms increase less than tonne-kms. Other structural developments could have the opposite effect on vehicle utilisation. For example, it is predicted that in the retail sector, the storage area in the shops is going to be reduced, forcing more frequent but smaller deliveries and potentially increasing the negative environmental impact of the store deliveries. Retailers, policy makers and logistics service providers expected greatest contraction of shop storage areas (scores of respectively, 3.1, 3.0 and 2.7) (Figure 3.10).

Commercial factors

Increases in the volumes of goods and services traded online and in the amount of product being returned for recycling or reuse were identified as two of the main commercial factors impacting on freight transport demand in 2020. Although previous research suggested that there would be a significant increase in local sourcing, particularly in case of food produce, (Piecyk et al., 2007), the Delphi panellists on average felt that this will occur only to a limited extent (Figure 3.11).

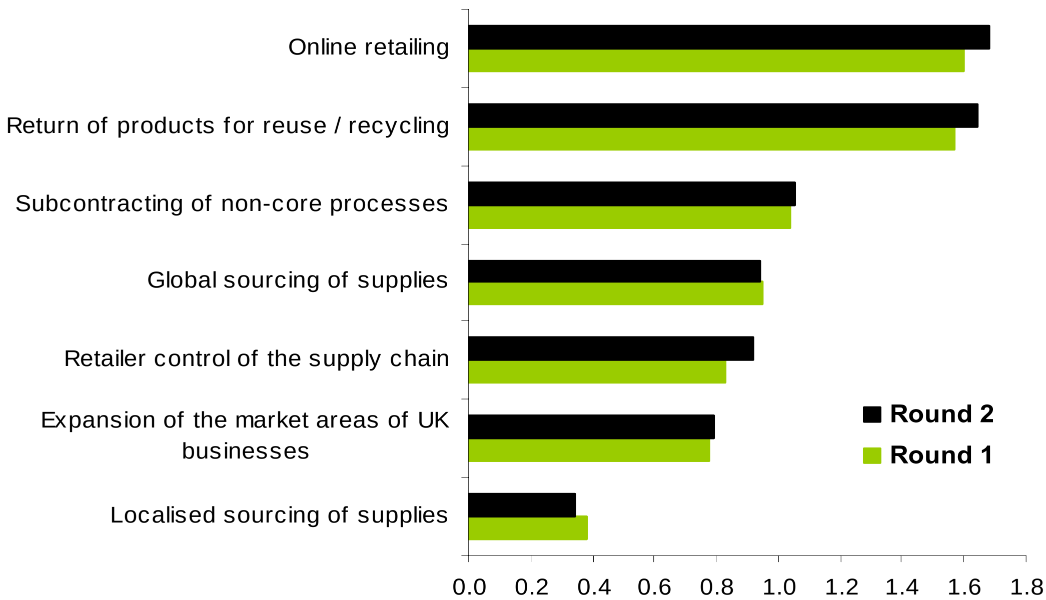

Figure 3.11. Commercial factors affecting road freight demand (where -2 = much less important than now and 2 = much more important than now)

There was, nevertheless, a divergence of opinion between retailers and logistics service providers who felt that local sourcing in 2020 will be less important than now (-0.3 and -0.2), whereas trade bodies, academics and policy makers expected it to be more common (0.9, 0.8 and 0.7) (Figure 3.12).

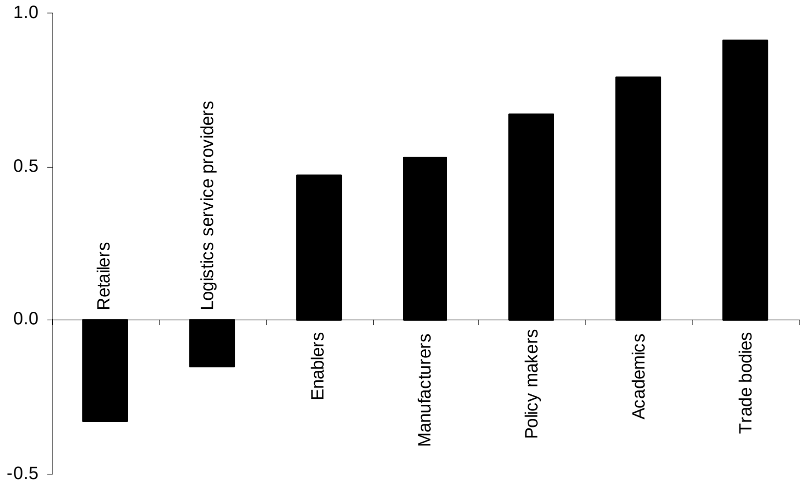

Figure 3.12. Differences in opinion on the importance of local sourcing in 2020 (where -2 = much less important than now and 2 = much more important than now)

On the other hand, there was unanimous agreement that global sourcing will expand, though opinions differed on the extent of the trend, with retailers (1.6) and logistics service providers (1.2) assigning it higher scores than academics (0.6) and manufacturers (0.7) (Figure 3.13). The increase in global sourcing will increase freight volumes on external links though may have the effect of reducing the freight transport intensity of the UK economy. This may make it easier to cut CO_2 emission from domestic freight movement in the UK, but at the expense of a net increase in freight-related CO_2 emissions at a global scale (McKinnon, 2007).

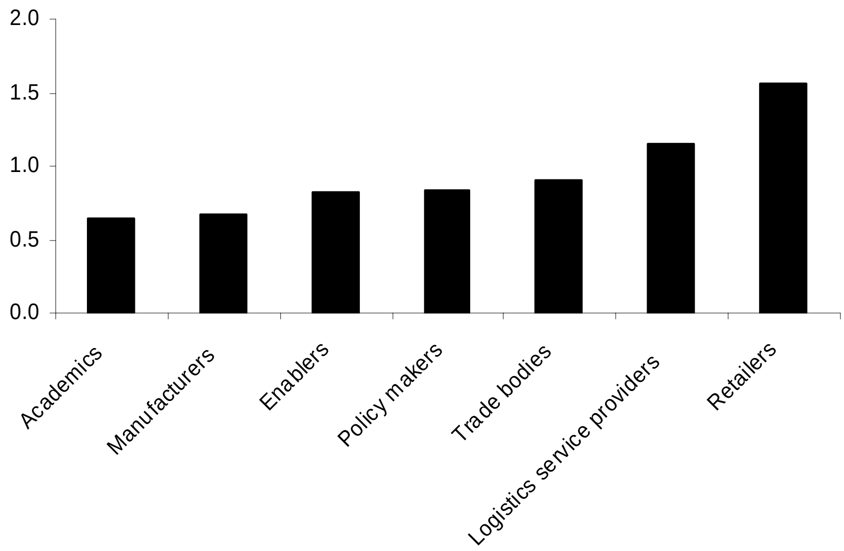

Figure 3.13. Differences in opinion on the importance of global sourcing in 2020 (where -2 = much less important than now and 2 = much more important than now)

According to the survey respondents, retailers' control over supply chains is going to strengthen even further, increasing their responsibility for improving the environmental performance across the chains. The largest growth in retailers' power was expected, perhaps unsurprisingly, by the retailers themselves (1.4), with logistics service providers (1.1) and trade bodies (1.1) averaging slightly lower scores (Figure 3.14). Academics, enablers, manufacturers and policy makers predicted smaller increases in retailers' domination. There was a general expectation that growing demand for "green" products and services may give retailers an incentive to involve supply chain partners in joint efficiency initiatives yielding an overall economic and environmental benefit.

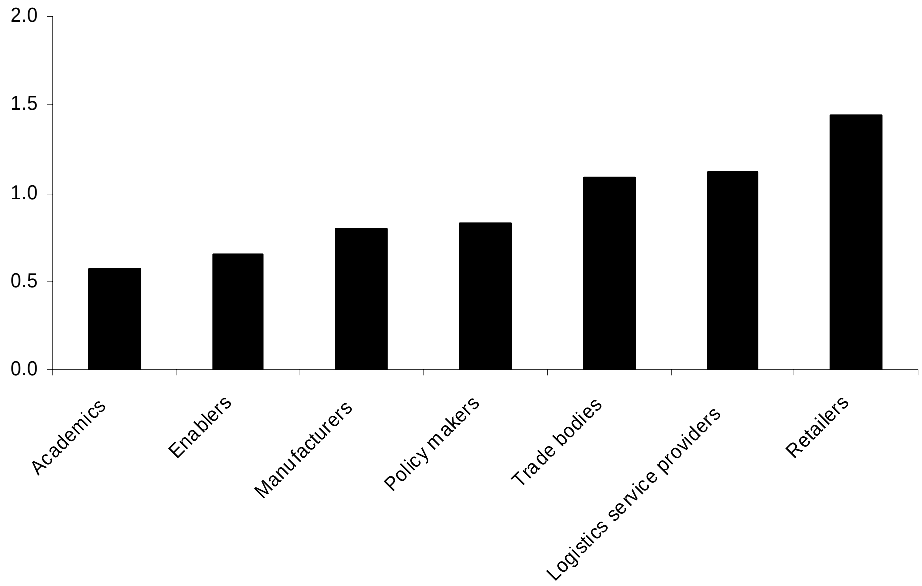

Figure 3.14. Differences in opinion on the importance of retailers' control over the supply chain (where -2 = much less important than now and 2 = much more important than now)

Panellists also anticipated a significant further increase in the 'vertical disintegration' of manufacturing operations with more non-core processes being subcontracted and, presumably, extra links being added to supply chains. The long term trend towards greater outsourcing of logistics is also expected to continue, with logistics service providers (1.4), enablers (1.3) and manufacturers (1.2) anticipating the strongest move in this direction (Figure 3.15).

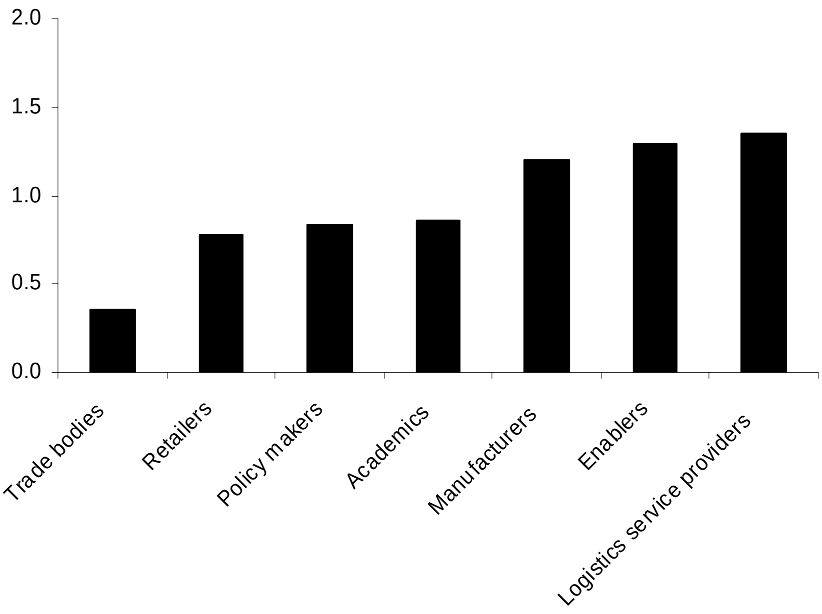

Figure 3.15. Differences in opinion on the importance of outsourcing in 2020 (where -2 = much less important than now and 2 = much more important than now)

Operational factors

Panel members forecast a further reduction of order lead times, modest tightening of the delivery windows, the need for slightly more frequent deliveries to retail outlets and even greater application of the Just-In-Time (JIT) principle. In 2020, variability of order sizes will make it more difficult for companies to match load and vehicle capacity efficiently. These trends are likely to frustrate companies' efforts to improve current levels of vehicle utilisation. Overall the Delphi panel did not endorse recent suggestions that environmental pressures to use transport capacity more efficiently will force a relaxation of JIT regimes. On the other hand, it was predicted that an increasing proportion of freight would be moved during the night, when deliveries would be made on less congested infrastructure and freight vehicles able to achieve more fuel efficient speeds (Figure 3.16).

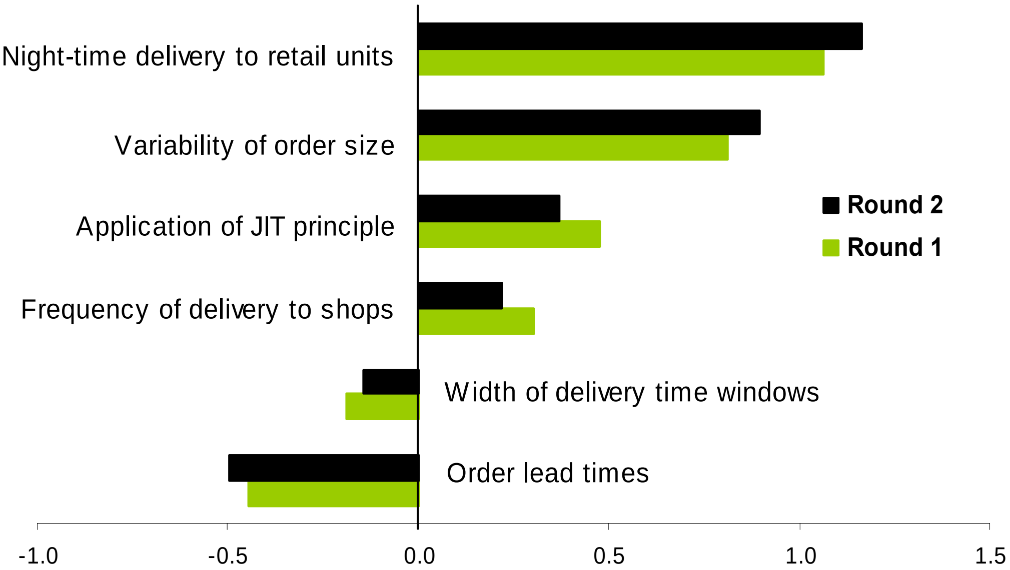

Figure 3.16. Operational factors affecting road freight demand (where -2 = large reduction and 2 = large increase)

Functional factors

Within a logistics system defined by higher-level decisions made at the strategic, commercial and operational levels, managers still have considerable scope to ‘green’ the transport operation at a functional level. The panel predicted that by 2020 this will be facilitated by wide application of telematics and computerised vehicle routing and scheduling systems (CVRS). Companies are also expected to get more heavily involved in various collaboration initiatives, to improve the utilisation of their fleets by increasing the level of backloading and to achieve greater integration of production and distribution operations. Panellists envisaged much greater use being made of online freight exchanges / load matching services by 2020, which will be likely to promote further reductions in empty running and exhaust emissions. Better matching of vehicle capacity to transport demands will lead to better resource planning and vehicle utilisation. Service quality requirements are going to remain important but increases in the real cost of transport will cause some rebalancing of cost and service priorities (Figure 3.17).

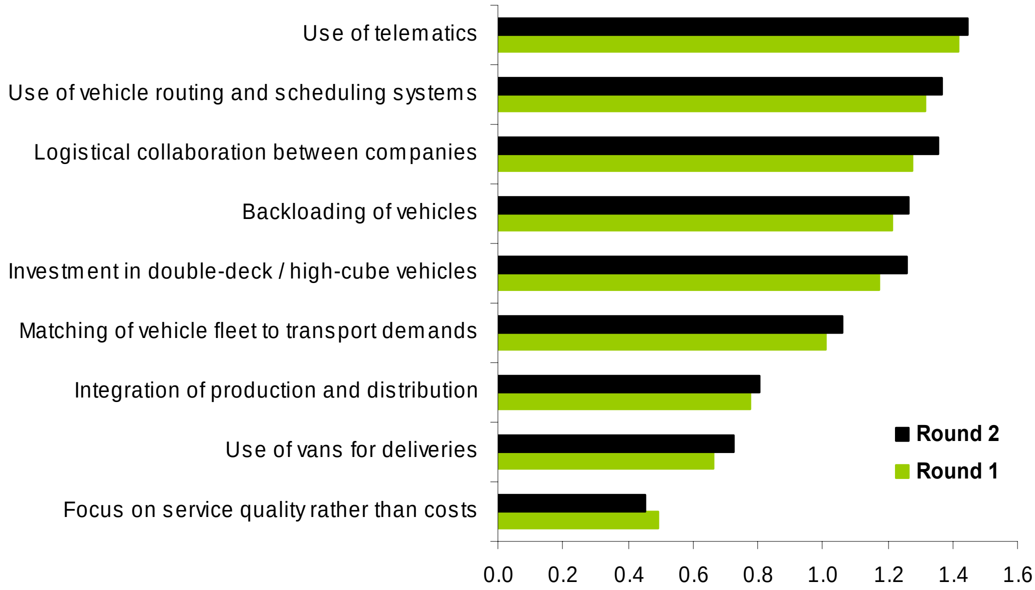

Figure 3.17. Functional factors affecting road freight demand (where -2 = much less important and 2 = much more important)

Investment in double-deck / high cube vehicles is expected to rise, with the greatest uptake in the retail, road haulage and grocery sectors (2.0, 1.5 and 1.5) (Figure 3.18).

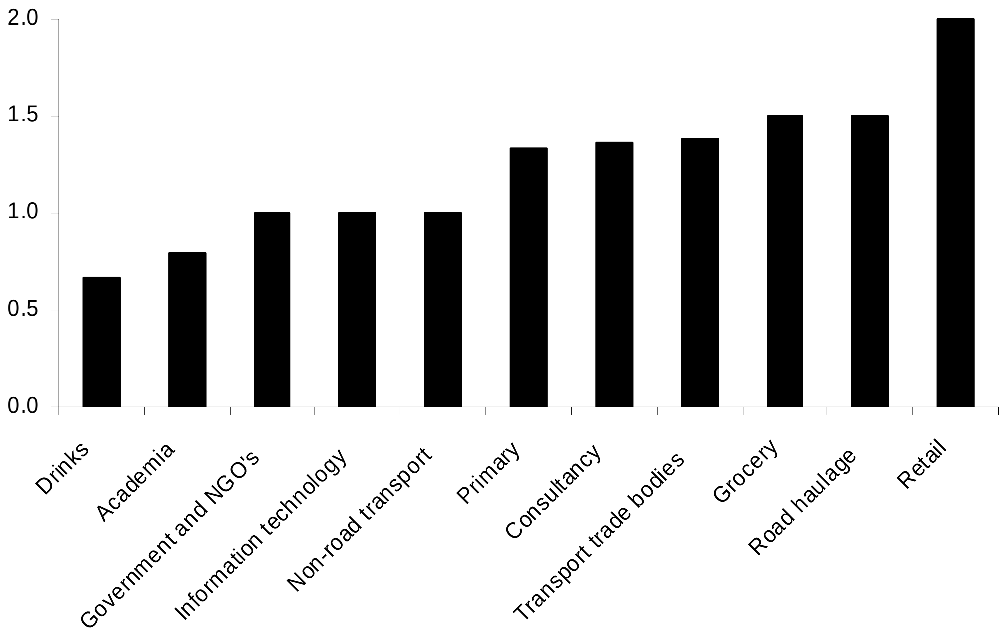

Figure 3.18. Differences in opinion on the uptake of double-deck / high-cube vehicles (where -2 = large reduction and 2 = large increase)

Almost all of the functional factors rated by the respondents are likely to bring significant savings in fuel consumption and emission levels in the short to medium term. Many of these best-practice measures, after all, require modest investment, are self-financing and carry little risk. As they are applied at the lowest and most flexible level in the decision-making hierarchy, they can allow companies to improve their environmental performance within fixed logistics structures or where commercial and operational constraints are imposed by a more powerful partner in the supply chain.

External factors

External factors will have an effect on all the key freight transport variables. Fuel prices were perceived as the biggest threat to transport operations. However, increasing fuel prices can have a beneficial effect in reinforcing fuel efficiency initiatives among road freight users (Figure 3.19). If combined with an extension of the European emissions trading scheme to transport and a switch to some types of alternative fuels[1] high oil prices may induce significant reductions in freight-related CO_2 emissions.

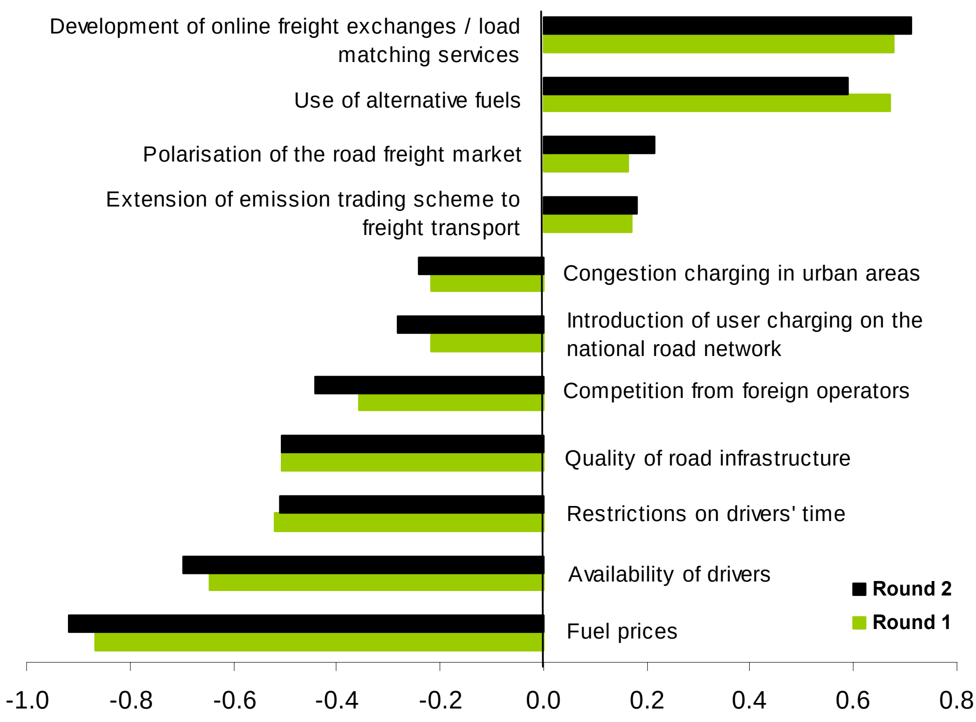

Figure 3.19. External factors affecting road freight sector (where -2 = large negative impact and 2 = large positive impact)

[1] Since the survey was completed, new scientific evidence has been published which suggests that, on a life-cycle basis, some biofuels are more carbon-intensive than conventional fossil fuels

Infrastructure charges on the national road network as well as congestion charging in urban areas were judged as likely to have slightly negative consequences for the UK freight transport sector. However, there were statistically significant differences in perceptions of the impact of the user charging on the national road network across the different groups of experts. The panellists from primary manufacturing, retail, road haulage and information technology sectors believed that road charging presented a threat to the road freight system (-1.0, -1.0, -0.8 and -0.6). On the other hand, participants from consulting, drinks industry, academia, government, NGOs and transport trade bodies predicted that national road charging would have a slightly positive or neutral effect on the UK road freight transport in 2020 (0.4,0.3, 0.0, 0.0 and 0.0) (Figure 3.20). From an environmental perspective, fiscal measures which reduce traffic congestion on both urban and rural roads are definitely beneficial, though they impose an additional economic burden on road transport operators using road infrastructure at busy times.

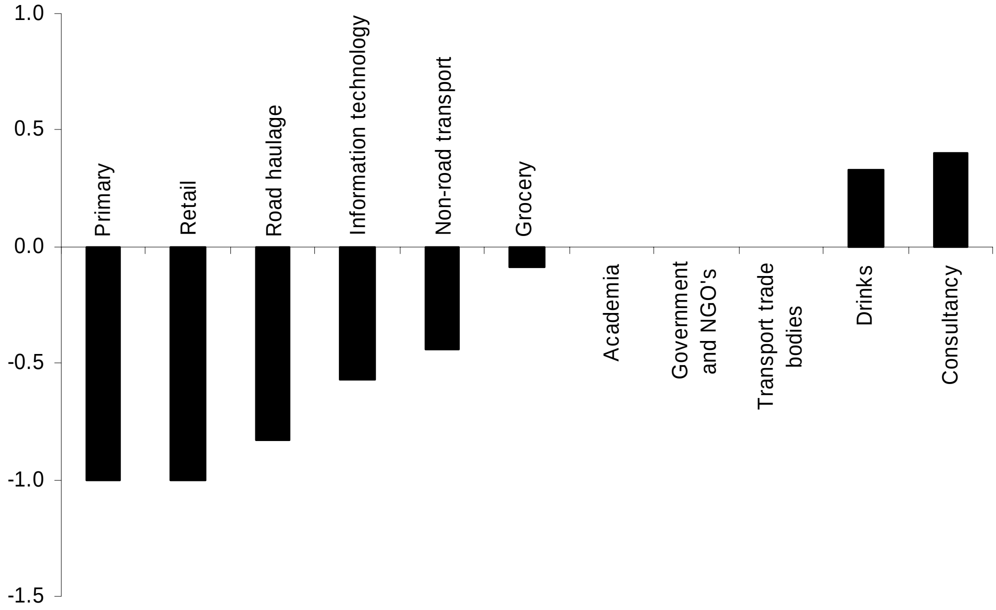

Figure 3.20. Projected impact of road charging on the road transport sector (where -2 = large negative impact and 2 = large positive impact)

Restrictions on drivers' time and a shortage of qualified drivers are expected to make management of delivery operations more difficult in 2020 resulting in a potential loss of flexibility and deterioration in performance. Driver availability was a particular concern of logistics service providers, retailers, and enablers (-0.9, -0.8 and -0.7) (Figure 3.21). Increased penetration of the UK haulage market by foreign operators was perceived as a moderate threat to the UK road freight market in 2020. At present, foreign operators, unlike their domestic counterparts, pay very little tax in the UK to compensate for their use of transport infrastructure and the related environmental impact (Piecyk and McKinnon, 2007). Current plans by the European Commission to internalise the environmental costs of freight operations across the EU should have corrected this anomaly by 2020.

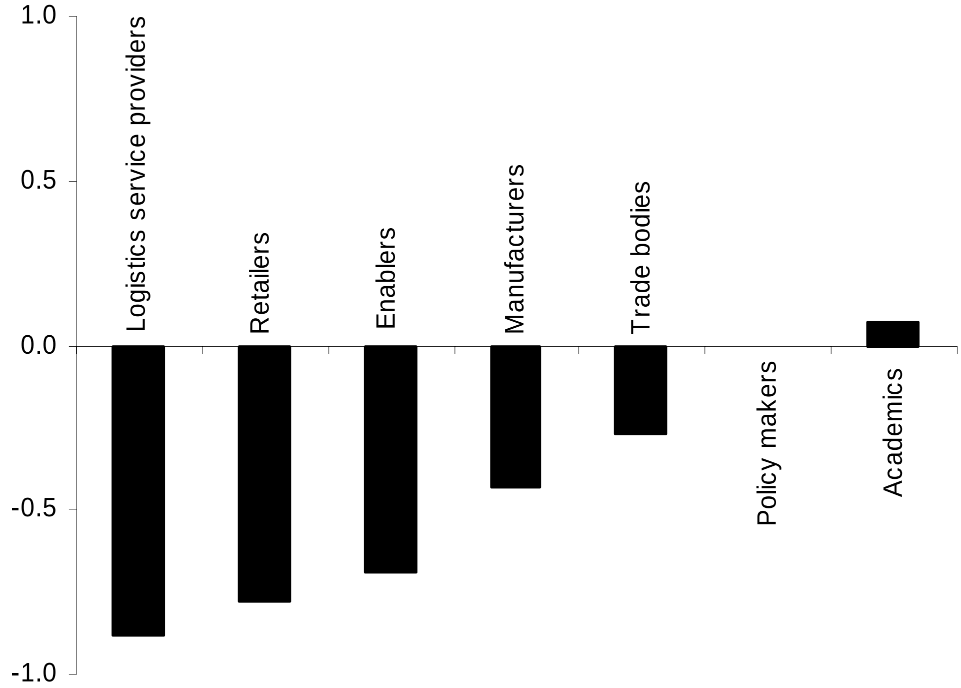

Figure 3.21. Projected impact of drivers' availability on the road transport sector (where -2 = large negative impact and 2 = large positive impact)

Product-related factors

Design of products and packaging can impact on vehicle utilisation and thus on the environmental performance of logistics. Two contradicting trends were identified by panel members. Greater use of space-efficient packaging and handling equipment and increase in the amount of attention given to logistical requirements at the design stage of the product development process should improve vehicle fill and cut emissions. On the other hand, the projected increase in the use of shelf-ready packaging and imports of goods in store-ready format may undermine efforts to optimise vehicle utilisation and lead to increased fuel consumption and emissions (Figure 3.22).

Further miniaturisation of products and an increase in their value-density can also have offsetting effects. If products are smaller and lighter, more of them can be transported in one vehicle and so fewer journeys are needed. The higher the real value of goods, however, the greater will be the emphasis on customer service and inventory minimisation, possibly at the expense of vehicle utilisation.

Figure 3.22. Product-related factors affecting road freight demand (where 0 = no impact and 4 = large impact)

3.4. Modal split

Modal shift is another important means of improving the sustainability of freight transport. By moving freight to less environmentally-damaging transport modes like rail or waterborne transport, significant savings in energy intensity and freight-related emissions can be achieved. Figure 3.23 shows the projected modal split in 2020 expressed as a percentage of the total tonne-kilometres moved.

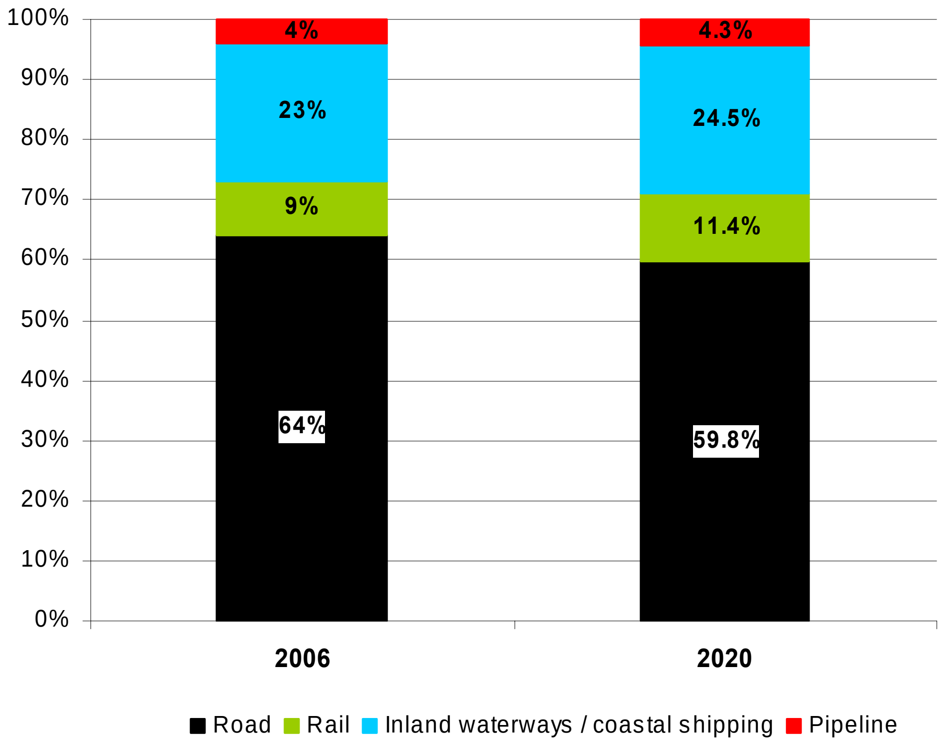

Figure 3.23. Modal split in 2006 and in 2020

As can be seen, there is going to be a modest positive change in modal split. The share of road freight transport is going to decline by over 4%, whereas other modes are going to gain market share. The biggest increase is expected in the case of railfreight (2.4%). Nevertheless, road transport still remains by far the dominant mode and the net environmental benefit from modal shift may not be as great as desired by policy makers and pressure groups. According to the Delphi projections 60% of total tonne-kms will be transported by road. Based on the projections of the increase in the total tonne-kms, this is equivalent to 195 billion tonne-kms in 2020. Hence, it is important not only to encourage modal shift but also to focus on the road freight system in order to maximise its efficiency and minimise the levels of associated externalities.

Forecasts of the future share of airfreight were excluded from the survey. Aeroplanes carry currently only 0.01% of all tonne-kms in the UK. Even assuming a huge percentage growth, this mode's share is going to be marginal. Airfreight, nevertheless, produces a high level of externalities per tonne-km. For example, domestic air cargo in the UK is estimated to emit 11 times more CO_2 per tonne-km than HGVs and 79 times more than railfreight (McKinnon, 2007).

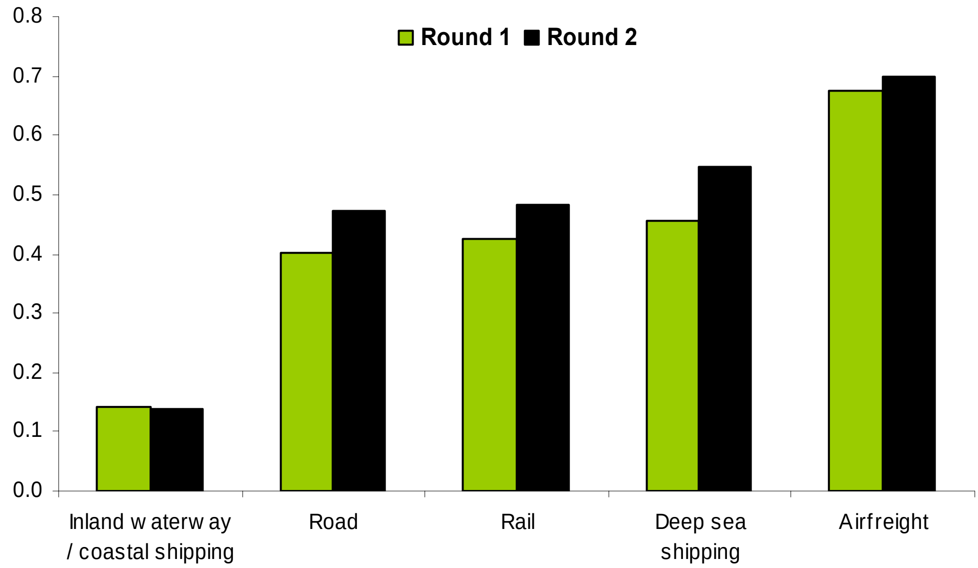

Figure 3.24. Projected change in value of goods carried by different modes (where -2 = large decrease and 2 = large increase)

The experts were also asked what changes they expect in the value of products moved by different transport modes (Figure 3.24). The biggest increase in value was anticipated in case of goods delivered to the UK by air. From an environmental perspective this could be a positive development, as only the most valuable goods might be transported by air. If airfreight operators are required to internalise the external costs of their activities, for instance through taxing kerosene fuel, it will become uneconomic to move by air some of the lower value commodities currently moved by this mode. On the other hand, the value of goods moved by inland waterway or coastal shipping was predicted to stay at the current level. This suggests that the experts were very doubtful about initiatives aiming to shift higher value-density products onto these modes. Bulk, low-value goods are going to remain the main products carried by inland waterway and coastal shipping services. A moderate increase in value was expected for goods transported by road, rail and deep-sea shipping.

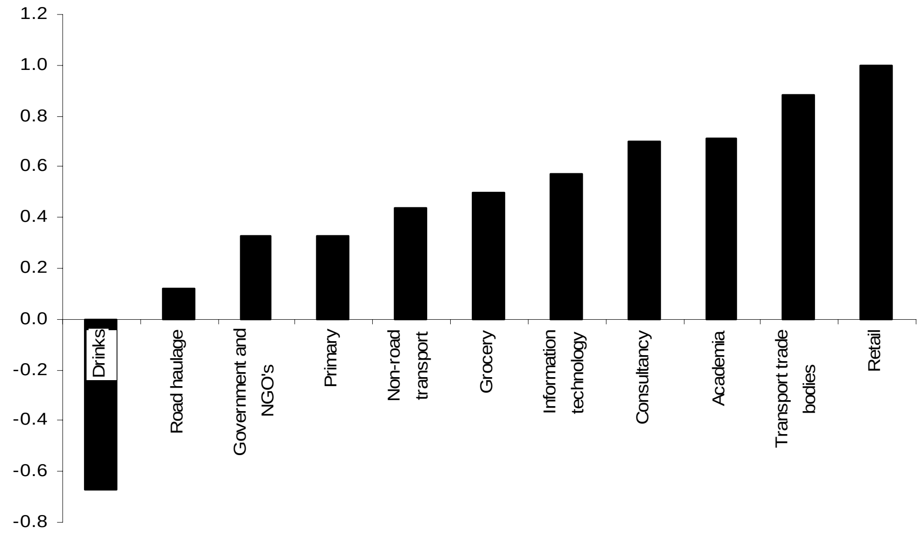

Figure 3.25. Differences in opinion on the change of value of goods carried by rail (where -2 = large decrease in value and 2 = large increase in value)

There was, nevertheless, a disagreement about the projected change in the real value of goods transported by rail amongst panellists representing different industry sectors. Experts from the retail sector and transport trade bodies expected a significant increase in the real value of products transported by rail (1.0 and 0.9). A decrease in the real value of products moved by this mode was predicted by panellists from the drinks industry (-0.7) (Figure 3.25).

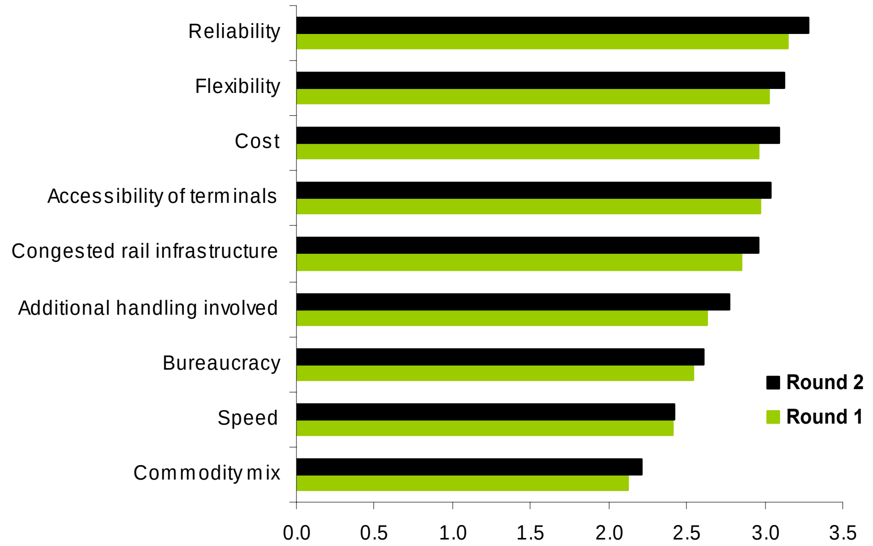

Figure 3.26. Factors influencing the amount of cargo carried by rail in 2020 (where 0 = no impact and 4 = large impact)

With regard to rail transport, reliability, flexibility, cost and accessibility of terminals were identified as the major factors influencing the amount of freight carried by 2020. Speed, commodity mix and bureaucracy were least important in comparison to other factors (Figure 3.26).

According to the experts, upgrading rail infrastructure, provision of dedicated freight lanes and simplifying administrative / regulatory framework for rail freight would be most effective means of increasing rail's share of the UK freight market. Encouraging modal shift by enforcing regulations on road freight more rigorously, increasing taxes on diesel fuel or extending emission trading scheme to freight transport were accorded much less importance (Figure 3.27).

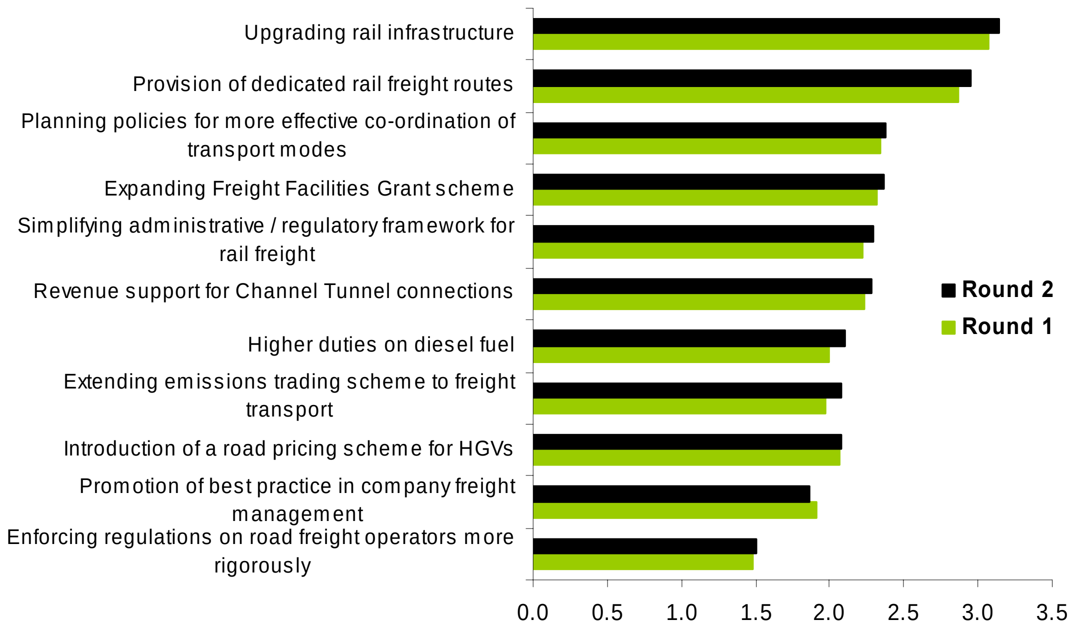

Figure 3.27. Efficiency of potential measures to increase rail's share of freight market (where 0 = no effect and 4 = very effective)

The amount of cargo carried by coastal shipping up to 2020 will be largely determined by the cost of using this transport mode. Accessibility of ports and congested infrastructure may be the key factors inhibiting an increase in coastal shipping's share of the freight market. Reliability of this transport mode was considered to be more important than its speed. Bureaucracy and additional handling associated with using coastal shipping were not considered as major obstacles (Figure 3.28).

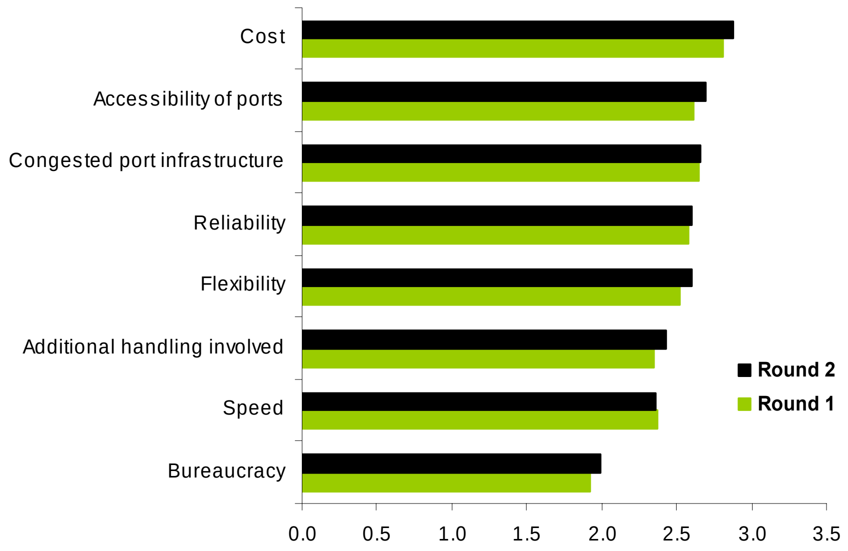

Figure 3.28. Factors influencing the amount of cargo carried by coastal / short-sea shipping in 2020 (where 0 = no impact and 4 = large impact)

In order to promote the use of coastal shipping, the UK Government should focus its efforts on providing better infrastructure and consider expansion of the Waterborne Freight Grant scheme. New policies are needed to support more effective co-ordination of transport modes. As in the case of promoting modal shift to rail, more rigorous enforcement of regulations on road freight operators, extension of emission trading scheme to freight transport or raising taxes on diesel fuel were not considered to be very effective means of encouraging businesses to use coastal shipping more extensively (Figure 3.29).

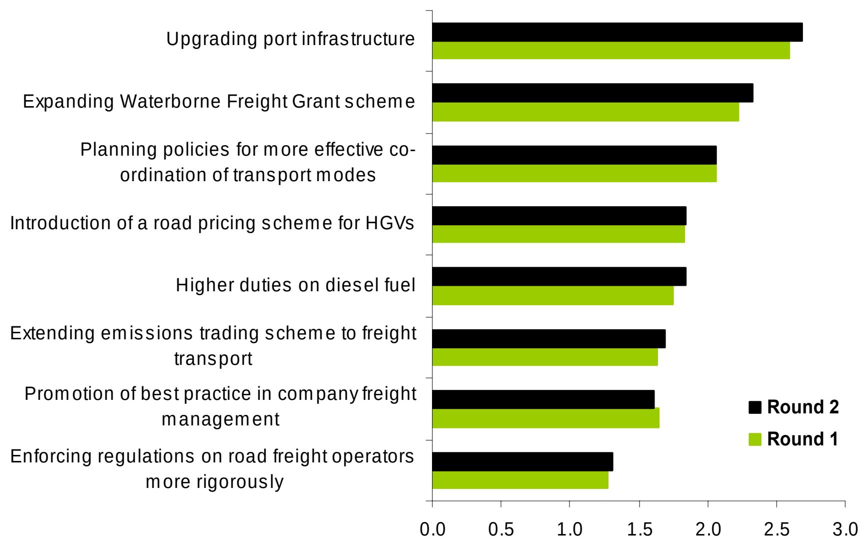

Figure 3.29. Efficiency of potential measures to increase coastal / short-sea shipping's share of freight market (where 0 = no effect and 4 = very effective)

Overall, the panellists predicted a slight relaxation of the constraints on using rail and shipping services by 2020. Furthermore, constraints on coastal shipping services are predicted to ease to a slightly larger extent than those on rail (Figure 3.30).

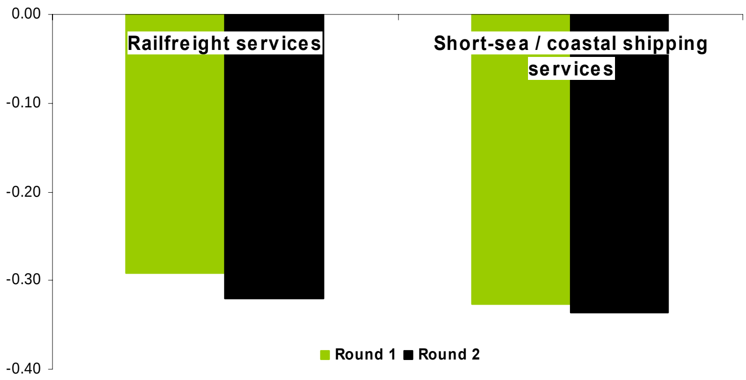

Figure 3.30. Projected changes in the constraints on using rail and shipping services (where -2 = constraints significantly easing and 2 = constraints significantly tightening)

3.5. Fuel management

According to the Delphi panellists, additional environmental benefit will accrue from increases in fuel efficiency (expressed as vehicle-kms per litre of fuel consumed) and a reduction in the carbon intensity of fuel (i.e. CO_2 emitted per litre of fuel) (Figure 3.31).

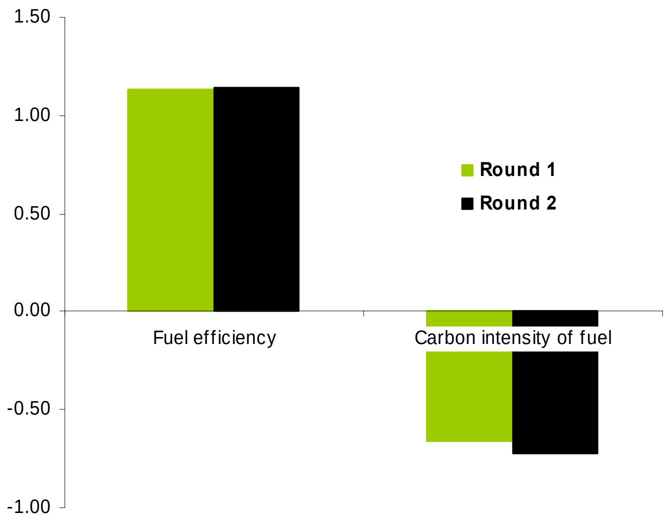

Figure 3.31. Projected changes in efficiency and carbon intensity of fuel (where -2 = large decrease and 2 = large increase)

Vehicle design, engine performance, information technology (telematics, vehicle routing software) and training schemes for fuel efficient driving were identified as the main drivers of improved fuel efficiency (Figure 3.32). The greatest external pressure on companies to reduce their fleets' fuel consumption will be high fuel prices. Relative to other factors, dissemination of best practice in fuel management was given a low rating. Overall, the results suggest that technological developments are going to play the main role in improving fuel efficiency. In order to achieve synergy of efforts, the promotion of best practice should focus on the dissemination about knowledge on available technological solutions to reduce fuel consumption.

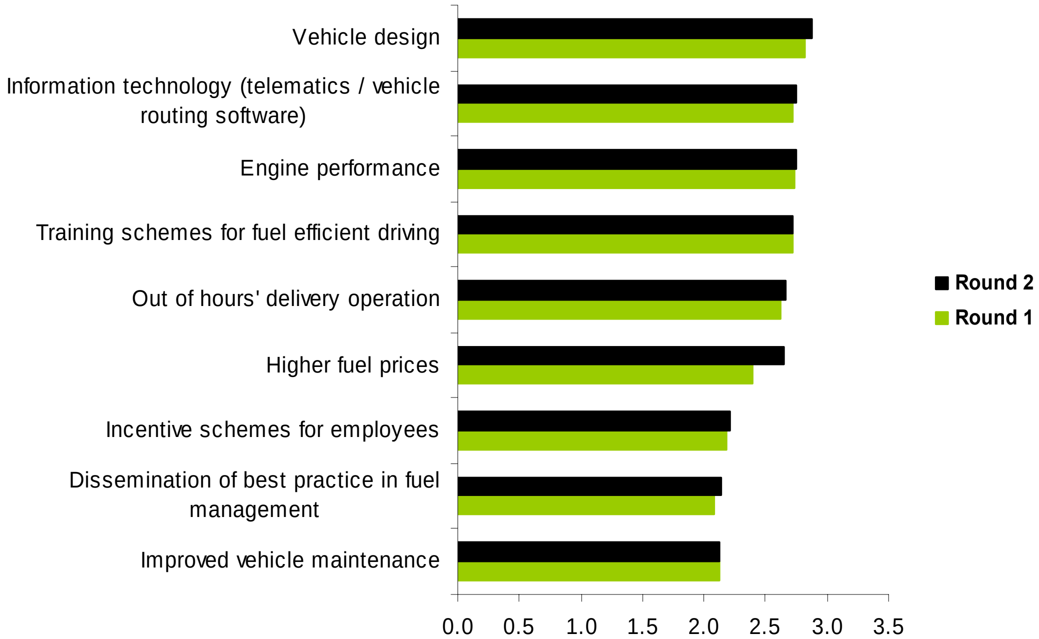

Figure 3.32. Projected importance of fuel efficiency measures (where 0 = no importance and 4 = very important)

Although all participants perceived higher fuel prices as an significant factor encouraging companies to improve their fuel efficiency, policy makers, academics and retailers regarded it as more important (3.3, 3.1 and 3.0) than representatives of trade organisations and manufacturers (2.1 and 2.1) (Figure 3.33).

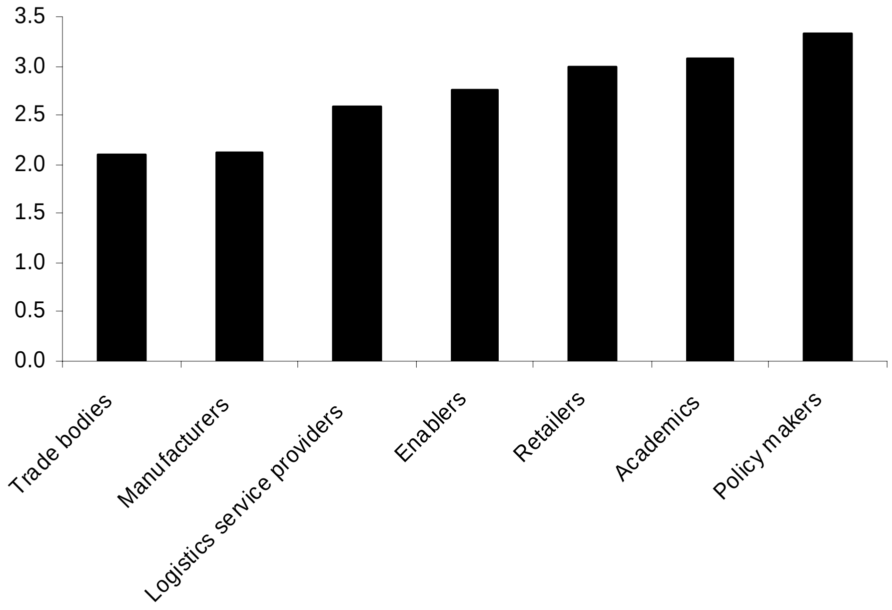

Figure 3.33. Projected impact of higher fuel prices on improving the fuel efficiency (where 0 = no importance and 4 = very important) – differences in opinion by type of organization represented

4. Effects on the carbon footprint of road freight transport in 2020

Based on the survey results three scenarios were constructed: business-as-usual (BAU), optimistic and pessimistic. The BAU scenario was based on the mean responses of the Delphi panellists. The optimistic and pessimistic scenarios were defined, respectively, as being one standard deviation above and below the mean value of each key parameter. Assumptions were made about changes in fuel efficiency and the carbon intensity of fuel to reflect the experts' opinions as discussed above. The results of the analysis are shown in Table 4.1. Please note that the results exclude Northern Ireland and apply to Great Britain only.

	Current Situation (2007)	**2020 BAU**	**2020 Optimistic**	**2020 Pessimistic**
Total tonne-kms (billion)	255	325	271	378
Share of road (HGVs)	63%	60%	54%	66%
Road tonne-kms (billion)	161	195	147	248
Lading factor	57%	64%	70%	59%
Empty running	27%	22%	18%	26%
Average length of haul (kms)	86	86	71	101
Tonnes lifted (billion tonnes)	1.9	2.3	2.1	2.5
Average load (tonnes)	9.8	11.1	12.1	10.1
Laden vehicle kilometres (billion)	16.4	17.5	12.1	24.5
Total vehicle kms (billion)	22.4	22.4	14.7	33.2
Projected change in fuel efficiency		+5%	+10%	-5%
Fuel efficiency (mpg)	8.7	9.1	9.6	8.3
Fuel efficiency (litre/km)	0.33	0.31	0.29	0.34
Projected change in carbon intensity of fuel		-5%	-10%	no change
Conversion ratio (kg CO2 / litre of fuel)	2.63	2.50	2.37	2.63
Total fuel consumption (billion litres)	7.3	7.0	4.3	11.4
Total CO_2 emissions (million tonnes)	**19.3**	**17.4**	**10.3**	**30.0**
% change from current level		-10%	-47%	+56%

Table 4.1. Carbon footprint of road freight transport in Great Britain now and in 2020.

When the BAU scenario is considered, positive developments in modal split, vehicle utilisation, fuel efficiency and carbon intensity are likely to result in a 10% percent reduction in CO_2 emissions from the current level, decreasing the carbon footprint of road freight transport to 17.4 million tonnes of CO_2 in 2020. This occurs despite the fact that there would be an underlying growth in road tonne-kms of 21%. As the average length of haul is likely to remain relatively stable, the increase in tonne-kms is driven mainly by a growth in the weight of goods transported (to 2.3 billion tonnes in 2020). Panellists predicted that the average number of links in the supply chain will also remain stable, suggesting that future increases in the transported weight will be due mainly to an increase in the physical mass of goods in the economy. The 21% of tonne-kms will be largely offset by better loading (resulting in the weight of an average load rising to 11.1 tonnes from 9.8 tonnes) and less empty running of HGVs. As a result, total truck-kms will not rise. When improvements in fuel efficiency and reductions in carbon intensity are factored into the calculation, total CO_2 emissions from road freight transport will actually fall by 2020.

In the optimistic scenario CO_2 emissions from road freight would be 47% below the current level (10.3 million tonnes of CO_2 in 2020). The decrease in road tonne-kms (8 percent) would be a result of a 9% shift of freight away from road transport to alternative modes and a reduction in the average length of haul by 15 kms relative to the present value. Significant improvements in vehicle utilisation parameters (lading factor of 70% and empty running of only 18%), would further convert this decrease in tonne-kms into a 34 percent reduction in the total vehicle kms. In this scenario, the fuel efficiency of HGVs is assumed to improve by 10% and the carbon intensity of fuel to fall by 10%, reinforcing the beneficial CO_2 trend.

In the pessimistic scenario, the carbon footprint of the road freight sector increases to 30.0 million tonnes of CO_2 in 2020 (56% above the present level). An underlying growth in tonne-kms of 48% is supplemented by a slight increase in road's share of the freight market (from 64 to 66%). Very modest improvements in vehicle utilisation will fail to offset this growth in road tonne-kms, resulting in a 48% increase in the total vehicle kms travelled. This scenario also assumes slight worsening of fuel efficiency (-5%) which could be a consequence, for instance, of increasing traffic congestion or a further tightening of regulatory controls on emissions of other pollutants (for example, the imposition of the Euro 6 emission standard in 2013 will carry a 2%-3% fuel penalty (European Commission, 2007)). No change in the carbon intensity of fuel is assumed in this scenario.

5. Conclusions

Climate change and CO_2 emissions are clearly becoming significant factors in logistical decision-making. Over 50% of companies involved in road freight transport operations are likely to see their activities affected by climate change concerns to a significant or large extent by 2015. This is expected to rise to over 80% by 2020.

Some long-established production and logistics trends which exert a strong influence on road freight demand, such as the centralisation of manufacturing and inventory, the adoption of JIT replenishment and the outsourcing of non-core activities, cannot continue indefinitely. The results of the Delphi survey reported in this paper suggest that these trends are likely to continue at least until 2020. They also show the complexity of the inter-relationships between a broad range of business trends, freight traffic levels and related CO_2 emissions. While some of the trends predicted by the panel of experts will increase the environmental footprint of road freight operations, others will have the opposite effect. Generally speaking, many of the trends anticipated at the upper strategic, commercial and operational levels in the decision-making hierarchy are likely to increase their environmental impact, while those projected to occur at a functional level in the management of transport resources will have an offsetting effect. However, if the BAU scenario is considered, overall changes in the key logistical variables, such as percentage of tonne-kms transported by road, average length of haul, empty running or lading factor, should have a positive or, in the worst case, neutral effect on the environmental performance of road freight transport (Figure 5.2).

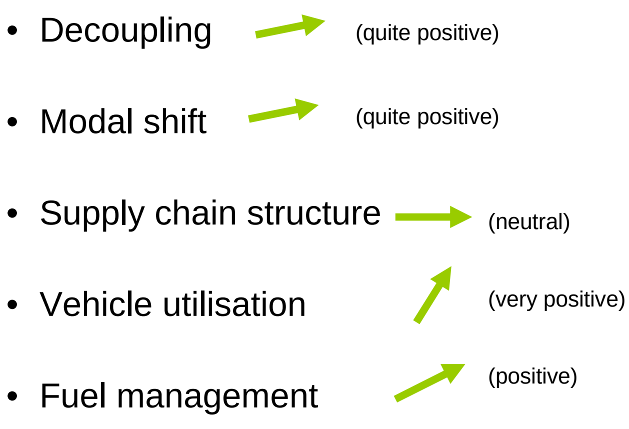

Figure 5.2. Likely environmental impact of changes in the key logistics variables.

The actual net impact of all these changes on freight-related energy consumption and emissions is difficult to quantify. Nevertheless, an attempt has been made to construct three possible road-freight CO_2 scenarios for 2020 using the experts' opinions to calibrate the spreadsheet-based forecasting model.

The standard deviation values in the first round of the Delphi survey revealed significant differences of opinion on some of the key variables. Overall, the Delphi process produced, on average, a 9% convergence of expert views. Where statistically significant differences in opinion persisted between respondents in different stakeholder or industry groups, additional analysis was carried out to avoid misrepresenting their viewpoints. The scenario-building exercise, however, relied on average scores for the Delphi panel as a whole

The mid-range BAU scenario indicates that the most likely outcome is a marginal reduction in CO_2 emissions from road freight transport of around 10%. This would occur despite an increase of 21% in the amount of road freight movement above the 2006 level. Substantial improvements in vehicle utilisation and fuel efficiency and shifts to alternative transport modes and lower carbon fuels would more than offset the effect of this growth in road tonne-kms on CO_2 emissions. The optimistic and pessimistic scenarios, defined by a one standard deviation range on either side of the mean Delphi scores, envisage road-freight-related CO_2 emissions falling by 47% or rising by 56%. If the optimistic projection proved accurate, the GB road freight sector would be on a trajectory that would comfortably meet the 80% CO_2 reduction that the UK government has set for the economy as a whole by 2050. If, however, the mid-range BAU forecast is adopted, as it reflects the majority opinion of the Delphi panellists, the road freight sector will fall well short of the necessary 'carbon pathway' to an 80% CO_2 reduction by 2050 (Department for Transport, 2008c). Government and business will then have to intensify their efforts to decarbonise the movement of freight by road.

References:

Armstrong, J.S. and Overton, T.S. (1977), Estimating nonresponse bias in mail surveys, *Journal of Marketing Research*, Vol. 14**,** pp. 396 - 402.

Carter, C.R. and Jennings, M.M. (2002), Social responsibility and supply chain relationships, *Transportation Research Part E*, Vol. 32**,** pp. 37 - 52.

Cooper, J.C. (1994), Logistics futures in Europe: a Delphi study, Cranfield, Cranfield Centre for Logistics and Transportation.

Cooper, M.C., Santosa, J. and Burgos - Dominguez, A. (2007), Career Patterns of Women in Logistics, Lombard, CSCMP.

Cranfield School of Management (1984), Distribution in the Year 2003: Summary of Delphi Forecasts, Cranfield.

Department for Transport (2008a), Transport Statistics Great Britain: 2008 Edition, London.

Department for Transport (2008b), Road Freight Statistics 2007, London.

Department for Transport (2008c), Carbon Pathways Analysis. Informing Development of a Carbon Reduction Strategy for the Transport Sector, London.

DETR (1999), Sustainable Distribution: A Strategy, London.

Diaz de Rada, V. (2005), Measure and control of non-response in a mail survey, *European Journal of Marketing*, Vol. 39 No.1/2**,** pp. 16 - 32.

Dickerson, A., Homenidou, K. and Wilson, R. (2008), Working Futures 2004 - 2014. Sectoral Report, Coventry, University of Warwick.

European Commission (2001), White Paper- European Transport Policy for 2010: Time to Decide, Luxembourg.

European Commission (2006), Keep Europe Moving. Sustainable Mobility for Our Continent, Luxembourg.

European Commission (2007), Impact Assessment. Annex to the Proposal for a Regulation of the European Parliament and of the Council on the Approximation of the Laws of the Member States with Respect to Emissions from On-road Heavy Duty Vehicles and on Access to Vehicle Repair Information, Brussels.

European Commission (2008), Oil Bulletin, Brussels, Directorate-General Energy and Transport.

Firth, M. (1977), *Forcasting Methods in Business and Management,* Edward Arnold Publishers, London.

Greatorex, J. and Dexter, T. (2000), An accessible analytical approach for investigating what happens between the rounds of a Delphi study, *Journal of Advanced Nursing,* Vol. 32 No.4**,** pp. 1016 - 1024.

Gupta, U.G. and Clarke, R.E. (1996), Theory and Applications of the Delphi Technique: A Bibliography (1975-1994), *Technological Forecasting and Social Change,* Vol. 53**,** pp. 185-211.

Hasson, F., Keeney, S. and McKenna, H. (2000), Research guidelines for the Delphi survey technique, *Journal of Advanced Nursing,* Vol. 32 No.4**,** pp. 1008 - 1015.

Hsu, C.-C. and Sandford, B.A. (2007a), The Delphi Technique: Making Sense Of Consensus, *Practical Assessment, Research & Evaluation,* Vol. 12 No. 10**,** pp. 1-8.

Hsu, C.-C. and Sandford, B.A. (2007b), Minimising non-response in the Delphi process: how to respond to non-response, *Practical Assessment, Research & Evaluation,* Vol. 12 No.17**,** pp. 1- 6.

Hudson, D., Seah, L.-H., Hite, D. and Haab, T. (2004), Telephone presurveys, self-selection and non-response bias to mail and Internet surveys in economics research, *Applied Economics Letters,* Vol. 11**,** pp. 237 - 240.

Lambert, D.M. and Harrington, T.C. (1990), Measuring nonresponse bias in customer service mail surveys, *Journal of Business Logistics,* Vol. 11 No.2**,** pp. 5 - 25.

Landeta, J. (2006), Current validity of the Delphi method in social sciences, *Technological Forecasting and Social Change,* Vol. 73 No. 5**,** pp. 467- 482.

Linstone, H.A. and Turoff, M. (2002), *The Delphi Method, Techniques and Applications,* Addison-Wesley, London.

Loo, R. (2002), The Delphi method: a powerful tool for strategic management, *An International Journal of Police Strategies & Management,* Vol. 25 No. 4**,** pp. 762 - 769.

Lummus, R.R., Vokurka, R.J. and Duclos, L.K. (2005), Delphi study on supply chain flexibility, *International Journal of Production Research,* Vol. 43 No.13**,** pp. 2687 - 2708.

MacCarthy, B.L. and Atthirawong, W. (2003), Factors affecting location decisions in international operations - a Delphi study, *International Journal of Operations & Production Management,* Vol. 23 No. 7**,** pp. 794-818.

McKinnon, A. (2007), CO_2 Emissions from Freight Transport in the UK, London, UK Commission for Integrated Transport.

McKinnon, A.C. (2003), Logistics and the Environment, in: Hensher, D.A. and Button, K.J. (Eds.) *Handbook of Transport and the Environment.* Elsevier Science Oxford.

McKinnon, A.C. and Forster, M. (2000), Full Report of the Delphi 2005 Survey: European Logistical and Supply Chain Trends: 1999-2005, Edinburgh, Heriot-Watt University.

McKinnon, A.C., Piecyk, M.I. and Somerville, A. (2008), Decoupling, recoupling and the future growth of road freight, *Logistics & Transport Focus,* Vol. 10 No.12**,** pp. 40 - 46.

McKinnon, A.C. and Woodburn, A.G. (1993), A logistical perspective on the growth of lorry traffic, *Traffic Engineering and Control,* Vol. 34 No. 10**,** pp. 466 - 471.

McKinnon, A.C. and Woodburn, A.G. (1996), Logistical restructuring and road freight traffic growth: an empirical assessment, *Transportation,* Vol. 23 No. 2**,** pp. 141 - 161.

Melnyk, S.A., Lummus, R.R., Vokurka, R.J., Burns, L.J. and Sandor, J. (2008), Mapping the future supply chain management: a Delphi study, *International Journal of Production Research,* Vol. fortcoming**,** pp.

Min, H., LaTour, M.S. and Jones, M.A. (1995), Negotiation outcomes: The impact of the initial offer, time, gender and team size, *The Journal of Supply Chain Management,* Vol. 31 No.4**,** pp. 19 - 24.

Office for National Statistics (2008), Material flow account for the United Kingdom 1970 to 2007.

Ogden, J.A., Petersen, K.J., Carter, J.R. and Monczka, R.M. (2005), Supply chain strategies for the future: A Delphi study, *The Journal of Supply Chain Management: A Global Review of Purchasing and Supply,* Vol. 3**,** pp. 29-48.

Okoli, C. and Pawlowski, S.D. (2004), The Delphi method as a reseach tool: an example, design considerations and applications, *Information & Management,* Vol. 42**,** pp. 15 - 29.

Piecyk, M., Edwards, J. and McKinnon, A. (2007), Modelling the future impact of freight transport on the environment, in: Lalwani, C., Mangan, J., Butcher, T. and Mondragon, A.C. (Eds.), *Logistics Research Network 2007. Conference Proceedings.* Hull, CILT.

Piecyk, M. and McKinnon, A. (2007), Internalising the External Costs of Road Freight Transport in the UK, Edinburgh, Heriot-Watt University.

Rieger, W.G. (1986), Directions in Delphi Developments: Dissertations and Their Quality, *Technological Forecasting and Social Change,* Vol. 29 No. 2**,** pp. 195- 204.

Rowe, G. and Wright, G. (1999), The Delphi technique as a forecasting tool: issues and analysis, *International Journal of Forecasting,* Vol. 15**,** pp. 353 - 375.

Runhaar, H., van der Heijden, R. and Kuipers, B. (2002), Flexibility of freight transport sectors. An exploration of carriers' responses to external pressure on prices and service, *European Journal of Transport and Infrastructure Research,* Vol. 2 No. 1**,** pp. 19 - 40.

Tatham, P. and Kovacs, G. (2008), Logistics skills and performance, *Logistics Research Network 2008.* Liverpool, CILT.

Walters, D. (1975), Physical distribution futures for UK food industry, *International Journal of Retail & Distribution Management,* Vol. 3 No.5**,** pp. 42 - 57.

Walters, D. (1976), *Futures for Physical Distribution in the Food Industry,* Saxon House, Farnborough.

Woudenberg, F. (1991), An evaluation of Delphi, *Technological Forecasting and Social Change*, Vol. 40 No. 2**,** pp. 131-150.

Appendix 1. Detailed results of the Delphi survey

To what extent will the following changes to logistics and supply chain systems occur within UK by 2020? (where 0 = not at all and 4 = large extent)	**Mean (round 1)**	**Mean (round 2)**	**Reduction of standard deviation**[1]
Centralisation of production	2.2	2.2	-9%
Decentralisation of production	1.5	1.6	-1%
Centralisation of inventory	2.3	2.2	-7%
Decentralisation of inventory	1.5	1.5	-1%
Relocation of production capacity to other countries	3.0	2.9	-10%
Relocation of warehousing to other countries	1.6	1.5	-10%
Concentration of trade through hub ports / airports	2.7	2.7	-14%
Growth of hub & spoke networks	2.6	2.6	-2%
Development of urban consolidation centres	2.6	2.6	-4%
Primary consolidation of inbound loads to distribution centres / factories	2.8	2.8	-17%
Increasing the storage area at retail outlets	1.1	1.1	-8%
Reducing the storage area at retail outlets	2.4	2.4	-11%

Table 1. Structural factors affecting road freight demand

[1] **between rounds 1 and 2 of the survey**

How are the following commercial practices likely to change by 2020? (where -2 = much less important than now and 2 = much more important than now)	**Mean (round 1)**	**Mean (round 2)**	**Reduction of standard deviation**
Online retailing	1.6	1.7	-11%
Return of products for reuse / recycling	1.6	1.6	-8%
Global sourcing of supplies	0.9	0.9	-15%
Localised sourcing of supplies	0.4	0.3	-7%
Expansion of the market areas of UK businesses	0.8	0.8	-5%
Retailer control of the supply chain	0.8	0.9	-18%
Subcontracting of non-core processes	1.0	1.1	-6%

Table 2. Commercial factors affecting road freight demand

Relative to today how are the following logistics and supply chain operations likely to change by 2020? (where -2 = large reduction and 2 = large increase)	**Mean (round 1)**	**Mean (round 2)**	**Reduction of standard deviation**
Order lead times	-0.4	-0.5	-10%
Width of delivery time windows	-0.2	-0.1	-6%
Frequency of delivery to shops	0.3	0.2	-5%
Application of JIT principle	0.5	0.4	-6%
Variability of order size	0.8	0.9	-16%
Night-time delivery to retail outlets	1.1	1.2	-7%

Table 3. Operational factors affecting road freight demand

What will be the uptake of the following management practices by 2020 relative to today? (where -2 = much less and 2 = much more)	**Mean (round 1)**	**Mean (round 2)**	**Reduction of standard deviation**
Use of telematics	1.4	1.4	-10%
Use of vehicle routing and scheduling systems	1.3	1.4	0%
Logistical collaboration between companies	1.3	1.4	-4%
Integration of production and distribution	0.8	0.8	0%
Matching of vehicle fleet to transport demands	1.0	1.1	-16%
Investment in double-deck / high-cube vehicles	1.2	1.3	-8%
Use of vans for deliveries	0.7	0.7	-1%
Backloading of vehicles	1.2	1.3	1%
Focus on service quality rather than costs	0.5	0.5	-13%

Table 4. Tactical factors affecting road freight demand

What will be the impact of the following external factors on the UK road freight transport by 2020? (where -2 = large negative impact and 2 = large positive impact)	**Mean (round 1)**	**Mean (round 2)**	**Reduction of standard deviation**
Fuel prices	-0.9	-0.9	-1%
Extension of emission trading scheme to freight transport	0.2	0.2	-6%
Use of alternative fuels	0.7	0.6	1%
Introduction of user charging on the national road network	-0.2	-0.3	-9%
Congestion charging in urban areas	-0.2	-0.2	-5%
Quality of road infrastructure	-0.5	-0.5	-13%
Availability of drivers	-0.6	-0.7	-5%
Restrictions on drivers' time	-0.5	-0.5	-8%
Development of online freight exchanges / load matching services	0.7	0.7	-9%
Polarisation of the road freight market	0.2	0.2	-5%
Competition from foreign operators	-0.4	-0.4	-10%

Table 5. External factors affecting road freight demand

To what extent will the following changes in product and packaging design occur within UK by 2020? (where 0 = not at all and 4 = large extent)	**Mean (round 1)**	**Mean (round 2)**	**Reduction of standard deviation**
Greater use of space-efficient packaging / handling equipment	2.9	2.9	-5%
Design of products more sensitive to logistical requirements	2.1	2.2	-11%
Increase in the use of shelf-ready packaging	2.6	2.6	-10%
Import of goods in store-ready format	2.6	2.7	-15%
Miniaturisation of products	2.1	2.1	-14%
Increase in the value-density of products	2.3	2.3	-8%

Table 6. Product-related factors affecting road freight demand

How will the value, in real terms, of 1 tonne of product moved by the following modes to, from and within UK change by 2020? (where -2 = large decrease and 2 = large increase)	**Mean (round 1)**	**Mean (round 2)**	**Reduction of standard deviation**
Road	0.4	0.5	-7%
Rail	0.4	0.5	-13%
Inland waterway / coastal shipping	0.1	0.1	-9%
Deep sea shipping	0.5	0.5	-14%
Airfreight	0.7	0.7	-9%

Table 7. Projected changes in value of goods transported by different modes

To what extent will the amount carried by rail by 2020 be influenced by the following factors? (where 0 = not at all and 4 = large extent)	**Mean (round 1)**	**Mean (round 2)**	**Reduction of standard deviation**
Reliability	3.1	3.3	-24%
Speed	2.4	2.4	-11%
Congested rail infrastructure	2.9	3.0	-18%
Flexibility	3.0	3.1	-17%
Accessibility of terminals	3.0	3.0	-17%
Cost	3.0	3.1	-15%
Bureaucracy	2.5	2.6	-9%
Additional handling involved	2.6	2.8	-10%
Commodity mix	2.1	2.2	-7%

Table 8. Factors affecting the amount of cargo carried by rail

How effective would the following Government measures be in increasing rail's share of the UK freight market? (where 0 = no effect and 4 = very effective)	**Mean (round 1)**	**Mean (round 2)**	**Reduction of standard deviation**
Upgrading rail infrastructure	3.1	3.1	-17%
Introduction of a road pricing scheme for HGVs	2.1	2.1	-1%
Expanding Freight Facilities Grant scheme	2.3	2.4	-10%
Revenue support for Channel Tunnel connections	2.2	2.3	-13%
Provision of dedicated rail freight routes	2.9	2.9	-14%
Promotion of best practice in company freight management	1.9	1.9	-9%
Planning policies for more effective co-ordination of transport modes	2.3	2.4	-9%
Higher duties on diesel fuel	2.0	2.1	-8%
Extending emissions trading scheme to freight transport	2.0	2.1	-12%
Enforcing regulations on road freight operators more rigorously	1.5	1.5	-5%
Simplifying administrative / regulatory framework for rail freight	2.2	2.3	-8%

Table 9. Efficiency of potential measures to increase rail's share of freight market

To what extent will the amount carried by coastal / short-sea shipping by 2020 be influenced by the following factors? (where 0 = not at all and 4 = large extent)	**Mean (round 1)**	**Mean (round 2)**	**Reduction of standard deviation**
Reliability	2.6	2.6	-7%
Speed	2.4	2.4	-4%
Congested port infrastructure	2.6	2.7	-7%
Flexibility	2.5	2.6	-13%
Accessibility of ports	2.6	2.7	-16%
Cost	2.8	2.9	-6%
Bureaucracy	1.9	2.0	-13%
Additional handling involved	2.3	2.4	-9%

Table 10. Factors affecting the amount of cargo carried by coastal / short-sea shipping

How effective would the following Government measures be in increasing coastal / short-sea shipping's share of the UK freight market? (where 0 = no effect and 4 = very effective)	**Mean (round 1)**	**Mean (round 2)**	**Reduction of standard deviation**
Upgrading port infrastructure	2.6	2.7	-12%
Introduction of a road pricing scheme for HGVs	1.8	1.8	-6%
Expanding Waterborne Freight Grant scheme	2.2	2.3	-15%
Promotion of best practice in company freight management	1.6	1.6	-9%
Planning policies for more effective co-ordination of transport modes	2.1	2.1	-7%
Higher duties on diesel fuel	1.7	1.8	-6%
Extending emissions trading scheme to freight transport	1.6	1.7	-8%
Enforcing regulations on road freight operators more rigorously	1.3	1.3	-1%

Table 11. Efficiency of potential measures to increase coastal / short-sea shipping's share of freight market

How are the constraints on using rail and shipping services likely to change by 2020? (where -2 = constraints significantly easing and 2 = constraints significantly tightening)	**Mean (round 1)**	**Mean (round 2)**	**Reduction of standard deviation**
Railfreight services	-0.29	-0.32	-5%
Short-sea / coastal shipping services	-0.33	-0.34	-9%

Table 12. Projected changes in the constraints on using rail and shipping services

What is the likely change in the following factors going to be between now and 2020? (where -2 = large decrease and 2 = large increase)	**Mean (round 1)**	**Mean (round 2)**	**Reduction of standard deviation**
Fuel efficiency	1.1	1.1	-16%
Carbon intensity of fuel	-0.7	-0.7	-14%

Table 13. Changes in fuel efficiency and carbon intensity of fuel

Please rate the likely importance of the following means of improving the fuel efficiency of freight transport operations by 2020 (where 0 = no importance and 4 = very important)	**Mean (round 1)**	**Mean (round 2)**	**Reduction of standard deviation**
Training schemes for fuel efficient driving	2.7	2.7	-8%
Higher fuel prices	2.4	2.6	-17%
Dissemination of best practice in fuel management	2.1	2.1	-9%
Out of hours' delivery operation	2.6	2.7	-8%
Information technology (telematics / vehicle routing software)	2.7	2.8	-8%
Vehicle design	2.8	2.9	-15%
Incentive schemes for employees	2.2	2.2	-9%
Improved vehicle maintenance	2.1	2.1	-3%
Engine performance	2.7	2.8	-8%

Table 14. Projected importance of fuel efficiency measures