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Driving forces of road freight CO_2 in 2030

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Abstract
Purpose – Road freight carbon dioxide (CO_2) emissions are determined by a complex interaction between shippers and hauliers within the boundaries set by regulations and economic factors. It is necessary to gain understanding about the various driving forces and trends affecting these to promote low carbon future. The purpose of this paper is to find out what factors affect the long-term future development of road freight CO_2 emissions and whether the long-term emission targets will be achieved.
Design/methodology/approach – An international comparison of similar Delphi surveys is carried out in Finland, Norway, and Sweden.
Findings – The Delphi surveys indicate that the structural change of the economy, changes of consumer habits, concerns of energy and environment and changes in logistics practices and technology are the overarching trends shaping the future of the energy efficiency and CO_2 emissions of road freight transport. The expert forecasts for Finland and Sweden highlight that reaching the carbon emission target of 30 per cent reduction for the year 2030 is possible. However, the CO_2 emissions may also increase significantly even though the CO_2 intensity would decrease, as the Norwegian forecast shows.
Originality/value – This study combined quantitative and qualitative analysis. The results confirmed that similar factors are seen to affect the future in all three countries, but with some national differences in the likely effects of the factors. Future research using the same methodology would enable wider analysis of the global significance of these driving forces.

Keywords Forecasting, CO_2 emissions, Delphi survey, Road freight transport
Paper type Research paper

Introduction
Road freight transport is usually considered to be a derived demand; a result of the exchange of goods within and between economies. The production of goods results in tonnes lifted and tonne-kilometres moved within the transport system. In order to fulfil the transport need, trucks need to move certain distances on the road. Making the trucks move requires energy, and the production of that energy causes emissions.

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Road freight transport is thus vital for securing social and economic welfare but also inevitably causes negative environmental impacts. In order to mitigate climate change, it is necessary to reduce greenhouse gas (GHG) emissions in all sectors of economy, including road freight transport. At the EU level, the White Paper for European Transport (COM/2011/0144) launched by the European Commission sets a target for reducing 60 per cent of transport GHG emissions from their 1990 level by 2050 and a 20 per cent reduction from their 2008 level by 2030. Despite these strategies, freight transport, and especially road freight transport, is growing in Europe, thus increasing the environmental effects (Eurostat, 2011).

Trucks are responsible for around 23 per cent of carbon dioxide (CO_2) emissions from road transport in Finland, and the share is even higher for emissions of particulate matter (PM) and nitrogen oxides (LIPASTO, 2011). In Norway, trucks were the source of around 24 per cent of the CO_2 emissions from road transport in 2010 (Statistics Norway, 2013). Swedish trucks emit approximately 28 per cent of that country's CO_2 emissions from road transport (Naturvårdsverket, 2011). In response to the European CO_2 reduction targets, the Nordic countries have set targets for reducing the emissions. Finland is aiming at 9 per cent energy savings by 2016: this is compared to the country's 2001-2005 average and the 15 per cent transport greenhouse gas (GHG) emission reduction from its 2005 level by 2020 (Motiva, 2008; MINTC, 2009). Norway, unlike EU countries, does not have specific goals regarding energy efficiency (Ukeblad, 2012). Instead, the Norwegian government's GHG abatement policy has defined an overall goal that sets out general requirements for all industries in Norway. The initial part of the goal is to not only meet the target set for the first period of the Kyoto protocol, but to surpass it by 10 per cent. The second phase of the goal is to achieve total carbon neutrality. Transport has proven to be the sector in which it is most difficult for Norway to achieve its emission targets (KLIF, 2010). In 2009, Sweden created and signed a series of national climate goals. For the country's transport sector, the baseline year is 2008, and the goals up to 2020 are: 10 per cent renewable energy, 20 per cent more energy efficiency in the sector, and 40 per cent reduction of emissions (Energimyndigheten, 2013). Furthermore, in 2030 the vehicle fleet should be fossil fuel free (Naturvårdsverket, 2013).

Framework

Driving forces of road freight demand, supply and CO_2 emissions have been retrospectively analysed in various countries. McKinnon and Woodburn (1996) presented a framework for performing such analyses, and the framework was further developed and internationally applied in the REDEFINE (1999) project. Cooper *et al.* (1998) extended this framework to include environmental effects. More recently, Kveiborg and Fosgerau (2007) performed a decomposition analysis in Denmark, and Sorrell *et al.* (2009) did so in Great Britain. Although these studies used different frameworks, they all explored the developments using "output" values found from the statistics (e.g. value of national production or weight of goods transported), and "variables", which are the ratios of the output values (e.g. value density or average length of haul). Changes in these variables have been analysed to decompose the changes in the output values, and various "determinants" or "drivers" of change (e.g. economic growth, changes in the commodity mix of freight transport or better utilisation of trucks) have been identified to explain changes in variables.

A similar framework of output values and variables is equally useful for forecasting purposes. Piecyk and McKinnon (2010) predicted the carbon footprint of road freight in

Great Britain in 2020. To do this, they used a Delphi survey to forecast selected variable values and to estimate the importance of some determinants. Their framework consisted of seven output values (weight of goods produced/consumed, weight of goods transported by road, road tonnes-lifted, road tonne-kilometres, total vehicle kilometres, fuel consumption, and CO_2 emissions) and seven key variables (modal split, handling factor, average length of haul, lading factor, empty running, fuel efficiency, and carbon intensity of fuel), with determinants consisting of six types of factors (structural, commercial, operational, functional, external, and product-related). Piecyk (2010) later added one more output and one more variable to the top of this framework: the former was the value of goods produced/consumed as an output, and the latter was value density as a key variable in determining the weight of goods produced/consumed.

The framework used in this research (Figure 1) is similar to the one Piecyk (2010) used, but some changes have been made because of differences both in available data and in the usefulness of terminology. The term "output" has been changed to "aggregate" and "key variable" to "indicator". The addition of three "key indicators" has also been made to allow future values to be analysed on a more aggregate level of

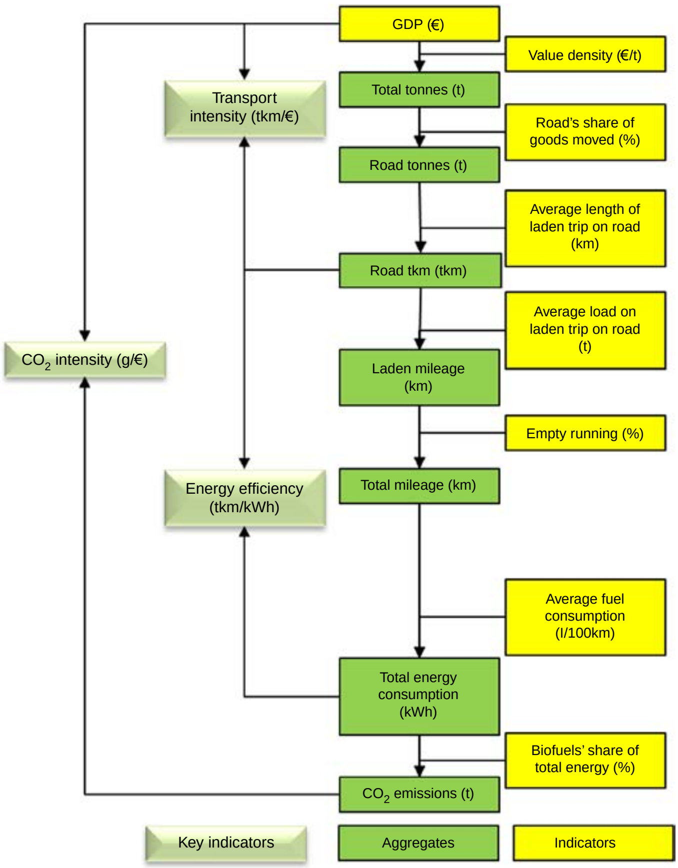


Figure 1.
Road freight decarbonisation framework

Source: Derived from Piecyk (2010)

road freight transport demand (transport intensity) and supply (energy efficiency). The "lading factor" has been replaced with "average load on laden trips" to allow the actual load to be analysed separately from the truck size. A new aggregate of "laden mileage" has been added between road tonne-kilometres and total mileage to further clarify the distinctions between laden, empty, and total mileage. The "fuel efficiency" has been changed to "average fuel consumption" as the unit l/100 km is used in the Nordic countries rather than the inverse mpg (miles per gallon) used in the UK. The "carbon intensity of fuel" has been replaced with "biofuels' share of total energy". It can be argued that the terms "fuel consumption" and "biofuels" should be replaced with "energy" and the units to be changed from l/100 km to kWh/km and from per cent to kg/kWh in order to include alternative energy sources, such as electricity. However, electricity is assumed to have a minor effect on the energy use of trucks up until 2030 and the Delphi experts may be unfamiliar with these terms and units. It is thus decided to keep the current common terms and units in the framework to enable the experts to forecast the future without specific expertise in the alternative energy and differences between tank to wheel and well to wheel emissions. Furthermore, the "handling factor" is omitted from the framework because no distinction between "weight of goods transported by road" and "road tonnes-lifted" can be made with the data available in the Nordic countries. Also, the units of the framework values have been added and "determinants" or "drivers" are referred to as "driving forces".

Liimatainen *et al.* (2014) used the same framework presented here to forecast the future of Finnish road freight transport CO_2 emissions and to explore the driving forces affecting the future. This paper uses the same method as Liimatainen *et al.* (2014) to forecast the road freight CO_2 emissions in Norway and Sweden in 2030 and combines the results with the existing original Finnish data in order to highlight national similarities and dissimilarities.

CO_2 emissions of road freight transport are the result of a series of decisions made at different stages of the supply chain (Aronsson and Huge Brodin, 2006). Opportunities to affect the decisions vary, but every indicator of the framework can be affected by the measures taken by policy makers, transport buyers, logistics service providers, and transport equipment manufacturers (Piecyk and McKinnon, 2010; FTA, 2012; IEA, 2009; Leonardi *et al.*, 2006). Hence, it is necessary to include these stakeholders in the process of forecasting the future of road freight transport CO_2 emissions. The purpose of this research is to include the effects of the stakeholders in order to answer the following research questions:

RQ1. What driving forces affect the long-term future development of road freight CO_2 emissions?

RQ2. Will the long-term road freight CO_2 emission targets be achieved as a result of these driving forces?

The first research question is justified as very few studies exist that assess the driving forces affecting the long-term future development of road freight CO_2 emissions. Previous studies mostly focus on the driving forces which have shaped the field's past development (e.g. Kveiborg and Fosgerau, 2007; Sorrell *et al.*, 2009) or present possibly influential issues without further consideration of their effects (e.g. IEA, 2009; Leonardi *et al.*, 2006). Piecyk and McKinnon (2010) assess the importance, likelihood, and direction of changes caused by some pre-defined influencing driving forces. However, this research begins its first Delphi round by asking an open question regarding the influencing driving forces and in the second round proceeds to an assessment of the driving forces identified by the experts.

The second research question is assessed in even fewer studies. Piecyk and McKinnon (2010) assess it in Great Britain, and Liimatainen *et al.* (2014) do so in Finland, but no previous international comparison, in which the same methodology is applied in various countries, exists.

Methodology

The Disaggregative Policy Delphi approach is used in this research. It is a futures studies method which, unlike traditional Delphi surveys, does not seek consensus. Rather, it contains a set of indicators and seeks open arguments that support future estimates of these indicators (Tapio, 2003; Tapio *et al.*, 2011). While the Disaggregative Policy Delphi contains the elements of the traditional Delphi, such as expertise, rounds of inquiry, feedback between rounds, and anonymity of responses (Linstone and Turoff, 1975; Adler and Ziglio, 1996), it better addresses the plurality of possible futures and views of those futures (Kuusi, 1999; Steinert, 2009).

Selection of Delphi panel

Selection of panel members is the key to a successful Delphi survey. Unlike in statistically based surveys, the Delphi experts do not have to be representatives of a larger group. What is needed, in this case, are knowledgeable persons who can give valuable ideas on the issue. Knowledgeable persons can be identified either from literature reviews or based on recommendations from other experts or institutions. Experts can also be selected by identifying stakeholders in the issue and inviting someone to represent each stakeholder in the panel. The panel size varies in number, containing from ten members to thousands, but 15-35 experts are commonly used. The first round usually involves the participation of 35-75 per cent of invited experts, and about two-thirds of these also complete the second round. This should be taken into account when considering the list of invited experts (Gordon, 2009; Tapio, 2002; Piecyk, 2010).

In this study, the stakeholders were identified and experts were invited. They represented the stakeholders identified in the literature: policy makers, transport buyers, logistics service providers, and transport equipment manufacturers as well as academics, trade associations and non-governmental organisations (NGOs) which are seen to have valuable views on the issue. The number of experts invited to participate in the Delphi survey was 135 in Finland, 25 in Norway, and 100 in Sweden. The invited experts represented all identified stakeholder groups. The invited experts were mainly identified using the existing contacts of the researchers and those of the colleagues of the researchers. An internet search of the representatives of various stakeholders was used to verify the expertise of the existing contacts and also to identify additional experts. The number of invited experts from Norway is smaller than those from Finland and Sweden because of the limited resources for research. Table I summarises the Delphi panel sizes in this study.

Table I. Numbers of invited and participating experts in the Delphi surveys

Country	Invited	1st round answers	2nd round answers	Total participants
Finland	135	24	20 (15 of which answered in 1st round)	29
Norway	25	11	7 (6 of which answered in 1st round)	12
Sweden	100	9	11 (9 of which answered in 1st round)	11

First round Delphi survey

As stated earlier, this paper reports a Nordic expansion of a national Finnish Delphi survey reported in Liimatainen *et al.* (2014). The Delphi surveys in Norway and Sweden were performed a year and a half after the Finnish survey, but all surveys use similar methodology to ensure comparability. Also, the original data from the Finnish survey is used in the analyses of this paper. In Finland, the first round was carried out in September 2011 as an e-mail survey. In total, 24 experts completed the survey in the first round, and responses were received from almost all of the invited stakeholder groups, except for the transport equipment manufacturers and NGOs. In Norway and Sweden, the first round was carried out in April 2013 as an e-mail survey. In all, 11 experts completed the survey in Norway, and all of the invited groups were represented, except for Norway's transport buyers. In Sweden, the nine participating experts represented all other stakeholders but transport equipment manufacturers.

The Delphi survey was carried out using a spreadsheet file which consisted of an introduction sheet, eight sheets on which the experts were to forecast the future values and contributing driving forces of the eight indicators, and a concluding sheet. The introduction sheet contained a description of the survey and the framework of the analysis (Figure 1). The concluding sheet showed the future values of the aggregates and key indicators of the framework based on the indicator values which the respondent gave. This gave the respondents a chance to instantly see the effects of their forecasts on the energy efficiency and carbon dioxide emissions of the road freight transport. The eight indicators which the experts were asked to forecast in the sheets were as follows:

(1) gross domestic product (GDP);

(2) value density;

(3) road's share of total tonnes transported;

(4) average length of haul on laden trips on road;

(5) average load on laden trips on road;

(6) share of empty running of total mileage;

(7) average fuel consumption; and

(8) share of biofuels of total energy.

A figure of the indicator, some possible driving forces of it, and the aggregates it affects was shown for each indicator on its sheet. Each sheet also contained a figure which showed the development of the indicator value from 1995 to 2009 in Finland, from 2000 to 2010 in Norway and Sweden, and onwards to 2030 based on the forecast value given to each indicator by the expert. In the first round, the experts were asked to answer these questions for each of eight indicators:

- What driving forces explain the historical development of the indicator?
- What is the probable value of the indicator in 2030? (Value in 2030 was determined by asking the average annual growth rate of the indicator in Norway.)
- Why will this development happen?

Second round Delphi survey

The second round was carried out in October 2011 in Finland using an e-mail survey. In total, 20 experts from that country answered in the second round. Five out of the 20 answers in the second round were from experts who had not answered in the first round; thus, there were 29 panellists in total, with a response rate of 21 per cent.

In Norway and Sweden, the second round was carried out in April 2013, at the beginning of a workshop on the future of CO_2 emissions in road freight transport. The workshop participants were given printed surveys to fill out by themselves before the workshop began. In Norway, seven experts answered in the second round. One of the seven answers in the second round was from an expert who had not answered in the first round; thus, there were 12 panellists in total, with a response rate of 48 per cent. In Sweden, the total number of participants was 11 as nine experts completed the survey in both rounds and an additional two completed the second round at the workshop. The response rate was 11 per cent.

In the second round, each respondent was shown both the median value of the first round 2030 forecast for each indicator as well as the respondent's own estimates, if he had answered in the first round. All the estimates from the first round were also shown in the figure of the indicator's development, enabling the respondents to see the dispersion of the estimates together with both the median value and their own estimate.

The respondents were also given a list of statements about the driving forces that could affect the future development of the indicator. These statements were formed based on the reasons for the future developments that the respondents gave in the first round. In the second round, the respondents were asked to answer the following questions for each of the eight indicators:

- What is the probable value of the indicator in 2030? (Value in 2030 was determined by asking the average annual growth rate of the indicator in Norway.)
- Will the given driving force affect the development of the indicator? ($-2 =$ totally disagree … $+2 =$ totally agree.)
- How will the given driving force change the development of the indicator? (Because of the driving force, the value of the indicator will $-2 =$ decrease a lot … $+2 =$ increase a lot.)

In Sweden, only the first question was answered. The other two were openly discussed in the workshop but not quantified. This is because of the limited resources in Sweden, which prevented the researcher from analysing the open responses from the first round in order to form the statements for second round. This prevents statistical analysis of results between countries, but still enables a qualitative analysis.

Data analysis

The data analysis consisted of three main phases. The results of each phase are presented in Sections 4.1-4.3, respectively. An overview of the analysis process and its relations to the framework is presented in Figure 2.

The answers given from all countries as reasons for the changes of each of the eight indicators were translated into English and combined. An analysis of the driving forces of change was carried out based on these. The driving forces which were mentioned in at least two out of the three countries were included in this analysis. The actual wordings of the driving forces may have varied by country, but similar issues were easily identified. Finnish and Norwegian data included the median values of the expert

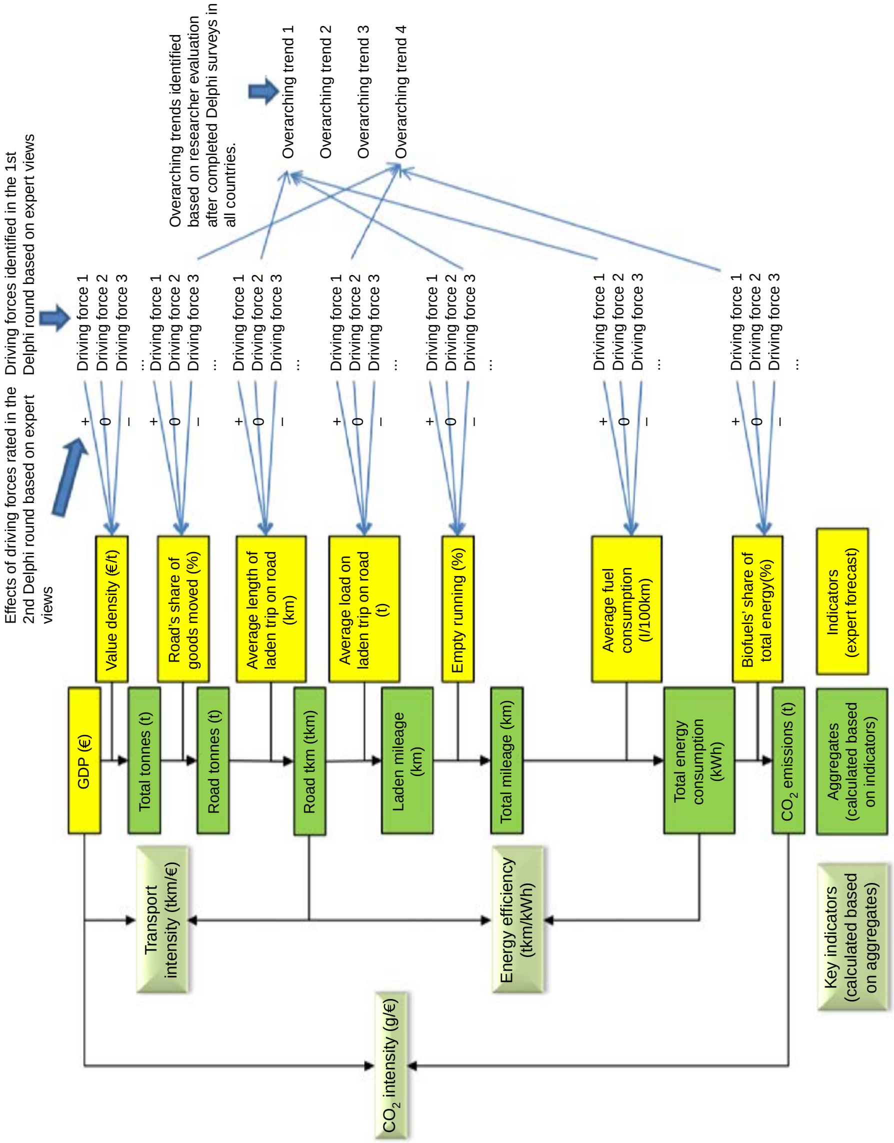
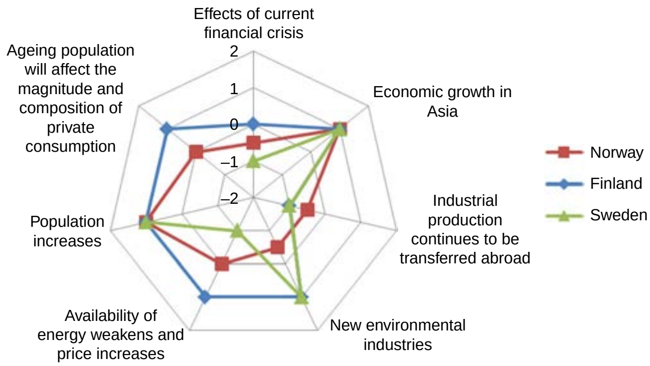


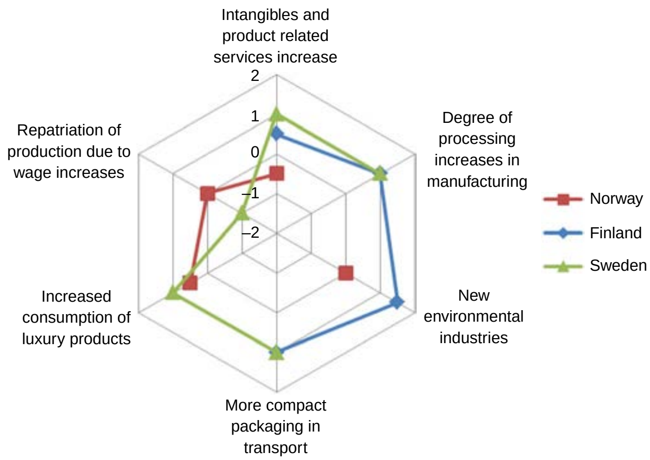
Figure 2.
Data analysis process and its relations to the framework

agreement on the driving forces (−2 = totally disagree … +2 = totally agree) and the direction of indicator change because of the driving force (because of the driving force, the value of the indicator will −2 = decrease a lot … +2 = increase a lot). This quantitative data enables quantitative analysis for Finland and Norway. However, the Swedish results were the written notes from the discussions about these aspects, so qualitative analysis performed to give the driving forces a numerical value of the direction of change (due to the driving force the indicator −1 = decreases, 0 = small or ambivalent effect, +1 = increases) to enable comparison between all three countries. The results of this analysis for each separate indicator are presented in Figures 3-10



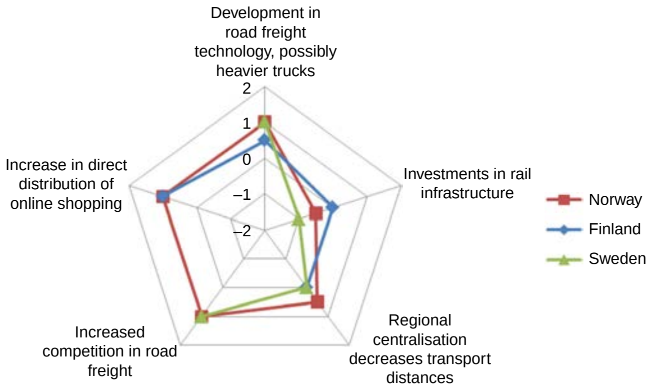
Notes: Due to the driving force, the indicator does one of the following: +2=increases a lot, +1=increases, 0=small or ambivalent effect, –1=decreases, –2=decreases a lot, empty=driving force was not mentioned

Figure 3.
Expert views on the effects of driving forces affecting GDP



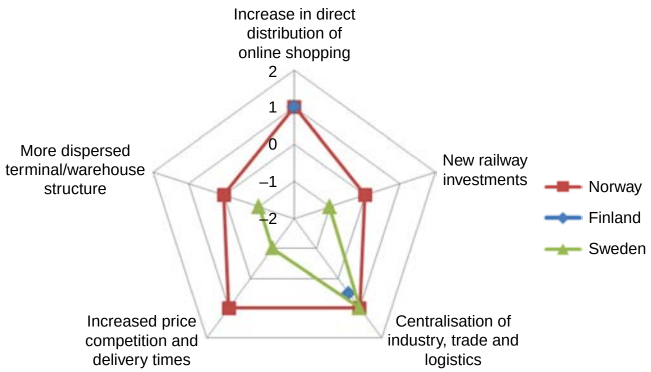
Notes: Due to the driving force, the indicator reacts in one of the following ways: +2=increases a lot, +1=increases, 0=small or ambivalent effect, –1=decreases, –2=decreases a lot, empty=driving force was not mentioned

Figure 4.
Expert views on the effects of driving forces affecting value density



Notes: Due to the driving force, the indicator does one of the following: +2=increases a lot, +1=increases, 0=small or ambivalent effect, –1=decreases, –2=decreases a lot, empty=driving force was not mentioned

Figure 5.
Expert views on the effects of driving forces affecting modal split

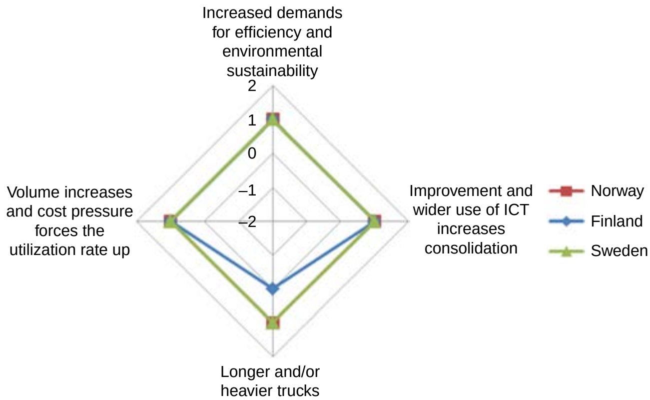


Notes: Due to the driving force, the indicator does one of the following: +2=increases a lot, +1=increases, 0=small or ambivalent effect, –1=decreases, –2=decreases a lot, empty=driving force was not mentioned

Figure 6.
Expert views on the effects of driving forces affecting average length of haul

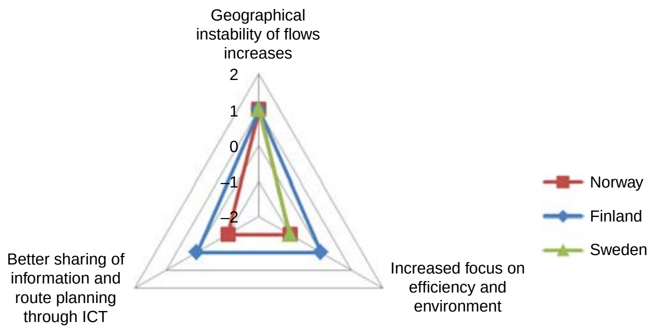
where the median values for Finland and Norway are presented with the qualitative estimate of the Swedish value.

Similar driving forces were cited as being likely to affect more than one indicator. Hence, an opportunity was perceived to identify overarching trends shaping the future of road freight CO_2 emissions. To do this, all of the driving forces included in the analysis were combined into a single table, with driving forces of similar types grouped together (Table II). The grouping was done subjectively based on the elaboration of the researchers. Four overarching trends were thus identified and named. The driving forces belonging to each overarching trend and their effect on the indicators are presented in Figures 11-14.



Notes: Due to the driving force, the indicator does one of the following: +2=increases a lot, +1=increases, 0=small or ambivalent effect, –1=decreases, –2=decreases a lot, empty=driving force was not mentioned

Figure 7.
Expert views on the effects of driving forces affecting average load on laden trips



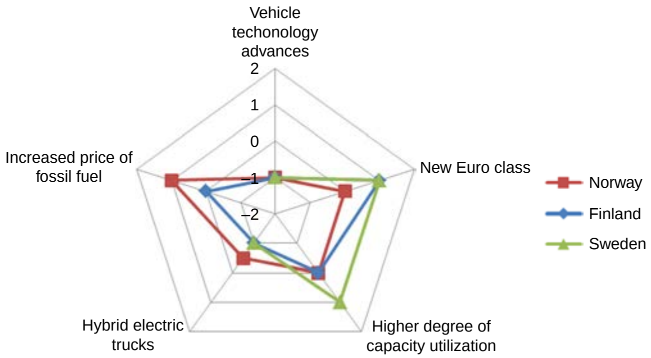
Notes: Due to the driving force, the indicator does one of the following: +2=increases a lot, +1=increases, 0=small or ambivalent effect, –1=decreases, –2=decreases a lot, empty=driving force was not mentioned

Figure 8.
Expert views on the effects of driving forces affecting empty running

Finally, the median of the forecasted 2030 values for each indicator was calculated after the second Delphi round and used to calculate the aggregate and key indicator forecasts in each country. The framework can be expressed as an equation:

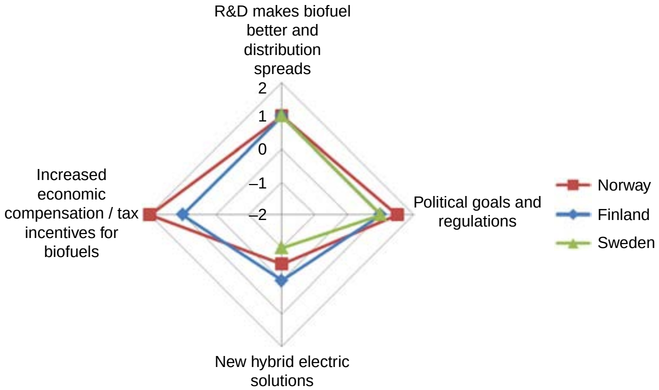
$$
\begin{aligned}
CO_2\ \text{emissions} = {} & \text{GDP/value density} \times \text{modal split} \times \text{avg. length/avg.load} \\
& \times (1 + 2.3053 \times \text{empty running}\verb|^|1.3971) \times (\text{avg.fuel consumption} \times 100) \\
& \times \left((2.66 \times (1 - (\text{biofuels' share of total energy} \times 0.35)))/10{,}000\right)
\end{aligned}
$$

Each aggregate value is calculated as one operation is completed in the equation (e.g. GDP/value density = total tonnes). The indicator "empty running" is given as



Notes: Due to the driving force, the indicator does one of the following: +2=increases a lot, +1=increases, 0=small or ambivalent effect, –1=decreases, –2=decreases a lot, empty=driving force was not mentioned

Figure 9.
Expert views on the effects of driving forces affecting average fuel consumption



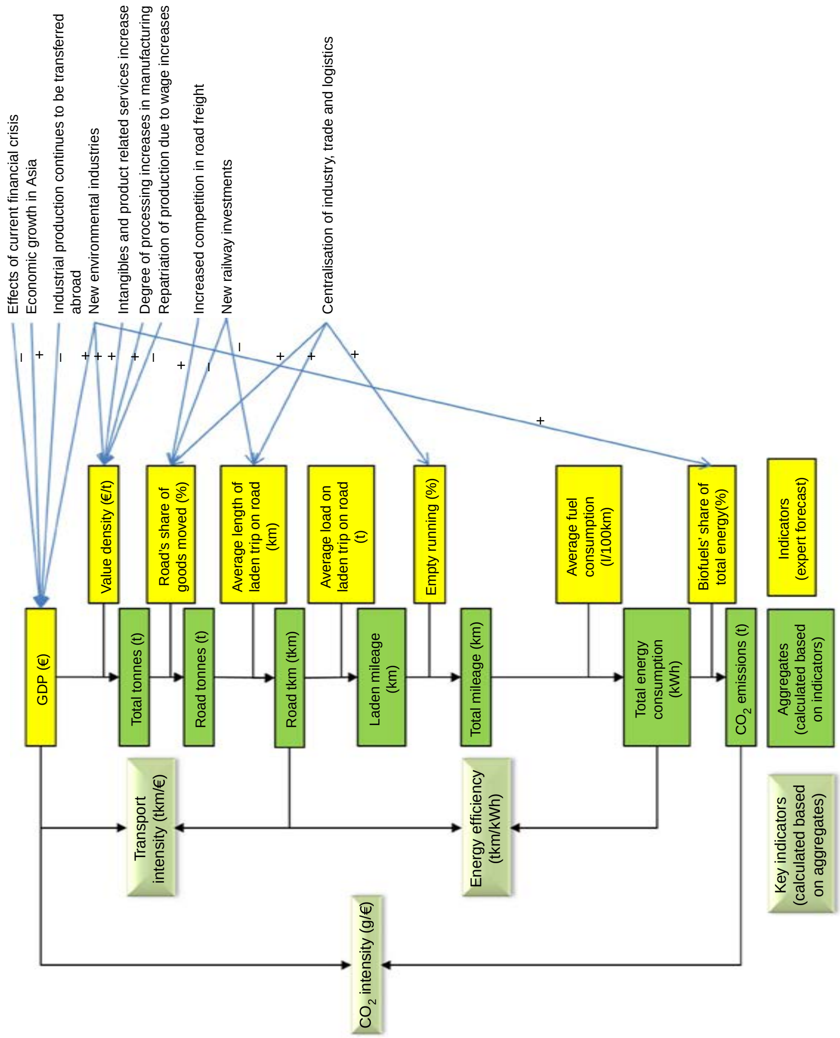
Notes: Due to the driving force, the indicator does one of the following: +2=increases a lot, +1=increases, 0=small or ambivalent effect, –1=decreases, –2=decreases a lot, empty=driving force was not mentioned

Figure 10.
Expert views on the effects of driving forces affecting the use of biofuels

per cent of total mileage by the experts while in the equation the total mileage is calculated based on laden mileage. Hence the equation $2.3053 \times$ empty running^1.3971 is required to convert the share of total mileage to the share of laden mileage. This equation has been derived from the historical data. The diesel consumption is converted to the energy consumption by using the energy content of diesel, which is 10.1 kWh/liter (LIPASTO, 2009). Furthermore, diesel has a fixed CO_2 content of 2.66 kg/l (LIPASTO, 2009). Biofuels are calculated to decrease the CO_2 content of diesel by 35 per cent following the definition of the EU Directive 2009/30/EC (2009). The results of the calculation (i.e. the forecasted values of indicators, aggregates, and key indicators) are presented in Table III.

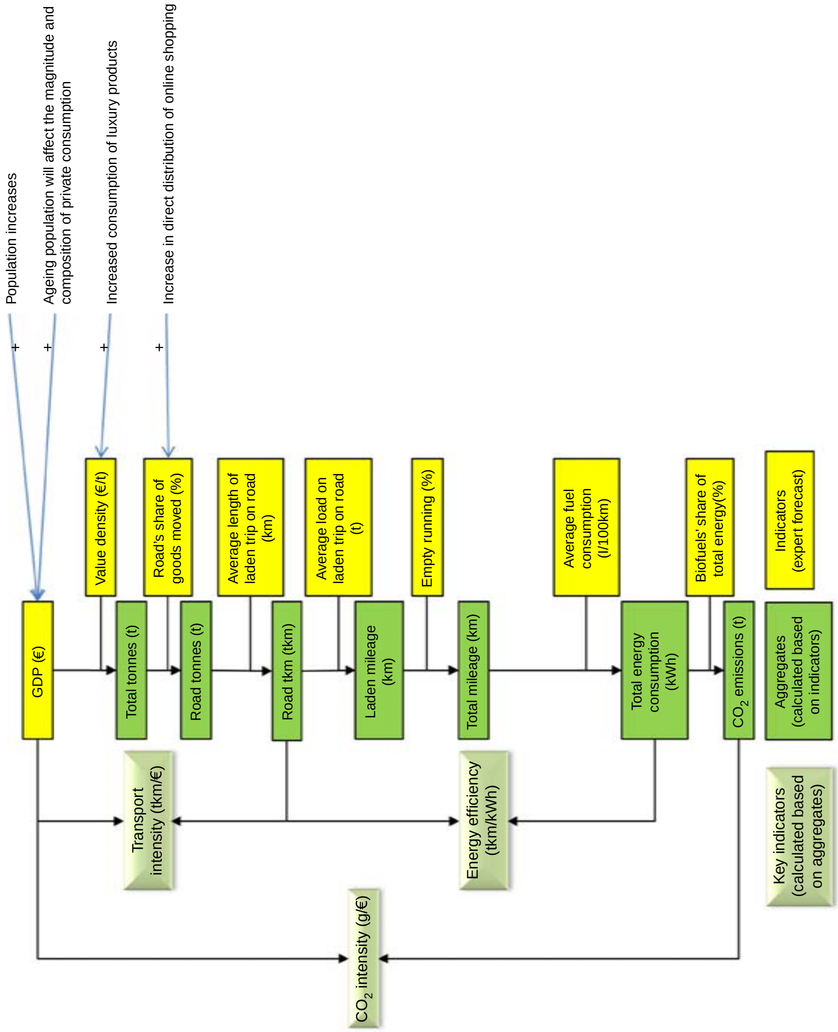
Table II. Grouping of driving forces into overarching trends

	GDP	Value density	Modal split	Avg. length	Avg. load	Empty running	Fuel consumption	Biofuels
Structural change of the economy	Effects of current financial crisis Economic growth in Asia Industrial production continues to be transferred abroad New environmental industries	Intangibles and product related services increase Degree of processing increases in manufacturing New environmental industries Repatriation of production due to wage increases	Regional centralisation decreases transport distances Investments in rail infrastructure Increased competition in road freight	Centralisation of industry, trade and logistics New railway investments		Geographical instability of flows increases		R&D makes biofuel better and distribution spreads
Changes of consumer habits	Population increases Ageing population will affect the magnitude and composition of private consumption	Increased consumption of luxury products	Increase in direct distribution of online shopping	Increase in direct distribution of online shopping				
Concerns of energy and environment	Availability of energy weakens and price increases				Increased demands for efficiency and environmental sustainability	Increased focus on efficiency and environment	Increased price of fossil fuel	Policy goals and regulations Increased economic compensation/tax incentives for biofuels
Changes in logistics practices and technology		More efficient logistics	Development in road freight technology, possibly heavier trucks	Increased competition with price and delivery time More dispersed terminal/warehouse structure	Volume increases and cost pressure forces the utilisation rate up Improvement and wider use of ICT increases consolidation Longer and/or heavier trucks	Better sharing of information and route planning through ICT	Vehicle technology advances New Euro class Higher degree of capacity utilisation Hybrid electric trucks	New hybrid and full electric solutions



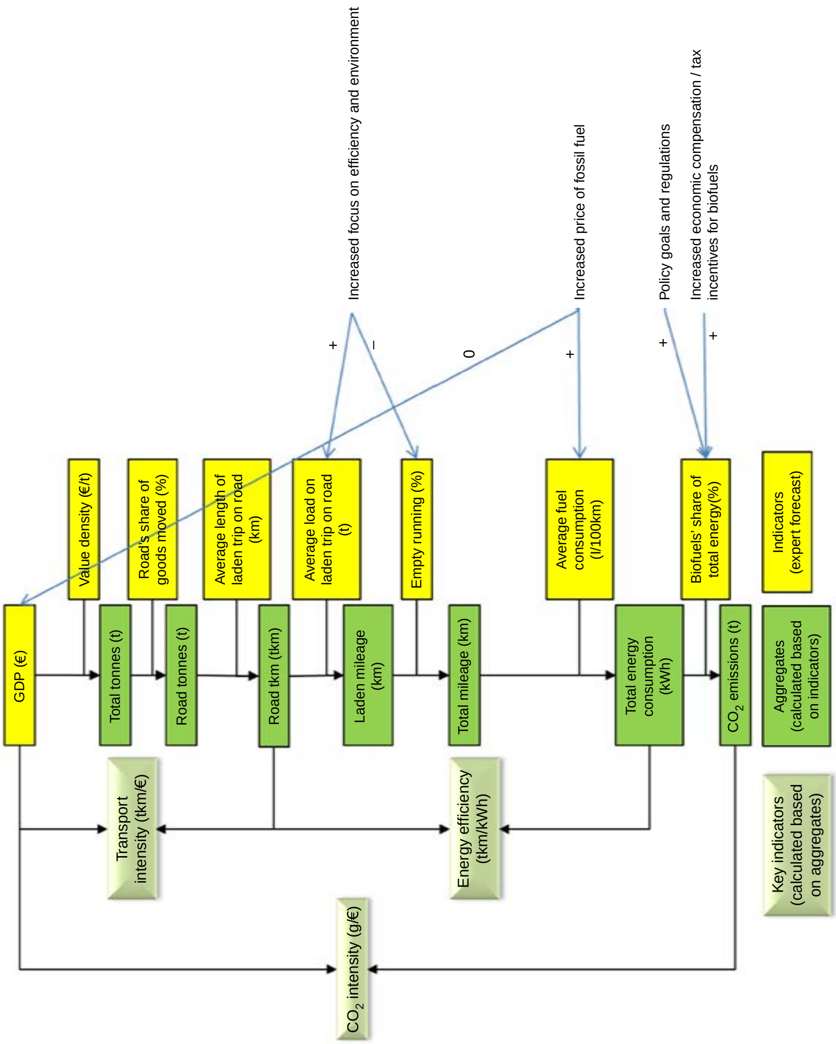
Notes: +, driving force increases the indicator value; 0, small or ambivalent effect; –, driving force decreases the indicator value

Figure 11.
Driving forces affecting the indicators within the overarching trend of structural change of the economy



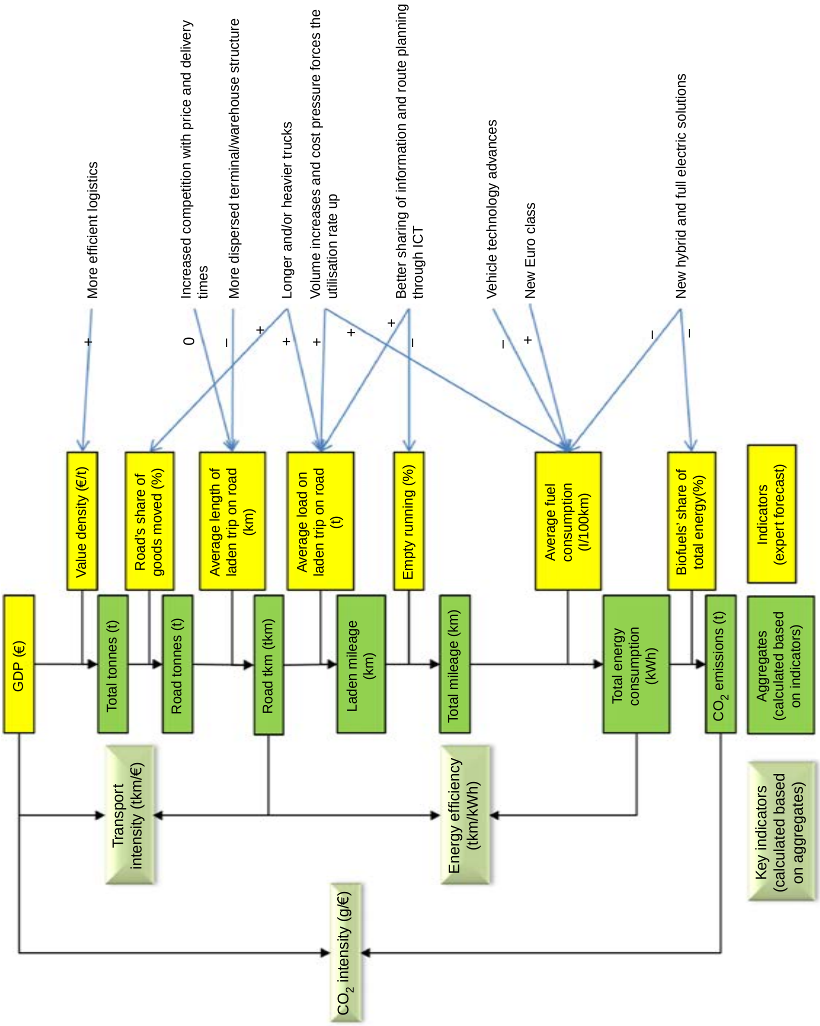
Notes: +, driving force increases the indicator value; 0, small or ambivalent effect; –, driving force decreases the indicator value

Figure 12.
Driving forces affecting the indicators within the overarching trend of changes of consumer habits



Notes: +, driving force increases the indicator value; 0, small or ambivalent effect; –, driving force decreases the indicator value

Figure 13.
Driving forces affecting the indicators within the overarching trend of concerns about energy and the environment



Notes: +, driving force increases the indicator value; 0, small or ambivalent effect; –, driving force decreases the indicator value

Figure 14.
Driving forces affecting the indicators within the overarching trend of changes in logistics practices and technology

	Finland		Norway		Sweden	
	2010	2030	2010	2030	2010	2030
GDP (billion €)	142	200	179	259	283	330
Value density (€/*t*)	323	480	563	897	767	900
Total goods moved (million *t*)	441	417	318	289	369	367
Road's share of goods moved (% of total)	90	88	88	92	86	80
Goods moved by road (million *t*)	397	367	261	266	316	293
Average length of haul (km)	59	62	62	96	82	85
Total haulage (billion *t* km)	26	25.2	17.2	25.6	32.7	27.7
Average load on laden trips (*t*)	13.9	14.5	12.8	13.7	12.9	15
Mileage on laden trips (billion km)	1.69	1.57	1.37	1.87	2.01	1.66
Empty running (% of total mileage)	27	21	27	27	19	17
Total mileage (billion km)	2.32	1.97	1.76	2.57	2.48	1.98
Average fuel consumption (l/100km)	35.7	32.1	32.3	30.1	34.4	30
Total energy consumption (GWh)	8,378	6,380	5,732	7,807	8,614	6,013
Biofuels' share of total energy (%)	0	20	5	10	0	15
Total CO_2 emissions (million *t*)	2.21	1.57	1.57	1.98	2.27	1.51
CO_2 intensity (g/€)	15.5	7.9	8.7	7.6	8	4.6
Transport intensity (*t* km/€)	0.18	0.12	0.09	0.1	0.12	0.08
Energy efficiency (*t* km/kWh)	3.1	3.96	3	3.28	3.8	4.6

Table III. Future forecasts based on Delphi surveys in Finland, Norway, and Sweden

Results

Driving forces

Kveiborg and Fosgerau (2007) concluded that growth in economic activity was the primary reason for growth in Danish freight transport until late 1990s. However, Sorrell *et al.* (2009) showed that the decoupling of road freight energy consumption from GDP in the UK from 1989-2004 was mainly due to the decline in domestic manufacturing. Piecyk and McKinnon (2010) report that British experts expect the relocation of production to continue until 2020. The Nordic experts share this view of the future. The GDP decreased from 2008 levels in Nordic countries due to the global financial crisis, and the experts think that the crisis will still affect the GDP in the future (Figure 3). Because of this, the GDP is forecasted to grow more slowly than before. The experts in Finland and Sweden agree that climate change and new, energy-related industries support the economic growth, but Norwegian experts point out that these may shrink the oil and gas industry of Norway. The population is increasing and ageing, which is expected to change private consumption. Energy prices are forecasted to grow, which may slow down economic growth. Though it may make industrial production in Asia less attractive and cause repatriation of industrial production, the major trend continues to be the transfer of industrial production abroad, which decreases GDP.

The experts forecast the value density to continue its growth in all Nordic countries; thus, they share the view of the British experts (Piecyk and McKinnon, 2010). This historical development, highlighted also by Kveiborg and Fosgerau (2007) and Sorrell *et al.* (2009), is expected to continue because of a shift from producing heavy investment and intermediate goods to producing valuable consumer goods and services (Figure 4). As a result, the degree of processing is expected to increase. In the long term, labour costs in Asia are expected to increase, causing the repatriation of industrial production to Nordic countries. This may decrease value density. Also, the efficiency of logistics was found to have increased, and this development is expected to continue in the future. The increasing efficiency of logistics mainly means, in this context, that the goods are handled fewer times than before in the supply chain and that the packaging becomes more efficient. The value density is expected to increase as a result.

The experts expect modal split to slightly change in Nordic countries. In 2030, the share of overall freight made up by road freight is forecasted to have decreased by 2 percentage points in Finland, increased by 2 percentage points in Norway, and decrease by 6 percentage points in Sweden. The experts said that because the modal split has been established for a long time, major changes are difficult to realise. This view can be historically justified, as Sorrell *et al.* (2009) showed a very small contribution of modal shift to decoupling in the UK. Rail or water transports are used when there is sufficiently strong and regular flow of goods. Expansion of rail infrastructure would be needed to increase the share of rail freight, but the experts do not think that expansive new rail connections will be built (Figure 5). An increase in direct customer deliveries due to online shopping is expected to potentially increase road's share. The road freight sector is also forecasted to become more competitive and technologically advanced, which is expected to decrease costs compared to other modes and may increase road's share of transported tonnes. Longer and/or heavier trucks, if allowed, may also increase road's share. Furthermore, implementation of strict SO_x emission limits may increase the costs of coastal shipping and move freight to road, especially in Norway where coastal transport initially consists of a major share of domestic transport performance in comparison to Finland and Sweden.

The SO_x regulations for short sea shipping are also expected to affect the average length of haul, which is forecasted to slightly increase by 2030 in Finland and Sweden but significantly increase in Norway. In addition to the effects of SO_x regulation, this change in Norway is expected to be due to reduction in shipment sizes, which is expected to cause a higher frequency of shipments, an increased need for consolidation in terminals, and an increase in the transfer from rail and sea to road transport. Centralisation of industry, trade, and logistics is the major cause for the increasing average length as companies aim to serve the countries from only a few central distribution centres (Figure 6). Historical evidence of this has been seen in Denmark (Kveiborg and Fosgerau, 2007), but in the UK there has been only a slight change in length of haul (Sorrell *et al.*, 2009). However, centralisation and consolidation development is expected to affect the UK logistics system in the future (Piecyk and McKinnon, 2010). Growth in international cross-deliveries of intermediate goods and subcomponents, followed by a specialised industry, also lengthens the transport distances. The limited maximum axle weight on certain railway lines causes loss of the market share of train transport, but investments in rail infrastructure may contribute to a decrease in the average transport distance of trucks if long distance freight is moved to rail. Online retailing was ranked as the most important commercial driving force affecting road freight demand by the British experts (Piecyk and McKinnon, 2010) and is also identified as a driving force of longer hauls by Nordic experts.

Kveiborg and Fosgerau (2007) found that both the increased use of larger trucks and their better utilisation have contributed to decoupling, while Sorrell *et al.* (2009) reported the opposite effect: there have been reductions in the average load. The Nordic panellists in all three countries forecast a moderate increase in average load by 2030. Pressure for lower transport costs from transport customers contributes both to frequent deliveries and to demands on delivery time and precision, but this also affects the shipment size (Figure 7). These requirements from the customer may affect the haulers' ability to utilise the cargo capacity efficiently. Over the long term, the importance of last-mile-distribution is growing because of an increase in home delivery and may result in smaller shipment sizes. However, these trends are counteracted by increasing transport costs and by environmental pressure, which forces companies to cooperate and consolidate loads. The improvement and wider use of information and communication technology (ICT) is expected to enable the consolidation. Longer and heavier trucks may also be allowed, which is expected to enable larger loads in bulk goods transport. These driving forces were also identified by UK experts (Piecyk and McKinnon, 2010).

Both Kveiborg and Fosgerau (2007) and Sorrell *et al.* (2009) report reduction in empty running as a significant contributing driving force in the historical decoupling of road freight energy consumption from GDP. Nordic experts forecast empty running to continue decreasing in the future in Finland and Sweden, while Norwegian experts forecast the empty running to remain at current levels. The panellists stated that reducing empty running has been necessary in order to maintain competitiveness in the road freight sector. Control over the haulage has also transferred to large LSPs, retailers, or manufacturers, which have better tools and greater ability to arrange the hauls efficiently. Also, the economic shift from the sectors with large shares of structural empty running (e.g. the forest industry) to sectors with smaller shares (e.g. the technology industry) account for the decrease in empty running (Figure 8). Tightening customer demands and the geographical instability of goods flows are expected to increase the empty running. The experts do not believe that empty running will be regulated directly in the future; nevertheless, an increased focus on efficiency and the environment can be seen in customer demands. ICT is seen by both Nordic and British experts as a way to reduce empty running (Piecyk and McKinnon, 2010).

Average fuel consumption is expected to decrease in the future, and the decrease is expected to be faster than in the past. Historically, the focus of heavy vehicle development has been on meeting the tightening EURO emission standards for nitrogen oxide (NO_x) and PM emissions (Kveiborg and Fosgerau, 2007), but some improvement in fuel economy has also been seen (Sorrell *et al.*, 2009). The decrease in the average fuel consumption in the past was thought to be mostly due to the development of vehicle technology. Environmental pressure and rising costs also force the companies to focus on eco-driving. The same driving forces are expected to continue to have effects in the future (Figure 9). In the future, the increasing average size of loads is not expected to have a significant effect on fuel consumption. Hybrid electric vehicles are seen to become significant in urban distribution. New local emissions regulations (NO_x, PM), on the other hand, are expected to have an effect on the average fuel consumption. EU regulation on the maximum CO_2 emissions for trucks may also be introduced following the examples of Japan and USA.

Neither Kveiborg and Fosgerau (2007) nor Sorrell *et al.* (2009) saw alternative fuels as having an effect on decoupling in their countries. Renewable energy, such as biodiesel, has only become widely available during the last few years, but Nordic experts forecast them to be much more significant in the future. Also, the British experts forecasted alternative fuels to have a positive impact on road freight CO_2 in the future (Piecyk and McKinnon, 2010). The experts said that the markets for biofuels have only developed recently as research and development have made them a viable option. The development has been strongly driven by EU transport and energy policy. Research and development of biofuels and their distribution networks are forecasted to increase the use of biofuels in the future (Figure 10). The EU policy and regulations are also expected to continue having an effect. Rising costs of fossil fuels and tax incentives for biofuels are also believed to promote wider use of biofuels. In the long term, there may also be "freight trolleys" (i.e. highways with overhead electrification to enable full electric road freight transport), which may decrease the share of biofuels.

Overarching trends

Based on the views of the experts, there were many identical or similar driving forces affecting the development of the indicators reported above. Hence, these driving forces can be grouped into four overarching trends to identify the major driving forces shaping the future of road freight CO_2 emissions (Table II):

- structural change of the economy;
- changes of consumer habits;
- concerns of energy and environment; and
- changes in logistics practices and technology.

Each overarching trend consists of many driving forces which have conflicting effects on the development of indicators in the future (Figures 11-14). For example, the overarching trend of structural change of the economy consists of four driving forces affecting the GDP, two of which are expected to increase the GDP and two of which are expected to decrease the GDP (Figure 11).

Structural change of the economy. The overarching structural change of the economy is forecasted to be the transfer of heavy export industry away from Nordic countries (Figure 11). The remaining industries are expected to renew and increase their degree of processing. Environmental industries, on the other hand, are seen to grow, as are the service sectors. The economic growth in Asia is expected to benefit the Nordic economies, but the European financial crisis will restrain the economic growth. These changes will have an effect on all indicators except average load and average fuel consumption. This overarching trend is expected to have a minor increasing effect on the GDP, but a major increasing effect on the value density. Structural change alters the modal split so that the share of road transport increases slightly. Average length of hauls is also expected to increase due to this overarching trend. Biofuels are also expected to be used more as the environmental industries increase. The centralisation of industry, trade, and logistics to a few large metropolitan areas in each country is expected to lead to a regional imbalance of goods flows and an increase in empty running.

Changes of consumer habits. Changes of consumer habits are caused by the growing and ageing population and the increasing variety of goods and services available online (Figure 12). Due to these changes, logistics is expected to shift more and more towards distribution of small shipments directly to the consumers, which is expected to increase the share of road freight compared to other modes. Changes of consumer habits are forecasted to increase the GDP and value density as there will be a larger and ageing pool of consumers that can spend money on luxury products and services rather than necessities.

Concerns of energy and environment. Concerns of energy and environment are forecasted to affect other indicators but value density, modal split, and average length of haul (Figure 13). An important driving force in this overarching trend is the decrease in the availability, and increase in the price, of fossil fuels. Another driving force is the growing awareness about the environmental issues and the related policy objectives (e.g. to promote biofuels). Concerns of energy and environment are expected to affect the GDP, but the effect will not be a decrease because of increasing costs but rather an increase due to new opportunities for environmental business. The average load on laden trips is forecasted to increase and empty running to decrease because of the increasing demands for efficiency and environmental sustainability. Increased price of fossil fuels is also expected to have a decreasing effect on the average fuel consumption as it makes energy efficiency investments financially viable. Utilisation of biofuels is also seen to increase due to strong policy objectives and measures such as tax reductions.

Changes in logistics practices and technology. The efficiency of road freight transport is expected to increase because of developments in vehicle technology and related ICT, but also because of changes in the operational methods of logistics service providers (Figure 14). Cooperation between the companies is particularly expected to increase and improve efficiency. This is expected to lead to increasing value density, possibly increasing the share of road transport and decreasing the length of hauls. Technological advances and cooperative practices also result in increasing average loads, reducing empty running and decreasing average fuel consumption. Hybrid or full electric vehicle technology decreases the fuel consumption of trucks and may decrease the need for biofuels, although hybrid and electric vehicles are primarily relevant for city distribution and therefore will have a relatively limited effect on national fuel consumption.

Forecasted values

As a result of the driving forces described above, the experts forecasted the indicator values for 2030. These values and the resulting aggregate and key indicator values are presented in Table III. The main difference between the countries is that for Norway, there is expected to be large growth in the average length of haul and increased market share for trucks. These result in a significant increase in total haulage and also transport intensity in Norway, while these are forecasted to decrease in Finland and Sweden.

Energy efficiency is forecasted to increase in all countries, but there is more optimistic expectation about reduction of empty running and average fuel consumption in Sweden and Finland than in Norway. There is also less optimistic expectation about biofuels' share in Norway compared to Finland and Sweden.

As a result of these changes, the total CO_2 emissions are forecasted to grow by 26 per cent in Norway and decrease by 29 and 33 per cent in Finland and Sweden, respectively. These emission changes are expected even though the GDP is expected to grow by 40 per cent in Finland, 45 per cent in Norway and 17 per cent in Sweden. Hence, the experts in all countries expect a decoupling of road freight CO_2 emissions from the GDP. The decoupling can be measured using the road freight transport CO_2 intensity (grams of CO_2/€) which is thus forecasted to decrease by 49 per cent in Finland, 13 per cent in Norway, and 43 per cent in Sweden.

Piecyk and McKinnon (2010) forecast a 10 per cent decrease in UK road freight CO_2 emissions by 2020. Finnish and Swedish experts, thus, have a more optimistic view on the potential reduction. However, Finnish and Swedish experts forecast a reduction in road tonne-kilometres while the British forecast a significant increase. The energy efficiency of UK road freight was about 3.46 *t* km/kWh in 2007 and was forecasted to increase to 4.60 by 2020 (calculation based on Piecyk and McKinnon, 2010). Hence, the UK forecast relies more heavily on rapid improvement of energy efficiency through changes in logistical practices and technology than do the Nordic forecasts.

Conclusions

This study aimed to answer two research questions:

RQ1. What driving forces affect the long-term future development of road freight CO_2 emissions?

RQ2. Will the long-term road freight CO_2 emission targets be achieved as a result of these driving forces?

The results of the Delphi surveys indicate that the structural change of the economy, changes of consumer habits, concerns of energy and environment, and changes in logistics practices and technology are the overarching trends shaping the future of the energy efficiency and carbon dioxide emissions of road freight transport. These overarching trends include several driving forces which may have conflicting effects on the indicators, but generally the experts expect a clear change towards more sustainable road freight transport in the future. This change is mostly driven by a growth in services and an increase in the degree of processing in manufacturing sectors. In addition to these economic changes, the experts expect technological advances of trucks and ICT, leading to better utilisation of vehicles.

The expert forecasts for Finland and Sweden highlight that reaching the carbon emission target of 30 per cent reduction for the year 2030 is possible. However, the CO_2 emissions may also increase significantly even though the CO_2 intensity would decrease, as the Norwegian forecast shows. The analysis highlighted that the energy efficiency and CO_2 emissions of road freight transport are the result of a complex chain of decisions and several affecting driving forces; hence, all the indicators, aggregates, and key indicators of the decarbonisation framework should be used when assessing the future. The Norwegian forecast highlights that road freight transport is derived demand, i.e. the demand of road freight transport depends on both the volume of GDP and the composition of it between various sectors of the economy. The importance of the structure of the economy is also highlighted by the fact that the Delphi experts identified the greatest number of driving forces belonging to this overarching trend.

This study has various implications for road freight shippers and hauliers. The experts forecast that the concerns of energy and environment are expected to lead to changes in logistics practices and technological development. Increased demand for environmental sustainability is anticipated by logistics experts. This may suggest a positive response from the logistics industry to new environmental policies and regulation by society; it is also a sign of further environmental goals and demands from the shippers. Hence, environmentally advanced hauliers may gain competitive advantage in the future. The experts also forecast that the price of fossil fuels will increase, which would further increase the significance of energy efficient operations and optimum utilisation of vehicles. Fuel prices may also make biofuels and other alternative energy sources financially viable. Hence, hauliers should familiarise themselves with new vehicle technologies in order to be able to implement them. Expected increase in online retailing may have a considerable effect on the logistics operations and efficient management of increasing numbers of small direct shipments to consumers requires collaboration between shippers and hauliers. Real-time exchange of information through ICT systems should be implemented to enable such collaboration. Implementing such systems require a high level of trust between shippers and hauliers.

The research helps policy makers in planning future transport policy as it gives an increased understanding of how the changes in one indicator affect the total

CO_2 emissions. In the three Nordic countries the study highlighted several trends which affect the future development of the emissions. This enables the policy makers to find measures affecting these trends and to focus on the indicators which will provide the greatest benefits. The experts estimated that the vehicle technology will decrease the fuel consumption of trucks, but this development may be hindered if new EURO emission standard are applied. Allowing longer and heavier trucks is also expected to improve energy efficiency. The Nordic logistics experts expect policy makers to drive wider utilisation of alternative fuels through regulation and tax incentives. The study also reveals which measures are likely to have a limited effect on future development. For example, the potential for modal shift from road to rail is seen to be rather small, even if investments in new rail infrastructure are made. This observation questions the applicability of the EU targets for significant modal shift of medium distance freight transport from road to rail and waterways, set in the White paper for European transport in 2011.

This study combined quantitative and qualitative analysis to better understand the past development and the trends shaping the future. Qualitative analysis combined with the quantitative framework was very useful, as it made it possible to have driving forces not available as statistical data analysed with the help of expert views. The results confirmed that similar driving forces are seen to affect the future in all three countries, but with some national differences in the likely effects of the driving forces. The Nordic expert views on the driving forces of the future of road freight transport are generally very similar to the historical development and future forecasts of other European countries. Future research using the same methodology would enable wider analysis of the global significance of these driving forces.

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