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Future of Energy Efficiency and Carbon Dioxide Emissions of Finnish Road Freight Transport

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Future of Energy Efficiency and Carbon Dioxide Emissions of Finnish Road Freight Transport

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Abstract

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The targets to reduce the carbon dioxide emissions to mitigate climate change are as much applicable to the road freight transport sector as they are to all other sectors of society. The aim of this research is to support the initiatives of the Finnish government for improving the energy efficiency and reducing the CO_2 emissions of road freight transport. This is done by forecasting the future development and giving the policy makers guidance on effective measures for promoting road freight energy efficiency and CO_2 reduction.

In the study a new method was introduced for connecting the fuel consumption data and goods transport data gathered from the official Finnish road statistics. This method enabled a detailed analysis of the interrelations between the economy, road freight transport, energy consumption and emissions. This analysis was conducted for the years 1995–2010 and the results were used as background information in the Delphi panel of experts. The experts estimated the development of the Finnish road freight sector to the year 2030. Furthermore, a web-based survey was conducted among Finnish road freight hauliers and shippers in order to explore the attitudes and measures related to the energy efficiency. Expert panel workshops were also organised to identify obstacles for the development of the energy efficiency of road freight transport as well as a wide selection of measures to overcome them.

The results indicate that the economic development of different branches has a great effect on the energy efficiency and carbon dioxide emissions of road freight transport. Reaching the carbon emission target for the year 2030 is possible in the light of the scenarios which were formed based on expert forecasts. However, the target can be achieved with very different development paths, e.g. the structure of the national economy and the volume of transport seem to vary widely in the different scenarios. In the proposed recommendations on the measures for achieving the targets, cooperation and division of responsibilities between various stakeholders of the road freight sector are emphasized.

Tiivistelmä

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Tiekuljetusalalta vaaditaan muiden yhteiskunnan sektoreiden tapaan hiilidioksidipäästöjen vähentämistä ilmastonmuutoksen hillitsemiseksi. Tämän tutkimuksen tavoitteena oli tukea Suomen hallituksen tavoitteita tiekuljetusalan energiatehokkuuden parantamiseksi ja hiilidioksidipäästöjen pienentämiseksi. Tavoitteen toteuttamiseksi ennakoitiin tulevaisuuden kehitystä ja tuotettiin päätöksentekijöille tietoa vaikuttavista toimenpiteistä energiatehokkuuden parantamiseksi ja CO_2-päästöjen pienentämiseksi.

Tutkimuksessa kehitettiin uusi menetelmä polttoaineenkulutustiedon yhdistämiseksi Tieliikenteen tavarankuljetustilaston aineistoon, mikä mahdollisti hyvin tarkan analyysin talouden, kuljetusten, energiankulutuksen ja päästöjen yhteyksistä. Menetelmällä analysoitiin vuosien 1995–2010 tilastoja, ja analyysin tuloksia käytettiin taustatietoina asiantuntijoille, jotka ennakoivat Suomen tiekuljetusalan kehitystä vuoteen 2030. Lisäksi tutkimuksessa toteutettiin Internet-kyselyt suomalaisille tiekuljetusalan yrityksille ja kuljetusasiakkaille niiden energiatehokkuuteen liittyvien asenteiden ja toimintatapojen selvittämiseksi. Asiantuntijoille järjestettiin myös työpajoja tiekuljetusalan energiatehokkuuden kehittämisen esteiden ja toimenpiteiden tunnistamiseksi ja arvioimiseksi.

Tutkimustulosten mukaan toimialojen taloudellisella kehityksellä on erittäin suuri merkitys tiekuljetusten energiatehokkuuteen ja hiilidioksidipäästöihin. Vuodelle 2030 asetetun hiilidioksidipäästötavoitteen saavuttaminen on mahdollista tutkimuksessa asiantuntija-arvioiden pohjalta tehtyjen skenaarioiden valossa. Haasteena on, että tavoitteiden saavuttaminen on mahdollista hyvin erilaisilla kehityskuluilla. Esimerkiksi kansantalouden rakenteet ja tiekuljetussuoritteet eroavat toisistaan hyvin voimakkaasti eri skenaarioissa. Toimenpide-ehdotuksessa korostuu erityisesti yhteistyö ja alan energiatehokkuuden kehittämisen vastuun jakautuminen monille sidosryhmille.

Foreword

"My purpose is that they may be encouraged in heart and united in love, so that they may have the full riches of complete understanding, in order that they may know the mystery of God, namely Christ, in whom are hidden all the treasures of wisdom and knowledge."

Paul's letter to the Colossians, chapter 2, verses 2 and 3.

It is a saddening thought, really, to think that one is able to achieve the highest degree of academic knowledge, the degree of Doctor, under the age of thirty. Yet that was my goal, set after receiving the master's degree. And here it is, right on the schedule. I feel blessed and grateful. Fortunately, there are still infinite treasures of wisdom and knowledge to explore in this life and beyond.

My academic career started in a small village school with just one other pupil in my class and a dozen pupils in the whole school. I wish to thank my first teachers, Raija Brandt and Pekka and Liisa Tourunen for their work. They were the last of their kind. In lower secondary school I realised that preparing for exams results in better degrees. This realisation came to me along with Jouko Innanen's essay exam on geography. In upper secondary school my thoughts focused on business and logistics on an economics course by Risto Palttala and the excellent teaching of mathematics and physics by Marketta Paloniemi opened the doors to industrial engineering and management studies at Tampere University of Technology. My deepest gratitude belongs to these and all other teachers.

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The research for this thesis was inspired by my time as a visiting scholar at Heriot-Watt University in Edinburgh. I wish to thank Professor Alan McKinnon for that opportunity and cooperation on this research. My time in Edinburgh was sponsored by the British Council and Pricewaterhouse Coopers, thank you for that. This research was made possible through the funding by Ministry of Employment and the Economy, Ministry of Transport and Communications, Finnish Transport Agency and Finnish Transport and Logistics SKAL, thank you for the funding. I hope you got value for your money.

It is hard even to begin to express my gratitude to my friends and family. Thank you all my friends, especially Ville Leppänen for cooperation during studies and companionship during life. Thank you my in-laws, Terho, Kirsti and Jaakko. I still believe Terho is the only person who has actually read my master's thesis. Thank you my older brothers, Tero and Jarno, for your example of the possibilities of academic studies and my younger brother, Antti, for the happiness you bring to our lives. My parents, Kari and Anna-Liisa, you did not have the possibility for academic studies, yet you gave all us boys that possibility. You let us decide our way and sent us to the world with your prayers and priceless lessons in the importance of integrity, hard work and faith.

Pauliina, you are the love of my life, my friend, my companion, inspiration, comfort and support. I could not have done this without you. I am looking forward for love and laughter for the years to come. Oliver, you were born yesterday. I can't wait to get to know you.

Above all, praise be to God my creator, Jesus my saviour and Holy Spirit my strength.

"The glory of God is a man fully alive."

Irenaeus of Lyons, 2nd century AD

Jyväskylä, 9.4.2013

Heikki Liimatainen

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1. Introduction

Sustainable development, especially improving the energy efficiency and reducing the carbon dioxide (CO_2) emissions has become highly important global goals during past few years. This development has been mainly due to the research findings on the global warming caused by human activities (IPCC 2007), but also due to limited sources of fossil oil, increasing demand of oil and the resulting rise in oil price. Information considering energy use and emissions and measures to improve energy efficiency and reduce CO_2 emissions are needed on every sector of the society in order to mitigate climate change and to respond to rising energy prices. This need also applies to freight transport and logistics sector. Transport sector is currently almost entirely dependent on fossil oil and transport is also the only sector which emissions have increased in the last few years. The emissions are forecasted to increase further without determined policy measures to reduce the emissions (COM/2011/0144; Eurostat 2011; SEC/2011/0358). The new White Paper for European Transport (COM/2011/0144) launched by the European Commission sets a target for reducing 60% of transport greenhouse gas (GHG) emissions from the 1990 level by 2050 and a 20% reduction from 2008 level by 2030. The target for transport is less ambitious than in other sectors (80-95% reduction to keep the global warming below 2°C), which underlines the challenging role of transport in climate policy.

The target is not further allocated to passenger and freight transport. While road traffic emissions dominate transport emissions and while passenger car emissions per kilometre are in decline (EEA 2011), addressing road freight emissions becomes increasingly relevant. It is difficult to find specific data on road freight transport emissions on an international scale, but estimates for major economies show that road freight is responsible for 30-40% of all road transport emissions (ITF 2010). More detailed studies in Germany (Léonardi & Baumgartner 2004) and UK (McKinnon & Piecyk 2009), and national statistics in Finland (LIPASTO 2010) show that the share of freight in road transport emissions has been increasing, but there are various inaccuracies concerning road freight CO_2 emission data.

The European Union has also set a target for reducing the CO_2 emissions by 20% and increasing the share of renewable energy sources to 20% of total EU energy consumption by 2020 (COM/2008/0030). The most important tool to achieve the targets is stated to be updating the Emissions Trading System (ETS). However, the ETS only covers less than half of the greenhouse gas (GHG) emissions and excludes, among others, the emissions from transport. Air transport was included in the ETS from the beginning of 2012, but is facing fierce opposition from other countries (Topham 2012). EU has proposed targets for each member state for the GHG reductions in the sectors outside the ETS (COM/2008/0017). For instance, the target for Finland is a 16% reduction by 2020 from 2005 level.

As an EU member state, Finland is also committed by the Energy Services Directive (2006/32/EC) to achieve a 9% energy savings target from the 2001-2005 average by 2016. To realize this target, EU has established an action plan for energy efficiency (COM/2006/0545). The action plan identifies transport sector as an essential sector to achieve energy savings, as it is the fastest growing sector in terms of energy use and heavily dependent of fossil fuels. Several energy efficiency measures are identified in the action plan. However, only a few of the measures are applicable in road freight transport. Applicable measures include developing markets for cleaner vehicles, maintaining the proper tire pressures and promoting co-modality (i.e. efficient use of transport modes on their own and in combination), which is also emphasized in the EU's transport policy (COM/2006/0314; COM/2007/0607). The action plan was subject to a revision and the public consultation for this revision identified several challenges which hinder the realization of energy savings (European Commission 2009). The challenges applicable for road freight transport include e.g. policy makers' reluctance to touch issues which are related with changing the behaviour of companies and individuals and difficulties in setting specific energy savings targets. Well in line with the new emission targets, albeit based on the earlier European Union 20 by 2020 target (COM/2008/0030; COM/2008/0017), Finland set in 2008 a target of reducing 15% of GHG emissions in the transport sector from the 2005 level by 2020 (MINTC 2009). In absolute numbers this requires a reduction of 2.8 million tons of CO_2. Of this amount approximately 0.3 million tons is planned to be achieved directly by improving the energy efficiency of transport, mainly in road freight transport, which currently emits around 2.7 million tons of CO_2 annually (MINTC 2009, LIPASTO 2011a).

In order to achieve this target, Finnish Ministry of Transport and Communications, Ministry of the Environment and Ministry of Employment and the Economy together with freight transport and logistics associations set out an energy efficiency agreement for freight transport and logistics in 2008. In accordance with the European energy services directive (2006/32/EC) the agreement comprises a 9% energy efficiency improvement target by 2016. The signees committed to promote the research and development of energy efficiency in transport sector, as well as to educate and guide transport companies towards more energy efficient operations. For transport firms joining the agreement is voluntary. The national target is to involve at least 60% of road haulage companies or of commercial trucks in the agreement by 2016. For joined hauliers the agreement means a continuous commitment to improve their energy efficiency and report their energy use monthly into a national energy efficiency database called PIHI. Additionally, the company should establish an environmental management system. (Motiva 2008.)

Although the energy efficiency agreement set a target of a 9% increase in energy efficiency, the agreement did not specify the sources of information to monitor the development of energy efficiency. In fact, the agreement did not even specify the current level of energy efficiency. Information on the current level of energy efficiency and CO_2 emissions, as well as understanding of their past trends and the factors affecting the development of these issues is necessary for effective policy-making. This work responds to calls for a comprehensive understanding of the energy efficiency issues in order to achieve the national GHG goals.

1.1. Research objectives and questions

As described above, the Finnish government has set targets for improving energy efficiency and reducing the CO_2 emissions of road freight transport. However, guidelines for monitoring and reporting of the targets, as well as strategies on how to achieve these targets, have not been presented. In order to address these deficiencies, the Finnish Ministry of Transport and Communications, Ministry of Employment and the Economy together with the Finnish Transport Agency funded the research project on which this thesis is mostly based. The funded research project and the thesis are closely interrelated as they have common aims and objectives and the data collection and analysis served both purposes. Only parts of the literature review and the shipper survey were not parts of the research project as they were completed earlier, but these closely relate to the same aim and are thus included in the thesis. Hereafter the term 'research' means both the research made within the research project and the earlier literature review and shipper survey, i.e. the whole doctoral research.

The aim of the research is to support the initiatives of the Finnish government for improving the energy efficiency and reducing the CO_2 emissions of freight transport. In order to provide such support, two primary objectives of the research are defined, which are to

1. forecast the future of road freight energy efficiency and CO_2 emissions in order to find out whether the policy targets can be achieved, and
2. give the policy makers guidance on effective measures for promoting the road freight energy efficiency and CO_2 reduction.

In order to achieve these two objectives, it is first of all necessary to identify the various factors which may affect the development of the energy efficiency and CO_2 emissions of road freight transport and understand the interactions between these factors. Various approaches for analysing the linkages of the economy, road freight transport and related energy use and emissions have been suggested in literature (e.g. Tapio 2005, Kveiborg & Fosgerau 2007, Cooper et al. 1998, Richardson 2005, Piecyk & McKinnon 2010). Hence, it is necessary to evaluate these approaches and select the best possible approach to be used in this research. This leads to the first research question of the thesis:

RQ1: What indicators can be used to analyse the relationship between economic development, road freight transport and its energy use and CO_2 emissions?

When the indicators have been identified, it is necessary to gather information about the past development of these indicators in order to gain deeper understanding about their interactions and provide background information for fulfilling the first research objective, i.e. to enable short-term and long-term forecasting of the energy efficiency and CO_2 emissions in order to find out whether the policy targets can be achieved. Previous research on the historical development and future forecasts of the indicators is available for many countries (e.g. Kamakate & Schipper 2009, Kveiborg & Fosgerau 2007, Piecyk & McKinnon 2010, Sorrell et al. 2009, Perez-Martinez 2009, Eom et al. 2012). However, in Finland such analysis has only been done considering the past and mid-term future of transport intensity (Iikkanen 2004) and past CO_2 intensity (Finel & Tapio 2012) on an aggregate level, while no detailed holistic analysis or long-term forecasts are available. Hence the following two research question can be set:

RQ2: How have these indicators developed in the past and what kind of a future can be expected in the short-term if the past trends continue?

RQ3: What factors affect the long-term future development of the indicators and will the long-term emission targets be achieved?

The past and future development of energy efficiency and CO_2 emissions of road freight transport are in the end the result of a series of decisions made in the supply chains (Wu & Dunn 1995, McKinnon & Woodburn 1996, Leonardi & Baumgartner 2004, Aronsson & Huge-Brodin 2006, Piecyk & McKinnon 2010). These decisions are made by both shippers and hauliers. In order to effectively promote more energy efficient and less CO_2 emitting road freight transport, i.e. to achieve the second research objective, it is necessary to gain understanding about the reasoning behind these decisions. It is also necessary to gain information about the environmental considerations currently affecting these decisions in order to identify and evaluate possible policy measures to make these decisions more environmentally friendly. This leads to the following three research questions:

RQ4: How do the shippers take the environmental issues into account in their operation and are they going to change their operations because of environmental policy targets?

RQ5: How do the hauliers take the environmental issues into account in their operation and are they going to change their operations because of environmental policy targets?

RQ6: What policy measures can be taken in order to promote a change towards more sustainable practices of shippers and hauliers which leads to achieving the energy efficiency and CO_2 emission targets?

1.2. Scope of research

As mentioned above, the aim of this study is to support the initiatives of the Finnish government for improving the energy efficiency and reducing the CO_2 emissions of freight transport. Modal split of freight transport has a great effect on the total emissions, but this research focuses on the road freight transport and only considers modal split as necessary for forecasting the future demand for road freight transport in relation to the development of gross domestic product (GDP) and total freight transport demand. Road freight transport is limited in this research to the operations made with goods vehicles with a gross vehicle weight (GVW) of more than 3500 kg registered in Finland. It is acknowledged that light goods vehicles with a GVW of less than 3500 kg have an important role in road freight operations, but the goods transport statistics exclude them. Only operations made within Finland are considered in this research and international operations are excluded.

Road freight operations have various external effects such as noise, accidents, air pollution caused by e.g. particulate matter (PM) and nitrogen oxide (NO_x) emissions and also other greenhouse gas emissions than CO_2. However, this research focuses only on CO_2 emissions and mainly on tank-to-wheel emissions. Well-to-wheel CO_2 emission reductions achieved with biofuels are touched upon.

This research is mainly done from the perspective of national policy making. This is due to the aim of the study being to support governmental targets. For example, the action plan developed in this research emphasises the actions to be done by governmental agencies and national freight associations. Nevertheless, achieving the policy targets depends eventually on the decisions made by companies operating often as a part of a global supply network. This viewpoint is taken into account in this research through involving the stakeholders in the research process.

1.3. Structure of thesis

The research and thesis are divided into six research phases, each stage aiming to answer one question with one research method in order to produce solid background for the synthesis fulfilling the two objectives of the research as presented in Figure 1.

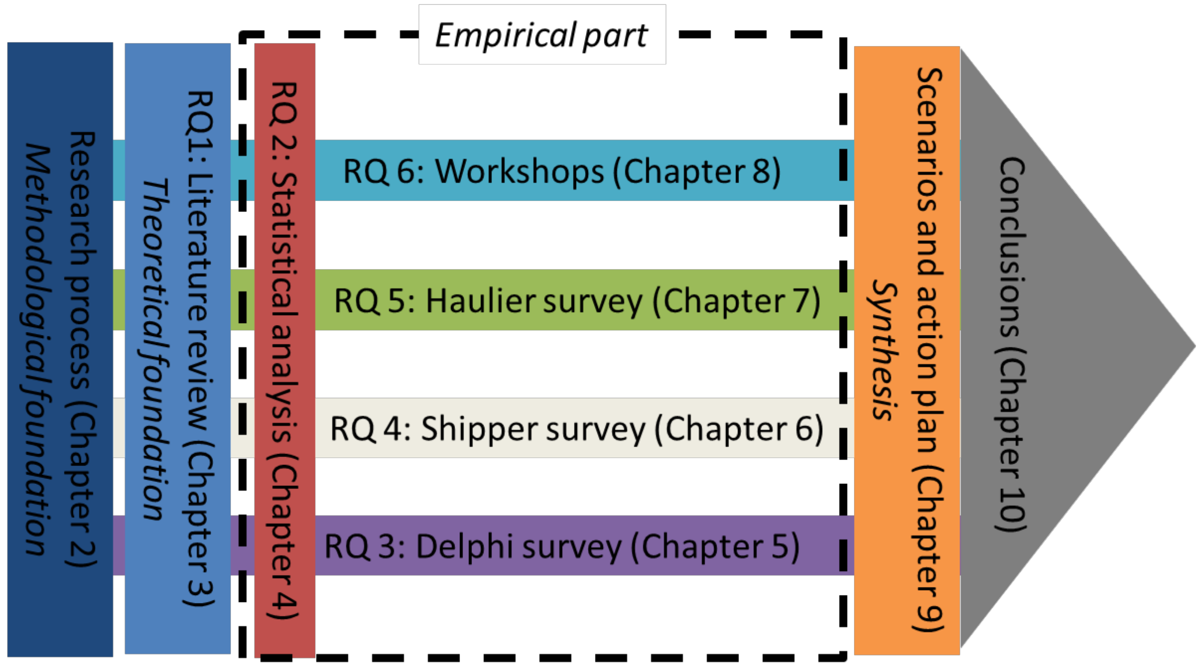

Figure 1. Structure of the thesis

Chapter 2 establishes the methodological foundations of the research and describes the research process in further detail. Possible research methods and justification for the chosen methods are explained with a description of the interrelations between the research phases.

The literature review aims at identifying the indicators and their determinants affecting the development of the aggregate values of the economy, road freight transport and its energy use and CO_2 emissions. The basic concepts related to the sustainability of road freight transport are also clarified within the literature review in order to establish the theoretical foundations for the research. Previous research in the field is reviewed in order to find measures which can be taken in order to affect the future of road freight energy efficiency and CO_2 emissions. The findings of the literature review are reported in Chapter 3. Findings of literature review are also reported in other chapters as necessary in order to evaluate the findings of each phase of the research.

The empirical part of the research consists of five phases. The statistical analysis presented in Chapter 4 forms the base for the empirical part of the thesis. Finnish road freight statistics are used to answer the second research question, i.e. statistical analysis aims to find out how the various indicators identified in Chapter 3 have developed in the past and what kind of a future can be expected if the past trends continue. To enable detailed analysis, methodological innovations are made in combining data and in acquiring sectoral information from various sources. The statistical data cannot fully capture the complexity of road freight operations. Because of this, the statistical data is reviewed using the findings from a survey of Finnish road hauliers. The statistical analysis also acts as an input for the Delphi survey, expert panel workshops and scenarios.

The Delphi survey, reported in Chapter 5, aims to answer research question 3. The purpose of the Delphi survey is to gather data for fulfilling the first objective of this research, i.e. to forecast the long-term development of the economy, road freight demand, energy use and CO_2 emissions in order to find out whether the policy targets for CO_2 reduction can be achieved. Also information about the factors shaping the future values of the indicators are explored with the Delphi survey. Delphi survey is performed in two rounds with spreadsheet files sent to selected experts.

Because the road freight operations mainly take place in the interface of companies and are mainly performed by an external operator to which the transport is outsourced to, it is seen essential to explore the environmental attitudes, level of knowledge as well as monitoring and reporting practices of both shippers and hauliers. The surveys aim to answer research questions 4 and 5, i.e. how do the shippers and hauliers take the environmental issues into account in their operation and are they going to change their logistics operations because of environmental policy targets? The surveys are performed as large scale Internet surveys. The results of the shipper survey are reported in Chapter 6 and the results of the haulier survey in Chapter 7. The results of the surveys are also used as an input to the workshops as well as scenarios and action plan.

Three workshops for an expert panel were organised during the research. Findings from the previous stages of the research were presented in the workshops as background information for the discussions between the invited experts of road freight transport. The workshop process aims to answer research question 6 and it is reported in Chapter 8.

The findings of the previous research stages are synthesised to fulfil the two objectives of the research by establishing scenarios of energy efficiency and CO_2 emissions up to year 2030 and an action plan for developing these issues in the short-term. The scenarios and action plan are presented in Chapter 9.

Finally, the main findings of the research as well as theoretical and practical contributions, limitations and recommendations for future research are presented in Chapter 10 of the thesis.

1.4. Researcher's contribution

The research was carried out in Transport Research Centre Verne at Tampere University of Technology in cooperation with University of Turku and Heriot-Watt University, Edinburgh. Heikki Liimatainen was the project manager and principal researcher of this research as well as the first author of the final report and conference and journal articles written based on this research. The following articles were modified and combined for this thesis:

Paper I: Liimatainen, H. 2010. Shippers' Views on Environmental Reporting of Logistics and Implications for Logistics Service Providers. Logistics Research Network Conference 2010 Proceedings. September 8-10, Harrogate, United Kingdom. 7 p.

Paper II: Liimatainen, H., Pöllänen, M. 2010. Trends of energy efficiency in Finnish road freight transport 1995-2009 and forecast to 2016. Energy Policy, Vol. 38, Issue 12, pp. 7676-7686.

Paper III: Liimatainen, H., Pöllänen, M. 2011. The impact of economic development on the energy efficiency and CO_2 emissions of road freight transport. 16^{th} International Symposium on Logistics (ISL 2011), July 10-13, Berlin, Germany. 8 p.

Paper IV: Liimatainen, H., Pöllänen, M. 2013. The impact of sectoral economic development on the energy efficiency and CO_2 emissions of road freight transport. Transport Policy, Vol. 27, pp. 150-157.

Paper V: Liimatainen, H., Stenholm, P., Tapio, P., McKinnon, A. 2012. Energy efficiency practices among road freight hauliers. Energy Policy, Vol. 50, pp. 833-842.

Paper VI: Liimatainen, H., Kallionpää, E., Pöllänen, M., Stenholm, P., Tapio, P., McKinnon, A. 2013. Decarbonising road freight in the future – Detailed scenarios of the carbon emissions of Finnish road freight transport in 2030 using a Delphi method approach. Technological forecasting and social change. DOI: 10.1016/j.techfore.2013.03.001.

Paper VII: Liimatainen, H., Kallionpää, E., Pöllänen, M. 2012. Building a national action plan for improving the energy efficiency and reducing the CO_2 emission of road freight transport. Proceedings of the 17^{th} International Symposium on Logistics (ISL2012). July 8-11, Cape Town, South Africa.

Heikki Liimatainen was responsible for the idea, methodological decisions, data collection, analysis, conclusions and almost all the writing in each paper. In Papers II-IV Pöllänen provided insight for developing the data analysis method, wrote minor parts of the introduction and conclusion sections of the papers and commented the papers throughout the process. In Paper V Stenholm performed and wrote minor parts of data analysis while Tapio and McKinnon commented the paper. In Paper VI Kallionpää wrote the introduction of the paper, Tapio wrote parts of the section on Delphi method and conclusions and other authors commented the paper. In Paper VII Pöllänen helped to direct the data collection in workshops and commented the paper together with Kallionpää.

2. Research process

The process of selecting the techniques and procedures of collecting and analysing data can be depicted in various ways. Saunders et al. (2009) use a 'research onion' in which the issues underlying the selection of data collection techniques and analysis procedures are the choices made regarding research philosophies, approaches, strategies, method choices and time horizons. Jonker & Pennink (2010) on the other hand depict the research process as a pyramid moving from the abstract top to very concrete bottom with the action levels of research paradigm, methodology, methods and techniques in the pyramid. Both Saunders et al. (2009) and Jonker & Pennink (2010) highlight the importance of the research questions as the primary criteria steering the choices made during the research process.

2.1. Research philosophy and paradigm

Research philosophy and paradigm deal with the way the researcher views the world. Both of these words have been given this meaning. Saunders et al. (2009) say that "research philosophy you adopt contains important assumptions about the way in which you view the world", while Mangan et al. (2004) refer to Wittgenstein who has said that a paradigm is basically a world view. Saunders et al. (2009) also acknowledge that paradigm has multiple meanings, but they define it as "a way of examining social phenomena from which particular understandings of these phenomena can be gained and explanations attempted", suggesting that paradigm relates to examining or researching rather than to a holistic world view. Kuosa (2009) supports this view by referring to Kuhn who defined that paradigm refers to the set of practices that define a scientific discipline during a particular period of time.

Despite of the term, both research philosophy and paradigm deal with the ontological, epistemological and value issues of research and these issues affect the preferred research approach and methods used in research under certain world view. This research combines the research paradigms or philosophies of two fields of research, namely management research and futures research. Both of these fields have their own established paradigms with some similarities and dissimilarities.

Kuosa (2009, 2011) describes futures research having three paradigms, which have evolved one after another (Table 1).

Table 1. Key characteristics of futures research paradigms (based on Kuosa 2009, Kuosa 2011).

	Ancient	Modern	Dynamic
Ontology (view of the nature of future)	deterministic	indeterministic, except in some limited law like causalities	chaotic, complex and layered
Epistemology (view of acceptable knowledge)	divine, supernatural	empirical knowledge produced by all scientific disciplines and human cultural knowledge; combination of syntax (methods), semantics (substance areas) and pragmatics (deeds of research)	strategic intelligence, up-to-date, reasoned, clearly expressed and reliable information about the complex world
Axiology (view of the role of values)	only professionals (priests, witches, etc.) can see the future and act as gatekeepers	value-rational, describes desired futures images, values can be rationally studied	value-open, need to produce a spectrum of ethically alternative futures
Preferred method	mystical methods, rituals	multiple and mixed methods, quantitative and qualitative, scenarios, Delphi and futures wheels are characteristic	experience-based methods, virtualisation, increasing use of imaginary worlds

This research fulfils the characteristics of the modern futures research paradigm. The future is considered to be indeterministic as far as the social phenomena are considered while the laws of physics, determining e.g. the fuel consumption of a truck, are deterministic also in the future. Empirical knowledge produced by multiple research methods are the basis for the multiple futures images with the desired futures image already stated in the aim of the research.

Saunders et al. (2009) summarise the key characteristics of management research philosophies as presented in Table 2.

Table 2. Key characteristics of four research philosophies in management research (adapted from Saunders et al. 2009).

	Positivism	Realism	Interpretivism	Pragmatism
Ontology (view of the nature of reality)	external, objective, independent of social actors	objective, exist independently, interpreted through social conditioning	socially constructed, subjective, multiple	external, multiple, view chosen to best enable answering research question
Epistemology (view of acceptable knowledge)	only observable phenomena provide credible data, focus on causality and generalisations, reducing to simplest element	observable phenomena provide credible data, insufficient data means inaccuracies in sensations, sensations are open to misinterpretation, focus on explaining within contexts	subjective meanings and social phenomena, focus on details of situation, reality behind these details, subjective meanings motivating actions	either or both observable and social phenomena provide acceptable knowledge, focus on practical applied research, integrating different perspectives
Axiology (view of the role of values)	value-free, researcher is objective and independent of data	value laden, researcher is biased by world view	value bound, researcher is part of what is researched	values have role, researcher adopts both objective and subjective points of view
Preferred method	structured, large samples, quantitative, may use qualitative	quantitative or qualitative, must fit the subject	small samples, in-depth investigations, qualitative	mixed or multiple methods, quantitative and qualitative

This research has a pragmatic aim of supporting the initiatives of the Finnish government for improving the energy efficiency and reducing the CO_2 emissions of freight transport. This aim contains a value statement in itself and fulfilling it requires understanding of a complex system containing both natural observable phenomena, e.g. the fuel consumption of a truck, and social phenomena, e.g. the requirements for energy efficiency in buying transport services. Multiple research methods are needed to provide the understanding. Hence, this research fulfils the characteristics of the pragmatic research philosophy.

2.2. Research purposes and approaches

The purpose of the research comes into consideration when the research questions are set as it guides the choices of research approaches and methods. There are three main purposes, although a research may have more than one overall purpose and the purpose may change between research phases. *Exploratory* research aims to seek new insight on the research question and clarify the issues related to the question. Main methods of exploratory research are literature reviews, expert interviews and focus group interviews. *Descriptive* research is used very commonly at least as a part of research process. It aims to portray an accurate and reliable picture of the researched phenomena through large evidence. *Explanatory* research aims to establish causal relationships between phenomena. In addition to these three traditional purposes, *forecasting* may also be regarded as a research purpose, although it may also be seen to belong to the exploratory research. (Saunders et al. 2009, Heikkilä 2005, von der Gracht 2008.)

Based on the research objectives, this research has a forecasting purpose as the first objective is to forecast the future of road freight energy efficiency and CO_2 emissions in order to find out whether the policy targets can be achieved. This research also has an explanatory purpose, because understanding about the causal phenomena between factors is needed in order to fulfil the second objective, i.e. to give the policy makers guidance on effective measures for promoting the road freight energy efficiency and CO_2 reduction. Furthermore, each research phase, aiming to answer one of the six research questions, has its own purpose, as explained in the following sections.

Research approach deals with the question of how scientific reasoning can be made. The main alternatives are *deductive, inductive* and *abductive* approaches, which may be traced back to Aristotle's definitions. Purely *deductive* reasoning moves from rule to case to result, i.e. from theory to hypothesis, testing of hypothesis and corroboration or falsification of hypothesis. *Inductive* reasoning moves from case to result to rule, i.e. generalizes theoretical contributions from observations. *Abduction* moves from rule to result to case, i.e. it begins from real-life observations like inductive process, but compares the observations to existing theory and commonly finds a mismatch between the observation and theory, which leads to an iterative process of theory matching, after which hypotheses are formed based on the new theory and conclusions are applied. Research approach is rarely explicitly discussed in logistics research, but mainly deductive approach is used while there is seen to be a need for more logistics research using inductive and abductive approaches. Research approach is rarely purely deductive, inductive or abductive, but rather a combination of these, which is often advantageous. (Saunders et al. 2009; Kovacs & Spens 2005; Tapio 2002).

This research also combines the research approaches. The research process as a whole uses the abductive research approach (Figure 2).

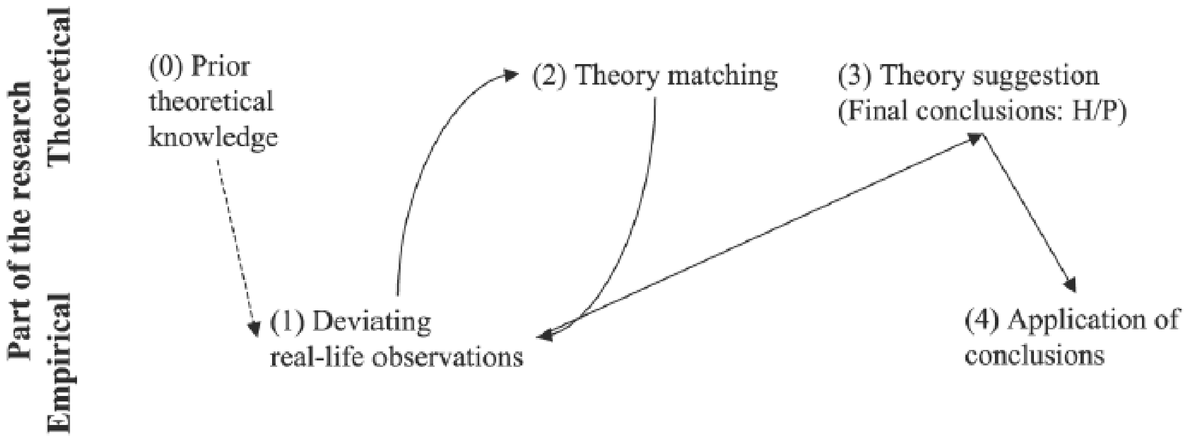

Figure 2. The abductive research approach (Kovacs & Spens 2005).

This research begins with prior theoretical knowledge describing what affects the energy efficiency and CO_2 emissions of road freight transport. Then understanding about the issue is deepened and reflected to prior theory using various research methods and gaining insight from various stakeholders. This understanding is finally synthesised and the conclusions applied in the context of the Finnish road freight transport system. Within the overall abductive research process, different parts of the process use deductive and inductive approaches, as described in the following sections.

2.3. Research methods

As with the choices of research philosophy, purpose and approach, the research aim, objectives and research questions are the primary criteria steering the choices regarding research methods. The aim of this research is to support the initiatives of the Finnish government for improving the energy efficiency and reducing the CO_2 emissions of freight transport. In order to provide such support, the objectives of the research are to forecast the future of road freight energy efficiency and CO_2 emissions in order to find out whether the policy targets can be achieved, and to give the policy makers guidance on effective measures for promoting the road freight energy efficiency and CO_2 reduction. The first objective of this research calls for alternative images of the future of road freight transport energy efficiency and CO_2 emissions and selection of preferable future in which the emission targets will be achieved. The second objective calls for understanding about the factors affecting the future in order to enable action towards the preferable future.

Based on the aim and objectives, this research is future oriented. Future oriented research typically has four premises, which affect the choice of research methods, as futures research is (JRC 2012, Rubin 2012):

- open to alternative futures, i.e. the future is not pre-determined but can be shaped,
- action oriented, i.e. alternative futures are not just analysed but preferable futures are chosen and actions for achieving that future are considered,
- participatory, i.e. futures studies involve different actors who can influence the future of the studied issue and
- multidisciplinary, i.e. it utilises a variety of research methods and findings from different academic disciplines to capture the wide range of variables shaping the future of the studied issue.

These characteristics of futures studies answer the requirements identified based on the research objectives. Characteristics should be taken into account in this research by constructing alternative futures and giving recommendation on actions to achieve the future preferred in transport policy, i.e. decarbonisation of road freight transport, as well as by involving various actors in the research process and utilising a variety of research methods. These characteristics are fulfilled in this research by using the scenario method as the overarching research method with information gathered and analysed with other methods to serve as input for the final synthesis of scenario building.

A scenario is a hypothetical sequence of events that can lead to a possible future. Scenario method is the most widely used futures research method, applied by public and private organisations from the 1950s, when it was pioneered by the RAND Corporation. Scenario method can be applied serving different purposes and using different approaches. *Normative scenarios* start with a view of a possible future and look back to see how that future could evolve from present situation. This can also be called backcasting and it typically follows a deductive approach, where pieces of data are fitted in an existing framework. *Exploratory scenarios* take the present as starting point and use data from past and present to forecast the implications of possible events leading to several futures. This uses an inductive approach, where the structures of the scenarios emerge from the data. Despite of the purpose of the scenarios, they should be based on a wide variety of different types of data gathered and analysed using several methods. (JRC 2012, von der Gracht 2008)

2.3.1. Classifications of research methods

Research methods are often classified either as quantitative or qualitative. However, this classification misses the point of some methods being both, meaning e.g. that the same method can produce both quantitative and qualitative results. For example scenarios can be based on both types of data and produce results that are either or – or even both types concurrently. Another way to look at the methods is to classify the methods based on whether they are produced emphasising expertise or interaction, or on the other scale creativity or evidence based, as Popper (2008) suggests (Figure 3).

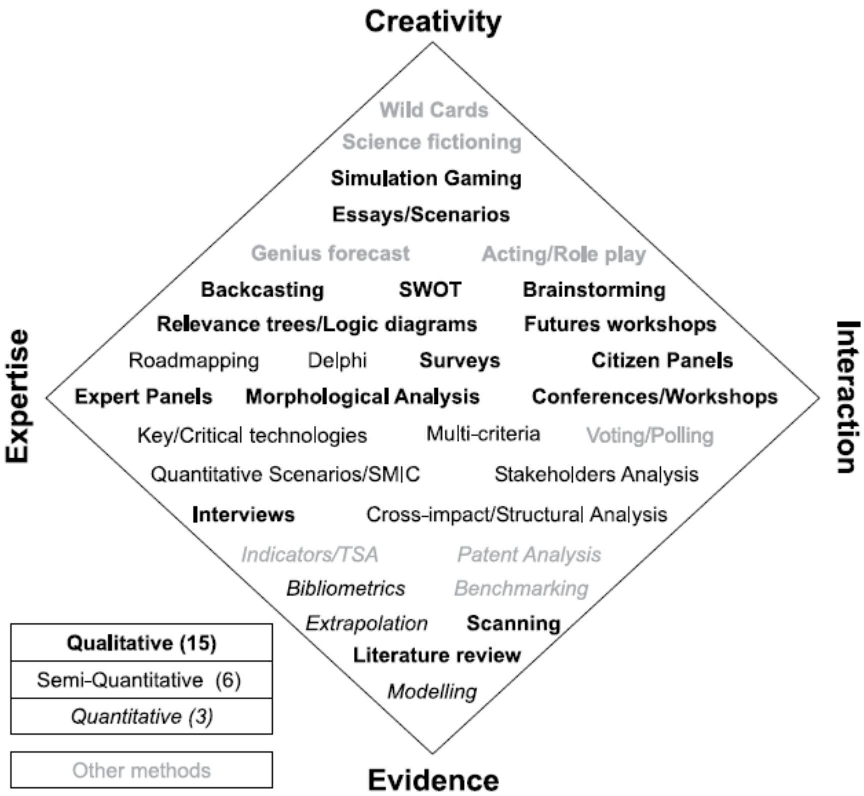

Figure 3. Foresight diamond (Popper 2008).

As can be seen in the Popper's foresight diamond, futures research methods include a variety of methods covering the various classifications. These methods can be and, following the modern futures research paradigm, should be integrated into the same study. It should be noted that some methods such as scenarios or visioning may be used as comprehensive concepts, and they may already include the use of several methods, e.g. scenarios can be based on environmental scanning, Delphi survey and futures workshops. (Banister et al. 2008, JRC 2012.)

2.3.2. Answering the first research question

The first research question is: W*hat indicators can be used to analyse the relationship between economic development, road freight transport and its energy use and CO_2 emissions?* This question establishes the theoretical foundation of the research and positions the research in the context of previous research in the field. These aims are best achieved through a critical literature review.

Literature review is an essential part of research because all qualified research is conducted in relation to prior knowledge. The purpose of literature review is to summarise the existing research and help to identify the relevant concepts, methods and findings so that the new research can be positioned against the existing and interesting research problems can be set. Literature review is conducted by systematically collecting and analysing the relevant literature, and it can be performed using various strategies. *Traditional literature review* is selective in literature search, but may not be specific on the criteria for selecting certain literature. Still it aims to establish a comprehensive background of the phenomena. *Systematic literature review* has the same aim, but it is explicit about the criteria for selecting certain literature and provides as complete a list as possible of the previous research on the subject. *Meta-analysis* is based on systematic literature review, but further analyses the findings using statistical techniques. *Meta-synthesis* also aims to draw further conclusions based on systematic literature review, but uses non-statistical techniques aiming to transform findings into new conceptualizations. Literature review process begins with defining the parameters of literature search based on the research questions and objectives. The next steps are to generate key words, conduct search, obtain literature, read and evaluate and record ideas for generating new key words and conducting new search. Literature review includes multiple searches, each with a more focused parameters and key words. The parameters include choices made regarding language, subject area, geographical area, publication period and literature type. (Saunders et al. 2009, Ghauri & Gronhaug 2005, Seuring et al. 2005, Cronin et al. 2008.)

In this study, the traditional literature review has an exploratory purpose and it is done using the deductive approach, i.e. literature is used to help identifying theories and ideas which will be tested and further developed using data. The parameters of the literature review are as follows:

- language: English, Finnish
- subject area: logistics, road freight transport, environmental issues, energy efficiency, CO_2 emissions
- geographical area: Europe, North America
- publication period: last 12 years
- literature type: journals, books, research reports, conference proceedings, government publications.

Various key words were used in searching the relevant literature, e.g. ‘energy efficiency’, ‘road freight transport’, ‘decoupling’ and ‘transport intensity’. The sources used for literature review included the library of Tampere University of Technology, as well as the online journal and ebook databases provided by the library, including Science Direct, Emerald Fulltext and Springer Link. The internet was searched using Google and Google

Scholar search engines and mainly reports and publications of research institutions and governments were searched. Citation trails were followed and also colleagues and research partners were consulted in order to ensure that relevant and up-to-date literature was found. Several separate searches were conducted supporting various research phases and the results of the literature survey are reported throughout the thesis as necessary, but the results of the initial literature review answering the first research question are reported in Chapter 3.

2.3.3. Answering the second research question

The second research question is: *How have these indicators developed in the past and what kind of a future can be expected in the short-term if the past trends continue?* The research question calls for longitudinal numerical data of the past and forecast of future values of the eight indicators identified as an answer to the first research question. Such primary data would be very difficult to gather, because of the variety of data required from the GDP to the fuel CO_2 content, and hence the large number of stakeholders having relevant data. However, there are secondary data available on all the indicators. Data on the volume of freight transport and most related indicators are available in national statistics, which have been compiled using continuous haulier surveys by Statistics Finland (2012a) and GDP data is available in the national accounts by Statistics Finland (2012b). The freight transport data does not include energy consumption or CO_2 emission data, but these can be found in fuel consumption databases provided by VTT Technical Research Centre of Finland (LIPASTO 2011a) and Network for Transport and the Environment (NTM 2008) and combined with the freight transport data, as explained further in Chapter 4.2.

Based on these secondary data, time series of the indicator values can be compiled. Time series is an ordered sequence of values of a variable at equally spaced intervals and time series analysis refers to a variety of statistical methods which can be used to understand the past and forecast the future values of that variable. The forecasts of future values are done using trend extrapolation tools provided in the Excel software. Trend extrapolation is a simple method for generating forecasts as it requires little data and can be performed without deep understanding about the forecasted variable. Simple trend extrapolation is done by fitting a trend line to the time series and calculating the future values using the trend line equation. Trends may be constant, linear, exponential, damped (logarithmic) or polynomial. The best trend line is chosen using the coefficient of determination (R^2) which is the proportion of total sum of squares explained by the least squares trend line. The R^2 can have a value between 0 and 1 and the nearer it is to 1, the better the trend line represents the data. Simple trend extrapolation has been criticised for being unable to recognise cyclic or seasonal or other variations in the data. Autoregressive and moving average (ARMA) functions have been developed to address these problems, but research shows that sophisticated methods do not always out-perform the simple extrapolation. Whatever method is used, trend extrapolation misses the effect of possible new factors changing the business as usual development shown in the data. Because of this, trend extrapolations should not be used as the only method for forecasting. Additionally, trend extrapolation cannot be used for long term forecasts if there is not sufficient amount of historical data available. There should be at least twice as much time series data compared to the forecasted period. (Carnot et al. 2011, NIST 2012, May 1996, Swift 2001, IEHIAS 2012, Flowers 2012.)

The secondary data from the statistics are used in this research for mainly descriptive purposes in filling the decarbonisation framework established in Chapter 3 with values for each year from 1995 to 2010. These historical values are used as background information for the Delphi panellists. Some explanatory conclusions are also made from the time series using the deductive approach and the decoupling framework presented in Chapter 3. These conclusions are used in the synthesis phase of the research. Furthermore, time series analysis and trend extrapolation are used for forecasting purposes in building three short-term business as usual scenarios for the energy efficiency and CO_2 emissions of road freight transport for the year 2016. Various aspects regarding the data and the research techniques used in analysis are described in further detail in Chapter 4.

2.3.4. Answering the third research question

The third research question is: *What factors affect the long-term future development of the indicators and will the long-term emission targets be achieved?* This research question is clearly future oriented and calls for futures research methods suitable for long-term forecasting. As mentioned in the previous section, trend extrapolation is not suitable for long-term forecasting if there is not sufficient amount of historical data available, as is the case here. Furthermore, trend extrapolation gives only one business as usual forecast, while the research question calls for understanding of the factors possibly changing the business as usual and leading to alternative futures. Hence, a collection of judgements by experts of road freight transport is required. This can be done using genius forecasting, Delphi survey, futures wheel, expert group meetings or interviews (Aaltonen 2005). Delphi survey method is the most common of these and it is commonly used in the scenario building process, e.g. von der Gracht (2008) reviewed 37 publications dealing with scenario planning in logistics and found that 14 of these used also Delphi method. Delphi is also a characteristic feature of the modern futures research and the disaggregative policy Delphi provides a structured method for producing scenarios to answer the research question.

Delphi is an expert view based method that includes several rounds of inquiry, feedback of statements and arguments of previous rounds while reconsidering the topic and maintaining anonymity of responses. Delphi is an especially suitable method for explorative studies, when changes in the relations between key variables are intuitively expected, respondents are not close to each other geographically and when there are strong persons dominating the discussion (Linstone & Turoff 1975; Rowe et al. 1991; Adler & Ziglio 1996; Kuusi 1999; Tapio 2003; Nowack et al. 2011).

Classical Delphi studies focused on expert estimates of the most probable future and the general aim was consensus. Non-consensual forms, such as Policy Delphi, have also been developed addressing the plurality of views of the future (Linstone & Turoff 1975; Tapio 2003; Steinert 2009). According to Kuusi (1999), Delphi method is at best in exploring the possible futures. This argument leads thoughts towards scenarios as alternative future paths of development. Nowack et al. (2011) reviewed 24 Delphi studies where scenarios were made. They concluded that Delphi and scenarios seem to fit together well.

In this research the Disaggregative Policy Delphi method is used for forecasting purpose. The Disaggregative Policy Delphi is a non-consensus building process producing scenarios of the future (Tapio 2003). The combination of qualitative and quantitative material is an essential part of the process, typically containing a set of indicators and open arguments supporting the future estimates of the indicators (Tapio et al. 2011). The quantitative responses are grouped together using cluster analysis (e.g. Everitt et al. 2001) and qualitative content analysis of the qualitative responses is carried out (e.g Graneheim & Lundman 2004).

In addition to Disaggregative Policy Delphi, an explanatory application is included in the Delphi survey in this research. The first round qualitative arguments for the factors causing the changes in the indicators are transformed to quantitative questions for the second round. Each factors' strength and direction of impact on the indicators is specifically asked for. Furthermore, similar factors are then combined under few megatrends and the strength and direction of impact of the megatrends on the indicators are then evaluated. This abductive research process uses the decarbonisation framework with historical values of indicators as an input and produces alternative future values for years 2016 and 2030, with descriptions of factors explaining the changes in indicator values, as outputs to the scenario building. Further details on the Delphi survey process are explained in Chapter 5.

2.3.5. Answering the fourth and fifth research question

The fourth and fifth research questions are the same with only the stakeholder changing from shippers in RQ4 to hauliers in RQ5: *How do the shippers/hauliers take the environmental issues into account in their operation and are they going to change their operations because of environmental policy targets?* The purpose of these questions is to describe the current environmental attitudes and practices of shippers and hauliers and their views of the likelihood of changes by the year 2016. Survey methods including observation, structured, semi-structured or unstructured interviews and questionnaires could be used for this purpose, but observation and semi- or unstructured interviews are usually more useful in exploratory research while questionnaires tend to be used in descriptive or explanatory research. Structured interviews and questionnaires may be used as the only data collection method, but it is beneficial to combine them with in-depth interviews or other participatory methods. (Saunders et al. 2009.) In this study more in-depth information on the issues covered in the questionnaires are gathered in the process of answering the sixth research question, as described in the next section. Hence, the questionnaires are used in answering the fourth and fifth research question.

Structured surveys are methods for collecting data from respondents through questionnaires or structured interviews and they have an important role in many disciplines, including business studies and supply chain management research. Structured surveys can be interviewer-administered or self-administered and performed through personal meeting, on telephone, by post or email and online. Posted questionnaires have been the dominant technique, but web-based techniques are increasingly used. (Ghauri & Gronhaug 2005, Grant et al. 2005, Kotzab 2005, Heikkilä 2005, Saunders et al. 2009.) Each technique has its advantages and disadvantages as can be seen from Table 3:

Table 3. Characteristics of different structured survey techniques (adapted from Heikkilä 2005, Saunders et al. 2009).

	Personal structured interview	**Telephone interview**	**Postal questionnaire**	**Online questionnaire**
Response rate	usually high (50-70%)	usually high (50-70%)	fairly low (30%)	low (<10-30%, depends on sample)
Number of interviewers	high	significantly lower than in personal interviews	not needed	not needed
Impact of interviewer	high	low	avoided	avoided
Lead time	quite short	short	long	short
Possibility to use long questionnaires	high	low	high, but affects response rate	high, but affects response rate
Possibility to ask delicate questions	low	low	high	high
Possibility to use open questions	high	fairly high	low, often left unanswered	low, often left unanswered
Accuracy of responses	high	high	questionable	questionable
Possibility for misunderstandings	low	fairly low	high	high
Possibility to identify respondents	yes	yes	no	yes
Possibility to use additional material	high	no	high	high
Possibility to make additional observations	high	fairly high	no	no
Financial resources needed	high (interview time, travel, data entry)	high (interview time, calls, data entry)	fairly low (postage, data entry)	low (if using automated systems), high (if needs web page design)

This research has limited financial and researcher resources, hence the expensive and time-consuming personal and structured interviews are not feasible. The selection is thus between postal or online questionnaire, between which the main differences are the shorter lead time and lower costs of online questionnaires against the higher expected response rate of postal questionnaire. The researcher's institution already has an online questionnaire software (Webropol) available and the researcher has good previous experiences from using this software. It is also considered that short lead time and financial gains due to time saved with the online software outweigh the possibly lower response rate. The sample size can also be larger when using the online questionnaire than it could be using the more expensive postal questionnaire, so the final number of responses could be about the same. Hence, online questionnaires are used in this research for both shippers and hauliers.

The questionnaires use a deductive approach with the decarbonisation measures identified in Chapter 3 as inputs for questionnaire design. The outputs of the questionnaires provide background information for the workshops used in answering the sixth research question, as well as for the final scenario and action plan building. The haulier survey also served as a way of verifying the sectoral average fuel consumption and empty running estimated in Chapter 4 using the secondary statistical data. Further details on the shipper survey are explained in Chapter 6 and on the haulier survey in Chapter 7.

2.3.6. Answering the sixth research question

The sixth research question is: *What policy measures can be taken in order to promote a change towards more sustainable practices of shippers and hauliers which leads to achieving the energy efficiency and CO_2 emission targets?* To answer the question, it is first necessary to identify the possible policy measures, which is done in Chapter 3. Secondly, it is necessary to evaluate the applicability of the identified measures. The applicability includes aspects such as acceptability of measures among shippers and hauliers, probable decarbonisation results of measures and financial implications of measures. In order to gain such in-depth information, it is necessary that the stakeholders of road freight transport are involved in the process of answering the research question.

Stakeholder involvement can be achieved using a participatory approach which can be defined as actively involving the stakeholders in a decision making or policy debate process. The reasons for using participatory approach include a pragmatic view that it is best to have as much knowledge and expertise as possible in addressing complex issues. From a normative perspective it is desirable to involve all stakeholders in order to ensure that all values and opinion are considered. Stakeholder involvement also increases their support for policy actions. Furthermore, participatory approach serves knowledge dissemination and networking purposes. Participatory methods are more likely to produce normative than analytic results, i.e. they can be used to produce general strategies rather than specific plans. (Glenn 2009, Slocum 2003.)

Participatory approach can be achieved using a variety of methods, including charrette, citizen jury, Delphi, expert panel, focus group, world café and scenarios. The first two are used primarily for average citizens, while Delphi, expert panel and focus groups typically involve experts and the final two methods can be participated by anyone. Answering the sixth research question requires expertise, so the first two methods are not suitable for this purpose. Scenarios and Delphi, on the other hand, are already used in this research for other purposes, so the selection of the method is between expert panel, focus group and world café. Focus group and world café are primarily used for initial concept exploration and generating ideas rather than for synthesising various inputs and producing recommendations, whereas the expert panels are used for the latter purpose. Hence, the expert panel is used in this research. (Slocum 2003, Vidal 2006, Glenn 2009.)

An expert panel can organise its work in many ways, typically in a series of meetings with clear topics and agreed milestones (Slocum 2003). In this study the work was organised using the structure of a future workshop. The future workshop usually involves 15-25 people who are experts of the theme of the workshop and can affect the future of the theme. Process consists of five phases, three of which are workshop phases which usually take place during one or two days. The five phases are (Vidal 2006, CIPAST 2012):

- preparation (invitations, facilities, timetable)
- critique (critical and open discussion of the current situation)
- fantasy (free visioning of the future and ideas for achieving the future)
- implementation (critical evaluation of ideas and development of strategy)
- follow-up (reporting and dissemination of results)

In this research three half-day workshops are held following these phases. The workshops comprise a continuing process to build a national action plan for improving the energy efficiency and reducing the CO_2 emissions of road freight transport (Chapter 9.7). In the first workshop (critique phase) the current situation of the energy efficiency of road freight transport in Finland is critically discussed in order to identify the obstacles of improvement. In the second workshop (fantasy phase) possible measures for overcoming these obstacles are identified. In the third workshop (implementation phase) these measures are evaluated and a strategy is developed. The results of the workshops are reported (follow-up) in a research report. More details of the composition of the expert panel and the outline of the workshops are described in Chapter 8.

2.4. Conclusions

This research has practical future oriented aim and objectives, which lead to pragmatic research philosophy and modern futures paradigm to be used. Pragmatism and modern futures research paradigm both highlight the importance of multiple research methods as means to produce results which have practical relevance. Hence, this research uses a variety of research methods to answer the six research questions, which all produce information for the scenarios and action plan produced in the synthesis phase to fulfil the research aim and objectives. Overall, the research uses abductive approach, but each phase has its own purpose and approach. Table 4 summarizes the research design of thesis:

Table 4. Research design of thesis.

Phase (month/year)	RQ1 (9/2009→)	RQ2 (1/2010-11/2011)	RQ3 (9-10/2011)	RQ4 (1-2/2010)	RQ5 (3-4/2011)	RQ6 (2, 5 & 11/2011)	Synthesis (11/2011→)
Research paradigm	Pragmatism, modern futures research						
Research purpose	exploratory	descriptive, forecasting	explanatory, forecasting	descriptive	descriptive	exploratory	forecasting
Research approach	deductive	deductive	abductive	deductive	deductive	abductive	deductive
Research method	literature review	time series and trend analysis	Delphi survey	structured internet questionnaire	structured internet questionnaire	expert panel futures workshops	futures table, scenarios, workshop
Type of data	secondary, qualitative	secondary, quantitative	primary, quantitative, qualitative	primary, quantitative	primary, quantitative	primary, qualitative	secondary, qualitative, quantitative
Time horizon	longitudinal 2000-2012	longitudinal 1995-2016	cross-sectional 2016, 2030	cross-sectional 2010, (2016)	cross-sectional 2011, (2016)	cross-sectional 2011, 2016	cross-sectional 2016, 2030
Input from other phases	-	decarbonising framework	decarbonising framework, historical values of the framework	decarbonising measures	decarbonising measures	attitudes and measures of shippers and hauliers	all outputs from other phases
Output for other phases	decarbonising framework, decarbonising measures	historical values of the framework, short-term scenarios	future values of the framework, factors affecting the future	attitudes and measures of shippers	attitudes and measures of hauliers	obstacles and measures of decarbonisation	long-term scenarios, short-term action plan

A variety of methods is used in this research and the methods cover the various aspects of Popper's (2008) classifications (Figure 4), so methodological triangulation is applied. Also data triangulation is applied as multiple sources of data are applied. Triangulation improves the level of detail on the issues studied and helps to identify new approaches to the issue, thus reducing the possibility for biases. (Jack & Raturi 2006.):

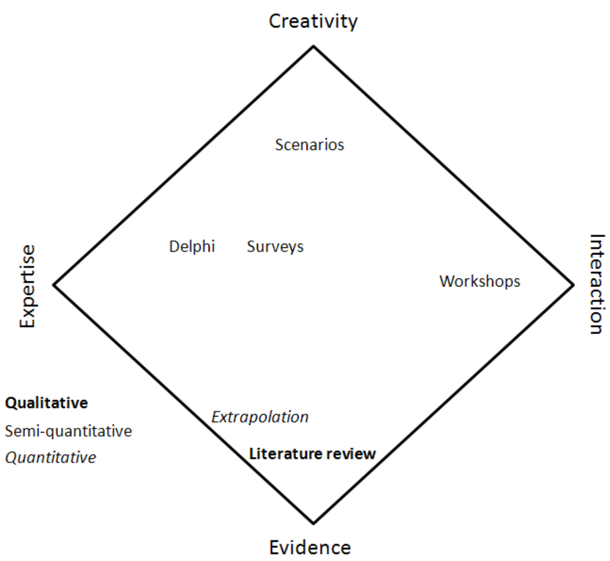

Figure 4. Classifications of the research methods of this research (adapted from Popper 2008).

3. Theoretical foundation

3.1. Sustainable road freight transport

Sustainable development was defined in the 'Bruntland report' (WCED 1987) as: "*a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development; and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations.*" This definition highlights the three aspects of sustainability, i.e. environment, economy and society, which should develop in harmony to enable also future generations to meet their needs. The concept of sustainable development stems from the realization that the natural resources are limited and human activities decrease the availability of resources, even the renewable resources, if the rate of consumption is greater than the rate of renewal. The report emphasises that the free goods such as air and water are also resources and adverse impacts on them should be minimised.

The key issues of sustainable road freight transport are laid out by the UK Department of the Environment, Transport and the Regions in its sustainable distribution strategy (DETR 1999). According to the strategy, sustainable freight transport should:

- contribute to GHG reduction, meet air quality and noise standards and minimise waste and impacts on biodiversity (environmental target),
- promote growth, secure jobs, reflect costs of transport, ensure fair competition and cheap supply of goods through efficient system (economic target) and
- improve road safety, protect health, minimise the impact of noise, promote good access to goods and services and provide efficient distribution service to all (societal target).

Sustainable road freight transport is in a way a self-contradictory concept. This is because on the other hand it is a prerequisite for economic development and social equality, but on the other hand it inevitably causes negative environmental and social impacts. Road freight operations have several adverse impacts on people and environment. Trucks are involved in around 17% of fatal road traffic accidents in Finland (Statistics Finland 2010a). Trucks are also responsible for around 23% of CO_2 emissions from road transport in Finland, and the share is even higher for emissions of particulate matter and nitrogen oxides (LIPASTO 2011a). The most serious adversity is, however, the continuous growth in the environmental effects of road freight transport. Despite of the European strategies, freight transport and especially road freight transport is growing in Europe, thus increasing the environmental effects (Eurostat 2011).

3.2. Decoupling of economy and road freight transport

Road freight transport is closely interlinked with the economy, i.e. the growth in freight transport is caused by growth in the economy and freight transport enables economic growth. However, the link is seen to be weakening in the developed countries where decoupling of road freight transport volume and GDP has been seen (see e.g. Tapio 2005; Kveiborg & Fosgerau 2007; Sorrell et al. 2012). Decoupling has been made possible by decisions concerning product design, logistics network design and inventory management, which largely determine the environmental effects of freight transport prior to the physical transport of goods (Aronsson & Huge Brodin 2006). Partly this decoupling is due to off-shoring manufacturing from developed countries to developing countries (McKinnon 2007a), which suggests that the decoupling is happening in the developed countries but not globally. The off-shoring would not be possible without cost efficient transport, particularly shipping as a part of global trade. Cost efficient transport is generally also environmentally efficient, but this leads to a rebound effect: increasing the efficiency of transport operations decreases the environmental impacts and costs, which enables longer transport in order to gain from e.g. lower labour costs, which in turn increases the environmental impacts of transport. In order to prevent the rebound effect, it has been proposed that the freight transport should fully internalize the external costs it is responsible for. However, the rebound effect mainly occurs on a global scale and therefore actions against it are difficult to take. On a national scale a study in the UK by Piecyk & McKinnon (2007) revealed that trucks already more than cover their external costs to the infrastructure and the environment.

Decoupling has been studied in various countries using the decoupling framework developed by Tapio (2005). He presented the framework in the context of GDP and transport volume changes, i.e. changes in the transport intensity, and between transport CO_2 emissions and GDP, i.e. changes in CO_2 intensity (Figure 5).

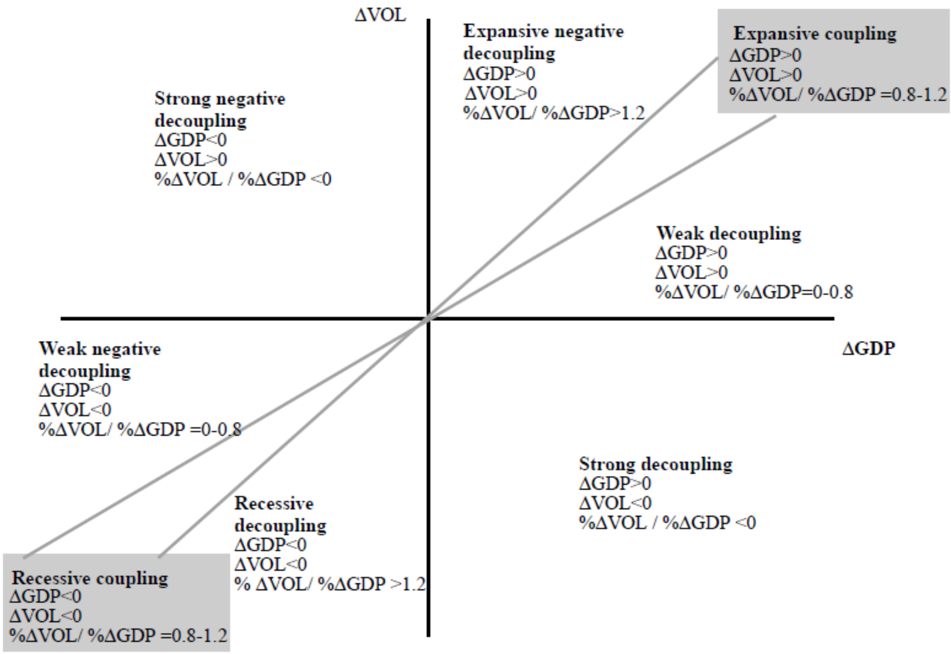

Figure 5. Decoupling framework (Tapio 2005).

The decoupling framework is a useful tool for analysing the sustainability of road freight transport, but on an aggregate level. The decoupling frameworks (Figure 6, Figure 7) utilised in this research are modified from Tapio (2005) and Finel & Tapio (2012). The framework is here utilised to analyse also the decoupling between energy consumption and transport volume, i.e. changes in energy efficiency, in addition to the transport intensity and CO_2 intensity decoupling analysis applied by Tapio (2005) and Finel & Tapio (2012). The framework illustrates sustainable development with green colour and the use of the term 'decoupling', while unsustainable development is illustrated by red colour and the term 'negative decoupling'.

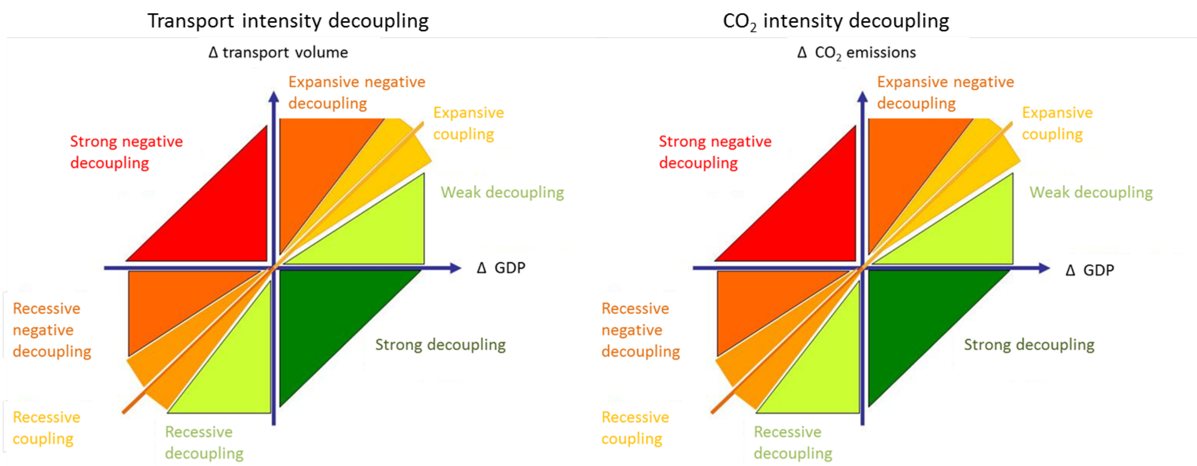

Figure 6. Transport intensity and CO_2 intensity decoupling frameworks (adapted from Tapio 2005, Finel & Tapio 2012).

In transport intensity decoupling analysis, if both GDP and transport volume (in tonne-kilometres) increase or decrease at the same time and their elasticity is 0.8-1.2, they are coupled. In this case the transport intensity remains fairly stable. If they change to different directions or at different speed, they decouple. Negative decoupling, i.e. unsustainable development, occurs when transport volume increases faster than GDP (or decreases more slowly), and transport intensity thus increases. Decoupling, i.e. sustainable development, occurs when transport intensity decreases, i.e. transport volume increases more slowly than GDP (weak decoupling) or when transport volume decreases even though GDP increases (strong decoupling) or when both decrease but volume deceases faster than GDP (recessive decoupling). Same definitions apply to the decoupling of CO_2 emissions and GDP when the term ‘transport volume’ is replaced by ‘CO_2 emissions’ (Figure 6).

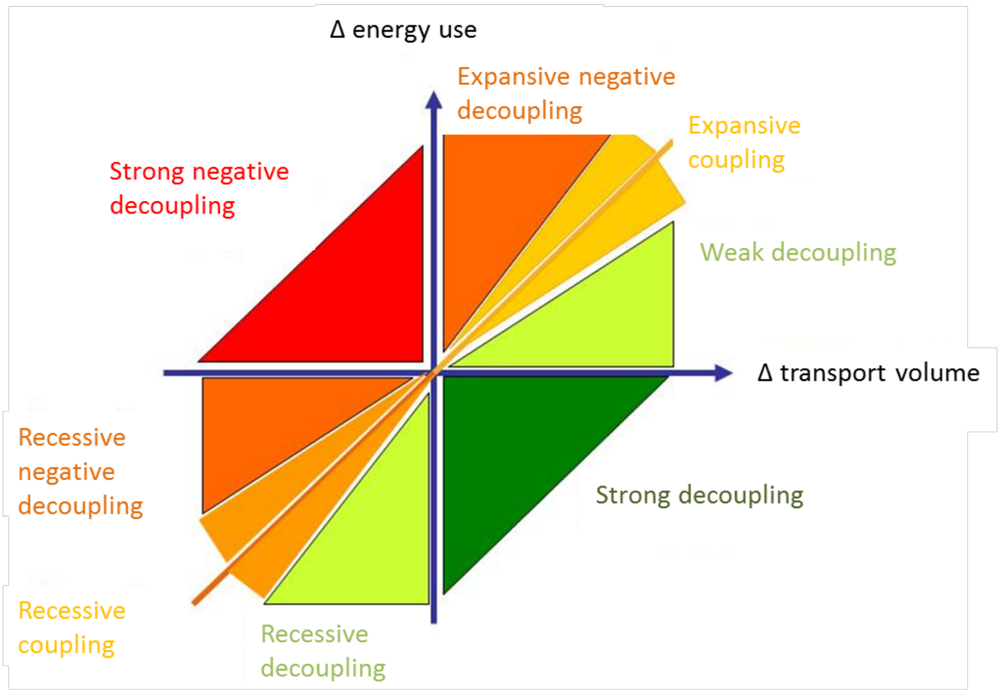

Figure 7. Energy efficiency decoupling framework (adapted from Tapio 2005, Finel & Tapio 2012).

In the case of energy efficiency decoupling analysis (Figure 7), the horizontal axis of the framework is changed from Δ GDP to Δ transport volume and Δ energy use is used in the vertical axis. Sustainable development, i.e. decoupling of energy use from transport volume, now occurs when both increase but energy use increases more slowly than transport volume (weak decoupling) or when energy use decreases even though transport volume increases (strong decoupling) or when both decrease but energy use decreases more rapidly than transport volume (recessive decoupling). Unsustainable development, i.e. negative decoupling of energy use and transport volume, occurs when both increase but energy use increases more rapidly than transport volume (expansive negative decoupling) or energy use increases although transport volume decreases (strong negative decoupling) or both decrease, but energy use decreases more slowly (recessive negative decoupling).

Even though the decoupling frameworks are useful tools for analysing the sustainability of road freight transport on an aggregate level, those do not reveal the reasons for decoupling. More detailed frameworks with several indicators explaining the changes in GDP, road freight transport volume and CO_2 emissions are required for that purpose.

3.3. Road freight decarbonisation framework

The decoupling framework presented in previous chapter is a useful tool for analysis on a national economy level, but it leaves the reasons for decoupling unanswered and difficult to grasp. Hence, a more detailed framework for analysing the various factors causing the decoupling is needed. There are a few frameworks available in academic literature illustrating these factors and their interactions. One such framework is presented by Richardson (2005) and aims to illustrate the systematic relationships, feedbacks and rebound effects of making changes to the freight transport system (Figure 8).

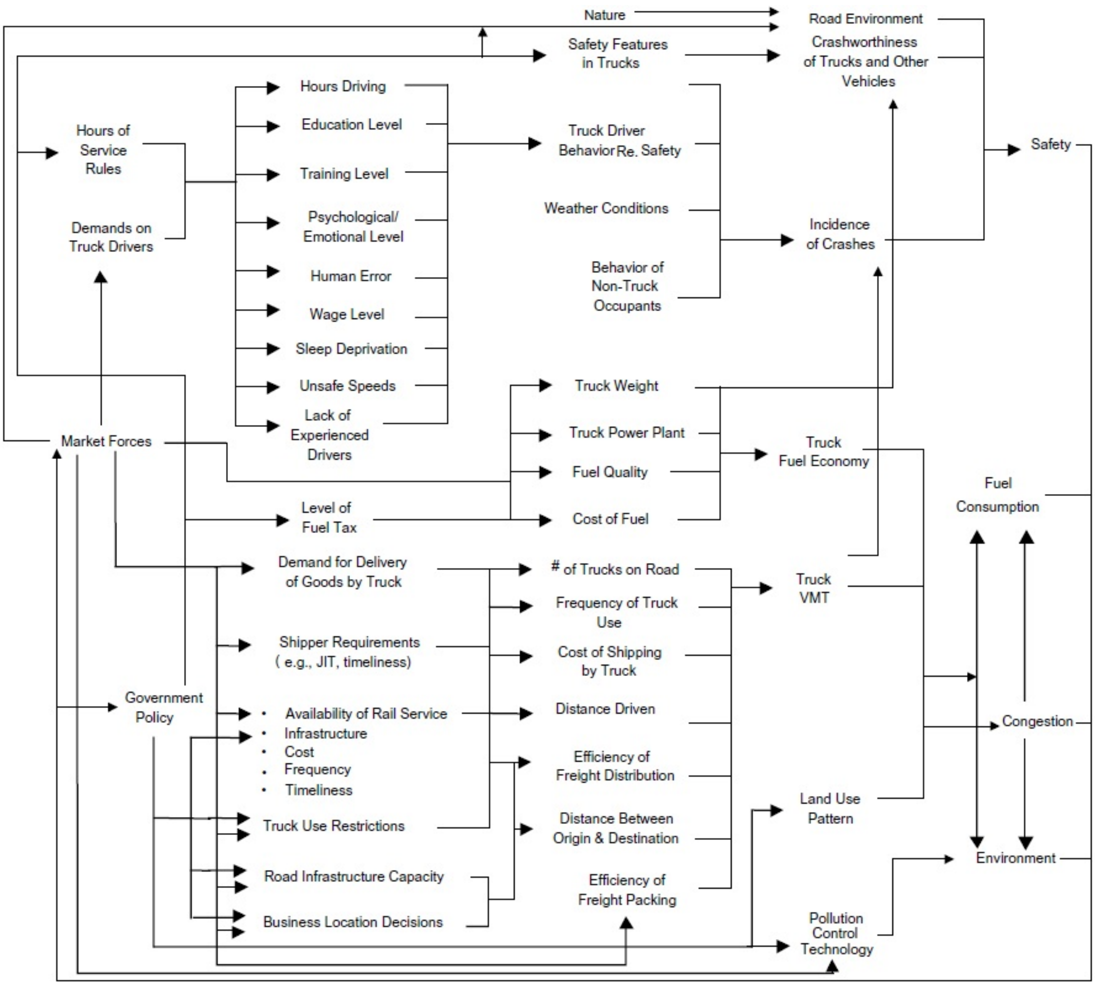

Figure 8. Freight sustainability framework (Richardson 2005).

Based on the framework Richardson (2005) argues that simple cause and effect approach will not be sufficient in developing sustainable freight transport. Richardson also highlights that government policy and market forces are primary factors affecting the mostly economic variables. Richardson's framework identifies several important determinants of sustainable road freight transport. However, it contains several variables which are very difficult to measure and the number of variables makes it also difficult to understand the interrelations of the variables. The framework is thus considered too complex for this research.

A widely accepted framework for analysing the relationships between the economy and road freight transport was introduced by McKinnon & Woodburn (1996) and further enhanced in a wide European research on the subject (REDEFINE 1999). Cooper et al. (1998) extended this framework to include the environmental effects and McKinnon (2010a) introduced also monetary valuation of the environmental effects for determining the external costs of logistics operations. The basic structure of the framework has, however, remained similar to the one used by Piecyk & McKinnon (2010) in their scenario analysis of the future of road freight transport emissions in Britain (Figure 9). Piecyk & McKinnon (2010) use seven key variables which they forecast to 2020 to produce alternative scenarios for CO_2 emissions.

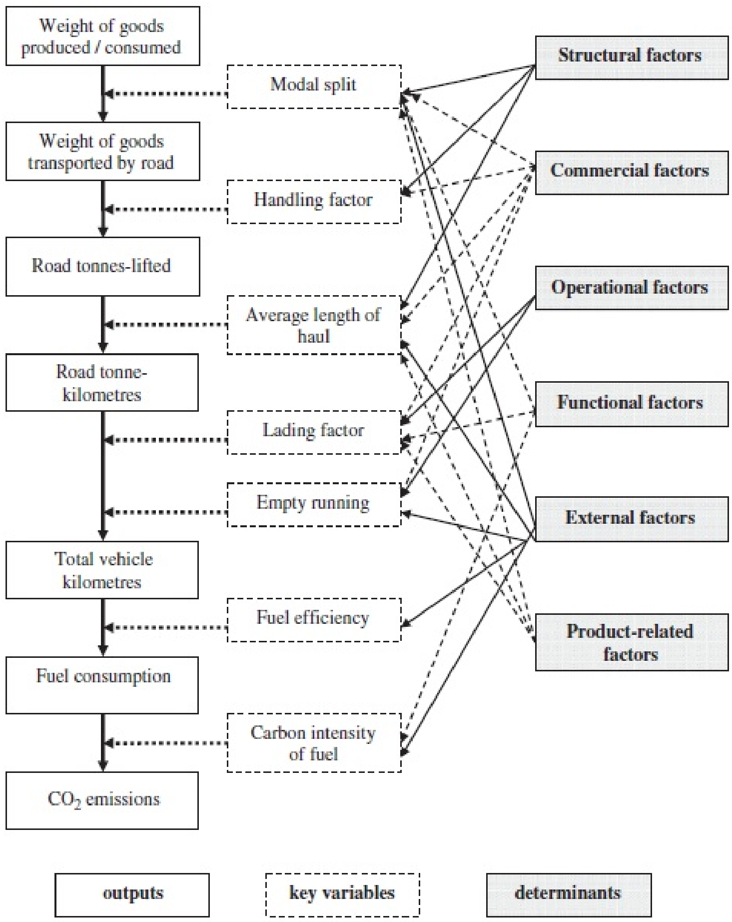

Figure 9. Analytical framework of economical performance, logistics parameters and freight transport externalities (Piecyk & McKinnon 2010).

Piecyk (2010a) adds one more output and key variable to the top of this framework, namely the value of goods produced/consumed as an output and value density as a key variable determining the weight of goods produced/consumed. This framework has been proven to be useful in forecasting the future of road freight transport as it is simple yet provides comprehensive view of the affecting factors. Hence, this framework is used in this research with a few modifications.

The framework used in this research (Figure 10) is similar to the one Piecyk (2010a) used, but the term 'output' has been changed to 'aggregate' and 'key variable' to 'indicator'. An addition of three 'key indicators' has also been made in order to enable decoupling analysis using the decoupling frameworks presented in the previous section. The 'lading factor' has been replaced with 'average load on laden trips' and a new aggregate of 'laden mileage' has been added between road tonne-kms and total mileage. Furthermore, the handling factor is omitted from the framework as no distinction between 'weight of goods transported by road' and 'road tonnes-lifted' can be made with Finnish data.

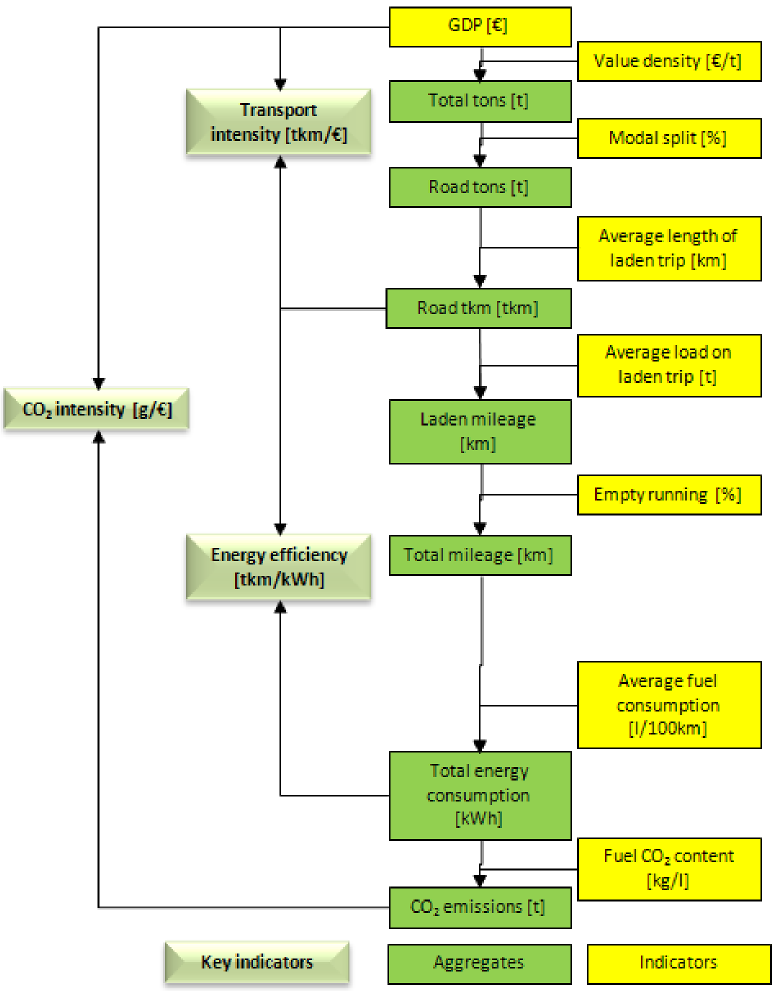

Figure 10. Road freight decarbonisation framework (adapted from Piecyk 2010a; Piecyk & McKinnon 2010).

3.3.1. The indicators and key indicators

The decarbonisation framework disaggregates the link between the economy and CO_2 emissions of road freight transport into 8 indicators. The first indicator is **Gross domestic product (GDP) or added value** in Euros using fixed prices to enable time series analysis. GDP is widely used indicator for the national economic output and it has usually been categorised in the decarbonisation framework as an aggregate or output value, but it is actually a variable which needs to be forecasted unlike the aggregates of the framework which are calculated as results of forecasted indicator values.

The **value density** is in this research defined as the ratio of GDP and the total weight of goods *transported* within Finland by all modes of transport. This definition differs from the one used by e.g. Piecyk (2010a), who defines value density as the ratio of GDP and total weight of goods *produced*. This difference is because of the fact also highlighted by Piecyk, namely that there is lack of data of the weight of goods produced in many countries, including Finland. Hence the indicator called 'handling factor', i.e. the ratio of weight of goods transported and produced, is also omitted from this framework. The value density is expressed as the unit €/t.

The **modal split** is here defined as the percentage of total weight of goods transported by road. The energy efficiency and CO_2 emissions of other modes than road freight can be studied using a similar framework as in Figure 10 for each mode. However, the scope of this study is the road freight transport because it is the most important mode of freight transport in Finland, accounting for approximately 90% of total weight of goods transported and 86% of freight transport energy consumption (FTA 2010; own calculations based on LIPASTO 2010).

Average length of laden trips expresses the average distance which trucks travel on one trip. It is calculated by dividing the mileage of laden trips with the number of laden trips. Average length can also be calculated by dividing the road haulage (tkm) with weight of goods transported by road (see e.g. Piecyk 2010a), but this method is slightly misleading as the payload and type of trip (long haul or pick up/distribution round) affect the road haulage.

The fifth indicator in the decarbonisation framework is the **average load on laden trips**, which is expressed in tonnes. It is calculated by dividing the weight of goods transported by road with the number of laden trips. This actually gives the value for the average maximum load on laden trips, i.e. the changes in the load during a pick up/distribution trip are not taken into account. Changes in the load during trip can be taken into account if the average load is calculated by dividing the road haulage with mileage of laden trips, as in e.g. Piecyk 2010a. The difference in average load and average length of laden trips calculated with the different methods described above is about 10%, the values calculated based on the number of laden trips being 10% smaller than values calculated based on road haulage. This difference in the calculation methods should be taken into account if international comparisons are made. The average load on laden trips can be disaggregated to vehicle utilisation rate, or 'lading factor', and the average maximum capacity of trucks. Vehicle utilisation rate is the ratio of actual load and maximum load.

Empty running is the percentage of total mileage run without load. It is a characteristic feature of road freight transport as goods, unlike persons, almost never return to the point of origin. Average load and empty running are sometimes analyzed together as a single vehicle utilisation indicator. One such indicator, proposed by Leonardi & Baumgartner (2004), is "the efficiency of vehicle usage" indicator, which is calculated by dividing tonne-kilometres by mass-kilometres, mass meaning the sum of vehicle's own weight and payload. However, some valuable information may be lost by doing this, because even though empty running and average loading are interrelated, they are also determined by separate affecting factors.

Average fuel consumption is the amount of fuel needed for the trucks to travel certain distance. In this study the unit l/100km is used. Average fuel consumption is the result of a very complex system of e.g. engine, vehicle design, driving behaviour, vehicle loading and traffic conditions. There is usually no direct data available in road freight statistics on the fuel consumption, so it has to be estimated separately. One method for doing this is presented in Chapter 4.

The last indicator in the decarbonisation framework is the **fuel CO_2 content** which expresses how much carbon dioxide is emitted when burning one litre of fuel. In Finland, as in many other countries, the fuel used in trucks is virtually solely diesel. Diesel has a fixed CO_2content of 2.66 kg/l (LIPASTO 2011b). Biodiesel or some other alternative fuels may replace some or all of diesel and change the CO_2 content.

In addition to the eight indicators, three key indicators are defined. These key indicators enable analysis of the issue on more aggregate level and can be used especially in decoupling analysis. On the most aggregate level, **CO_2 intensity** can be analysed to find out whether *decarbonisation*, i.e. the decoupling of road freight transport CO_2 emission from economic growth (Tapio et al. 2007), has occurred. CO_2 intensity is the ratio of road freight CO_2 emissions and GDP (g/€), so decreasing CO_2 intensity means decarbonisation has occurred. However, usually some additional information about the reasons for decarbonisation is wanted and the simplest way of doing this is by introducing the key indicators of **transport intensity** and **energy (or CO_2) efficiency**. Until recently the changes of energy and CO_2 efficiency were the same due to the fixed CO_2 content of diesel, the only energy source used in trucks, but biofuels are increasingly used and need to be taken into account in the future.

Transport intensity is the ratio between road haulage (tkm) and economic output (GDP). It expresses the changes in the **demand** for road freight transport in the economy (Piecyk & McKinnon 2009, Åhman 2004, Stead 2001, Tapio et al. 2007, Kveiborg & Fosgerau 2007, Sorrell et al. 2012, McKinnon 2007b). Tapio et al. (2007) use the term *immaterialisation* of a situation where decoupling of road haulage from economic growth occurs.

Energy efficiency expresses the changes in the efficiency of the **supply** of road freight transport. Also the term *dematerialisation* can be used to describe the decoupling of transport CO_2 emissions (or energy consumption) from road haulage (Tapio et al. 2007). Energy efficiency is defined in the Energy Services Directive (2006/32/EC) as "a ratio between an output of performance, service, goods or energy, and an input of energy". The energy efficiency of road freight transport is thus generally the ratio between road haulage and energy consumption, indicated as tonne-kilometres per kilowatt-hours [tkm/kWh]. This can also be turned other way around to energy intensity [kWh/tkm], which is consistent with some previously proposed indicators. Other possibilities for indicating the same subject include energy intensity [MJ/tkm] by Kamakate & Schipper (2009), fuel efficiency [koe/tkm] (koe means kilograms of oil equivalent) and emission efficiency [g CO_2/tkm] by Perez-Martinez (2009) as well as CO_2 efficiency [tkm/kg CO_2] by Leonardi & Baumgartner (2004). All these indicators are interdependent as the current major fuel of road freight vehicles, diesel, has fixed energy content (approximately 10.1 kWh/l, 36.3 MJ/l or 0.87 koe/l) and produces a fixed amount of CO_2 (2.66 kg/l) when burned in the engine (LIPASTO 2011b).

3.3.2. Limitations of the decarbonisation framework

The decarbonisation framework disaggregates the relationship between the economy and CO_2 emissions into indicators which can be analysed to find out the causes for changes. However, by reducing the number of indicators to the eight used here and simplifying the complicated interactions of these indicators some complexity may be lost. One should be cautious not to lose sight of the various feedback loops between the indicators illustrated by Richardson (2005). For example, the value density affects the modal split as high value goods are more often transported by road or air (van Essen et al. 2009) and the average load on laden trips and share of empty running affect the average fuel consumption (Coyle 2007). While the framework includes the modal split, other modes of transport than road freight are omitted from the framework, but similar analysis can be made to other modes and changes in indicators in other modes can affect road freight. The geographical scope of the study is also an important issue, as highlighted in the earlier discussion about off-shoring. It can be seen from the various studies cited by Lehtonen (2008) that analyses have mostly been made on national level as the data is best available for that scope. As van de Riet et al. (2008) point out there is limited and scattered data available for freight analysis because of a variety of units for measuring freight movements, confidentiality issues, various decision makers involved in a shipment and different types of loads. The solution they propose is to combine both quantitative and qualitative data from several sources.

The framework has mainly been utilised for studying the changes that have affected the road freight transport sector. It has also been used somewhat, and increasingly, for forecasting the future development of road freight transport and its environmental effects, mainly CO_2 emissions. Piecyk (2010a) forecasts the CO_2 emissions of road freight transport in the UK by combining focus group discussions, Delphi survey, scenarios and spreadsheet modelling with the framework. This variety of methods was chosen since the accuracy of forecasts which rely on trend extrapolation or linking freight transport with economic development was considered low. This was because extrapolation and linkage only are useful in stable conditions with continuous trends but road freight transport has changed over the past decades and is likely to change in the future due to e.g. globalisation and climate change mitigation. Morcheoine & Chateau (2008) also highlight this aspect as they point out that the elasticity of freight transport to GDP changes over time in relation to the maturity of commercial exchange between countries. This has to be taken into account when building long-term business-as-usual scenarios, but on short-term (10-15 years) scenarios they see elasticity having only a minor effect.

3.4. Decarbonisation of road freight transport

There is wide variety of measures for decarbonising road freight transport. For example, a decarbonisation model by Heriot-Watt University and Freight Transport Association presents 36 decarbonisation measures which may be applied by logistics companies (FTA 2012). International Energy Agency presents 26 policy measures and analyses the complex outcomes of these measures (IEA 2009). British Freight best practice programme's Fuel Ready Reckoner presents 28 decarbonisation measures for fleet management and analyses their interrelations as well as ease and cost of implementation (DfT 2010a). Leonardi et al. (2006) list 76 decarbonisation measures affecting various indicators of the decarbonisation framework. These examples highlight that each indicator of the decarbonisation framework can be affected in many ways to change the indicator towards more sustainable direction.

3.4.1. Gross domestic product

The necessity of economic growth (measured by GDP) has been the dominant paradigm in politics since the Second World War. GDP is widely, albeit incorrectly, identified with social welfare and hence the need for growth is taken for granted. However, there is a growing critique towards GDP for being inadequate to capture human welfare and continuous growth for leading to environmental and social problems. Several alternatives for GDP have been developed, including e.g. the Index of Sustainable Economic Welfare (ISEW), Sustainable National Income (SNI), Genuine Savings (GS) and Human Development Index (HDI). Economical and social concerns have lead to the emerging idea of *degrowth* which is defined as "*an equitable downscaling of production and consumption that increases human well-being and enhances ecological conditions at the local and global level, in the short and long term.*" (Schneider et al. 2010, van den Bergh 2009.)

Downscaling of production and consumption of goods results in decreasing GDP and would decrease the demand for road freight transport. An example of this can be seen in Finland as a result of the global economic crisis in 2008-2009. The GDP decreased 8% year on year, while the total weight of goods transported decreased 18%. However, it seems highly unlikely that any government in Finland would take downscaling of production and consumption as a policy measure for decarbonising road freight transport in the foreseeable future because the new Finnish government foresight report has a theme of sustainable growth (Prime Minister's Office 2012) and the two opposition parties in the Finnish parliament also highlight economic growth in their programme statements (True Finns 2011, Keskusta 2012). Because of this, measures for decreasing GDP are not considered further.

3.4.2. Value density

Decarbonising road freight transport through increasing the value density is politically much more acceptable than through decreasing GDP. When value density is considered, it is essential to distinguish between changes on national and global scale. On both national and global scale, decarbonisation through increasing value density may occur if (Cogoy 2004, McKinnon 2007a, IEA 2009):

- lighter materials are used to produce same goods,
- smaller goods are produced to fulfil the same purpose,
- goods are substituted with services and
- the effect of these changes is greater than the growth of consumption (GDP).

Off-shoring of manufacturing to other countries while maintaining the headquarters of the company in Finland decreases the weight of goods produced and transported in Finland, but maintains the level of GDP generated in Finland and maintains the weight of goods produced on global scale. The effect of off-shoring on the global total haulage (tkm) is yet another matter, as it depends on the locations of raw materials, production and final consumption, and thus the handling factor (ratio of weight of goods transported and produced) and the average length of trips. The handling factor can be reduced through (McKinnon 2008, IEA 2009):

- disintermediation, i.e. eliminating links in supply chains,
- vertical integration, i.e. locating interrelated processes on the same site and
- decreasing intermodality, i.e. eliminating road feeder movements by connecting or relocating the site to railroad, port or airport.

3.4.3. Modal split

Modal split affects the energy efficiency and CO_2 emissions of road transport as it defines what kinds of goods are transported in each transport mode. Waterway and rail transport are generally considered to be more energy efficient than road transport, but this view is also questioned. The energy efficiency is highly dependent on the utilisation of payload capacity in each mode. With average loading, rail transport has the lowest CO_2 emissions per tonne-km, closely followed by coastal shipping and inland waterways, while trucks have considerably higher emissions and vans far higher still (McKinnon 2007b, LIPASTO 2010). The research by Spielmann et al. (2010) indicates that no mode of freight transport can be categorically designated as the most environmentally friendly. Also McKinnon (2008) highlights that the potential for decarbonisation through modal shift depends on:

- energy intensity of the mode,
- carbon intensity of the energy source,
- utilisation of equipment and
- energy use of modal interchange.

This has to be taken into account when considering the energy efficiency and CO_2 emissions of different modes. It can also be seen for instance in EU's transport policy that it is desired from the ecological perspective to promote co-modality, the efficient use of transport modes on their own and in combination (COM/2006/0314; COM/2007/0607). If sufficient decarbonisation potential is available, modal shift can be promoted through infrastructure investments and direct support for rail and waterways equipment purchase and operation (McKinnon 2008).

3.4.4. Average length of laden trips

The average length of laden trips is mainly affected by the geographical scale of sourcing and market areas of production as well as the location of production sites. Globalisation of sourcing and markets with centralisation of production and warehousing has been the major trend in global economy (McKinnon 2008). These changes may decrease or increase the average length of haul on national scale and it is very difficult to influence these changes. Furthermore, the changes in average length of haul influence the modal split, vehicle loading and level of empty running, so it is very difficult to implement decarbonising policy measures directed at the average length of laden trips (McKinnon & Ge 2006, McKinnon 2008, Piecyk 2010a).

On haulier level, decreasing the average length of laden trips is possible by improving the vehicle routing and scheduling, possibly with the help of optimisation software (Computerised vehicle routing and scheduling, CVRS). Also relocating distribution centres, using a hub and spoke network and participation in open cooperation networks are possible decarbonisation measures, which also affect the vehicle loading and empty running. CVRS system is estimated to reduce the total mileage by 5-15% and relocation of distribution centres may result in similar reductions of total mileage. (FTA 2012, McKinnon 2008, Leonardi et al. 2006.)

3.4.5. Average load on laden trips

Increasing the average load on laden trips increases the fuel consumption on l/100km basis, but decreases the mileage required to perform the same haulage (tkm) and thus improves the energy efficiency (tkm/kWh) and decreases the total CO_2 emissions. Average load is here considered in terms of weight, although in many cases the area or volume of the cargo space is the limiting factor rather than maximum weight (IEA 2009, McKinnon & Edwards 2010). However, data on volumetric vehicle fill is not available on sufficient level of detail for analysis. Average load may be disaggregated further to maximum payload weight and vehicle utilisation rate. This disaggregation may be helpful as the largest trucks are not suitable for every operation, e.g. in urban areas, and hence the changes in the average load may be caused by necessary changes in average maximum payload weight of the fleet.

Opportunities for decarbonising road freight transport through increasing average load on laden trips are numerous, but mainly constrained by the the inter-functional relationships between transport and other business activities (McKinnon 2008). Increasing the transport cost through fuel taxation or road user charging may be used as policy measures to increase the importance of vehicle utilisation. Other policy measures include allowing larger trucks and relaxing access restrictions, as well as promoting better vehicle loading through awareness campaigns and benchmarking information. (IEA 2009.)

Policy measures can only guide companies to improve their vehicle utilisation, but better results are gained if companies realise the potential cost savings and implement measures such as:

- nominated day delivery system, which decreases the inefficiency caused by demand fluctuations (McKinnon & Edwards 2010),
- more space efficient cargo handling equipment and packaging, which reduce the need for packaging without compromising the protection of goods from damages (McKinnon 2008, FTA 2012),
- double deck trailers, which allow stacking pallets or roll cages to better utilise the maximum payload weight (FTA 2012),
- intra- and inter-company cooperation, which decreases the inefficiency caused by geographical imbalance of goods flows and lack of inter-functional coordination (McKinnon & Edwards 2010, McKinnon 2008, Leonardi et al. 2006) and
- lightweight vehicles, which decrease the own weight of the vehicle and increase the maximum payload weight for transporting more high density goods (FTA 2012).

3.4.6. Empty running

Most reasons for inefficiency and decarbonisation measures mentioned for the average load on laden trips also apply for empty running, but empty running is even more dependent on the inter-company cooperation. The potential for increasing backloading and reducing empty running is not fully utilised quite simply because there is a lack of knowledge of available loads. Even if there is such knowledge, backloading may not be realised because outbound delivery is prioritised and there is an increased risk for delays with backloading. Also the vehicles or cargo handling equipment may not be suitable for the backloading products, or the driver's working hours limit the possibilities for backloading. (McKinnon & Ge 2006.)

Inter-company cooperation through outsourcing of freight operations to a logistics service provider or through establishing a network of hauliers improve the sharing of knowledge on backloads. Also wider use of web-based tendering of freight transport services improves the level of knowledge. Increased visibility of freight operations and cooperative efforts for avoiding delays can be used to develop confidence between the shipper and haulier and thus make backloading more acceptable. Empty running also decreases when reverse logistics, such as recycling of packaging waste, reuse of handling equipment or refurbishment of products increases. Transport policy may affect the empty running by increasing the cost of transport, relaxing the working time and cargo handling restrictions as well as by standardising cargo handling equipment. (McKinnon & Ge 2006, McKinnon & Edwards 2010, IEA 2009, Leonardi et al. 2006.)

3.4.7. Average fuel consumption

In addition to the vehicle loading, the fuel consumption is determined by three main factors: traffic conditions, vehicle specifications and driver's behaviour (Leonardi & Baumgartner 2004). Traffic conditions include road geometry and traffic flow. Road geometry affects fuel consumption mostly in hilly terrain, but also winding roads may cause braking and acceleration which increases fuel consumption. Traffic flow is affected by the number and behaviour of other road users and by the regulation of traffic flow, i.e. traffic lights, speed limits, etc. The effects of road geometry are minor compared to the effects of irregular traffic flow. The fuel consumption is lowest at average speed of around 70 km/h and the consumption increases by about 50% if the average speed reduces to 20 km/h and more than doubles with average speed of 10 km/h (JAMA 2008). A Finnish research found that the fuel consumption of an 18 ton delivery truck increased by about 33% from highway cycle to delivery cycle (Erkkilä et al. 2008). Hence, transport policy may decarbonise road freight transport by investing in road infrastructure, improving road traffic management, introducing road user charges and relaxing restrictions for night deliveries (IEA 2009). Hauliers, on the other hand, may use dynamic vehicle routing to avoid congested roads and negotiate with their customers to reschedule the deliveries. These measures may result in fuel savings of around 6%. (Leonardi et al. 2006, Palmer & Piecyk 2010, FTA 2012.)

Vehicle specifications affect the fuel consumption in numerous ways. Firstly, there are significant differences in the fuel consumption between the new trucks of different brands (Erkkilä et al. 2008). Unfortunately, there are no standards or tests for the fuel consumption of trucks in place in Europe, so no objective information is available for hauliers. Only Japan has introduced standards for trucks and significant reduction in fuel consumption is expected to be achieved (IEA 2007a). Historically, the fuel consumption of trucks has improved by around 1% annually, but this development may be disrupted because of the tightening limits for NO_x emissions (IEA 2007a). However, there are several possibilities for improvements in truck engine and transmission, such as: downsizing, supercharging and automated manual transmission, which combined result in substantial fuel savings (RICARDO 2009, IEA 2007a). The improvement with greatest fuel saving potential is hybrid electric powertrain. Potential fuel savings range from 5% to 30% depending on the duty cycle. Greatest savings can be achieved in urban delivery operations. (RICARDO 2009.) Truck manufacturers are responsible for the development of truck powertrain, but the hauliers may decarbonise their operations by purchasing trucks with low consumption and the government can help hauliers to make the right decision by introducing fuel consumption standards. In addition to engine and transmission, there is a variety of measures which the haulier can implement to achieve considerable fuel savings. Table 5 summarises some of these measures and their potential fuel savings.

Table 5. Fuel saving measures and potential savings (FTA 2012, RICARDO 2009, DfT 2010a, RASTU 2009).

		Potential savings			
		DfT 2010	RICARDO 2009	FTA 2012	RASTU 2009
Aerodynamics	Under-run air dam	<1%			
	Cab roof fairing	4%	7%	4%	
	Cab side edge turning vanes	<1%			
	Body/trailer side panels	<1%		1%	
	Body/trailer front fairing	3%			
	Tipper sheeting systems	<1%			
	Teardrop trailer	10%	10%	6%	
	Sloped roof trailer	5%		5%	
	Reduce height of vehicle			3%	
	Spray suppression flaps	2%	4%		
Tyres	Fuel efficient tyres (all axles)	3%	5%	2%	4%
	Super single tyres	2%	6%	2%	
	Tyre pressure management	1%	7%	2%	
	Regrooving tyres	1%			
	Wheel alignment	4%			<2%
Other	Synthetic engine oil	2%	2%	<1%	
	Anti-idling campaign	2%		3%	
	Speed limited to 84 instead of 90 km/h	<1%		<1%	5%
	Reduced vehicle own weight			1%	1% per 1t

Drivers' driving behaviour has a great effect on fuel consumption. The difference between drivers can be up to 30% (Liimatainen 2011). Because of this, many companies have implemented ecodriving training and gained 5-15% short-term fuel savings. However, the effects of ecodriving training often decrease to about 5% in long term if the driving behaviour is not monitored and feedback is not given. (IEA 2007b.) Regular monitoring can also include an incentive system for drivers. Brown & Coyle (2004) conducted an extensive survey about drivers' incentive systems in Great Britain. Only six companies out of 88 had an incentive system aimed at reducing fuel consumption. Two surveys from Canada show similar results. According to Barton et al. (1998) only one company out of 40 had fuel reduction incentive systems. In a latter survey by Canadian Office of Energy Efficiency OEE (2000) the figures were 10 out of 42. According to Brown & Coyle (2004) transportation companies are interested in implementing incentive systems and 58 % of the companies think that such a system would certainly or possibly be beneficial for the company. Brown & Coyle (2004) also identified some challenges facing incentive systems that are operated within transportation companies. The greatest challenges were: complexity of implementation, lack of accurate consumption data and lack of information on how to operate such a system. Monitoring drivers' performances fairly is a complex matter. Technical issues may cause difficulties and even if these problems are solved, incentive systems are often criticized for unfair comparison between drivers. Unfairness is a difficult problem to solve owing to the complexity of measuring drivers' performances. Weather, traffic, road geometry, vehicle and load carried are all constantly changing independent of a driver's actions but each can have a considerable effect on fuel consumption. Nevertheless, current on-board computers enable taking these issues into account to establish a fair incentive system (Liimatainen 2011). Policy makers can promote ecodriving through awareness campaigns, mandatory ecodriving as part of driving license training and fiscal incentives for purchasing of on-board monitoring equipment (IEA 2007b).

3.4.8. Fuel CO_2 content

The last indicator in the framework is the carbon dioxide content of fuel. Road freight transport may be decarbonised by using alternative fuels such as biodiesel, natural gas or electricity. Electric vehicles depend on batteries, which are heavy and also quite large but still have very limited range (Cullinane & Edwards 2010). These characteristics make them unsuitable for transporting heavy goods over long distances, but possible to exploit in urban distribution operations. However, the decarbonising effect of electric vehicles depends on the source of electricity.

Natural or biogas vehicles have a greater range than electric vehicles, but require large investments in distribution infrastructure. Natural gas has about the same CO_2 content as diesel and thus does not have decarbonising effect. Biogas, on the other hand, reduces methane which would otherwise be emitted from waste disposal process and thus reduces greenhouse gases, but the production of biogas is still very limited. (Cullinane & Edwards 2010, IEA 2009.)

Biodiesel is currently the most viable option for decarbonising road freight transport through decreasing the CO_2 content of fuel. Biodiesel may be produced from various sources, including vegetable oil, frying oil and animal fat and the CO_2 reduction depends on the source. The EU directive 2009/30/EC defines that biofuels should reduce well-to-wheel GHG emissions by at least 35% and the well-to-wheel GHG emission savings from biodiesel are typically 30-70% compared to fossil diesel. However, the savings may be much smaller when the changes in land use are taken into account. Nevertheless, biodiesel has advantages as an alternative to diesel. Firstly, it is partly or completely compatible with the current diesel engines and it uses the same distribution infrastructure. Secondly, it can be produced from waste or cellulosic crops so it does not compete with food production or require land use change. Because of these issues, biodiesel is already widely used blended with fossil diesel and its use is likely to increase. The political pressure for increasing the use of biodiesel is certainly great due to its benefits in decreasing the oil dependency and increasing the number of sources of energy and domestic self-sufficiency of energy. (Cullinane & Edwards 2010, IEA 2009, 2009/30/EC, McKinnon 2008.)

3.5. Company-level monitoring of decarbonisation

The decarbonisation framework is suitable for monitoring the development of road freight energy efficiency and CO_2 emissions in a national transport policy setting. It can also be used in a company setting (Tacken et al. 2011), but this requires data which may not be available or even of interest to shippers or hauliers. Growing interest towards carbon auditing of products and supply chains may provide new data usable in the decarbonisation framework on company level.

Environmental reporting and measures to reduce the environmental impacts of businesses have become an important part of corporate social responsibility. The global challenge of climate change drives governments to set reduction targets for carbon dioxide emissions. Media coverage of climate change has exploded in the 21st century making consumers increasingly environmentally conscious. These trends continuously increase the pressure in companies to develop their environmental reporting and reduce their environmental impact. Some companies have responded to these challenges by publicising efforts to equip their products with carbon labels (McKinnon 2010c; Aitken 2008; WEF 2010a). Also governments in several countries have been actively promoting carbon labelling of products (McKinnon 2010c). Finnish government, for example, included a statement for promoting development and piloting of carbon labelling in its foresight report on climate and energy policy. (Finnish government 2009).

There are currently some international guidelines for carbon auditing issued by e.g. British Standards Institution (PAS 2050), World Business Council for Sustainable Development (Greenhouse Gas Protocol), International Organization for Standardization (ISO 14064:1) and Carbon Trust. However, none of these guidelines has become a dominating global standard. These guidelines are also quite general and leave several important decisions to the company performing the carbon auditing. (Piecyk 2010b; WEF 2010a.) Product-level carbon auditing sets challenges also for monitoring and reporting the environmental effects of logistics operations. McKinnon (2010c) identified the following five major problems:

- boundaries: what is the scope of auditing
- allocation: how to allocate emissions for products using same vehicles, warehouses etc.
- variability: how to keep up with rapid changes in supply chains
- scalability: how to carry out audits for extensive product ranges
- cost: is it worthwhile to invest great amount of resources to perform audits

Because of these problems McKinnon considers product-level carbon auditing as a wasteful distraction that can take resources away from much more efficient decarbonisation measures, which can be identified on a supply chain level.

Within the logistics sector, introducing environmental labelling of transport services could facilitate the comparison of different transport options and shippers may even be willing to pay a little extra for more environmentally friendly transport. This willingness is not enough to cause modal shift, however. (Fries et al. 2009.) The same ambiguity of guidelines that is the reality for carbon auditing in general, is also the case within logistics sector. There are two major guidelines for reporting environmental performance in transport chains, one by the European Committee for Standardization (CEN 2010) and the other by World Economic Forum (WEF 2010b).

The CEN guidelines state as a general principle that the calculations, results and data sources should be presented in a transparent way to enable the evaluation of the environmental performance of transport operation. Furthermore, the method used for calculating energy consumption and emissions for one customer should be such that when calculating those for all customers, all the energy and emissions from the company are accounted for. However, no method for conducting such calculations is presented. Also, the recommendations for contents of a declaration of energy consumption and emissions from a transport operation are presented, but leave many decisions for the company to make. Minimum requirements for a declaration of a road transport operation are as follows (CEN 2010):

- transport profile (identification of transport; amount of goods in e.g. l, kg, t or m^3)
- description of vehicle (EURO standard or year of production and/or engine rating in kW; type, weight or dimensions in e.g. empty and gross weight and volume)
- basic transport data (transport distance in km; transport work in e.g. tkm)
- calculated transport data (use of energy in e.g. l, l/km, km/l, MJ or kWh; emissions of CO_2, NO_x, SO_2, HC, CO and PM in g or kg; capacity utilization with maximum or average load; percentage of empty running)
- documentation of calculation method and data used (specific data; description of data sources, system boundaries and calculation methods)
- issuer responsible for declaration (identification of company and/or person)

WEF guidelines are intended to promote consistency in reporting carbon emissions on consignment or customer level and to complement existing or upcoming reporting standards. Similarly to CEN guidelines, the general principles in WEF guidelines are transparency and the allocation of all the emissions within the company and its subcontractors. For road freight operations the allocation of emissions for each consignment or customer is said to be done based on tonne-kilometres. However, no method for calculating or allocating tonne-kilometres e.g. on a multiple-stop distribution operation is presented. Another possible allocation unit is said to be dimensional weight, which can be company's own dimensional factor. In addition, backhaul operations can be allocated on the basis of economic values of related consignments. The scope of the reporting should include

GHG Protocol scopes 1 and 2, i.e. the direct emissions from fuel consumption and the indirect emissions from electricity generation. (WEF 2010b.)

In addition to these guidelines, there are several online calculation tools and other sources of information for energy consumption and emission factors for different transport modes (see e.g. EcoTransIT 2010, LIPASTO 2010, NTM 2012). However, guidelines on how to actually measure the energy consumption and emissions, and allocate them to consignments or customers, on a company level seem to be virtually non-existent. General guidelines assume that companies have the information on e.g. dimensions of each consignment and fuel consumption from every single journey, which is not the case in most companies. Some attempts have been done to develop the information systems needed for CO_2 measuring and allocation based on actual data, but it seems likely to take a long time for such systems to become commonplace (Yoshifuji et al. 2008; Goto et al. 2006).

In theory, carbon footprinting should not be difficult for LSPs to carry out. The data required for carbon footprinting is the same that is needed to monitor the efficiency of vehicle usage, fuel consumption and driver behaviour. Thus the data should be already available in every company. According to Yoshifuji et al. (2008) three interacting processes are needed to calculate consignment-level carbon footprint:

1. Fuel consumption measurement for each section of a delivery round
2. RFID-based identification of consignments upon loading and unloading
3. Calculation system and database for allocating the fuel consumption to consignments

However, the data collection doesn't have to be as sophisticated as Yoshifuji et al. suggest. Consignment-level carbon footprinting is possible when the following data is available: fuel consumption (l) for the trip (consumptions for each leg of a trip are even better), the weight (kg) of each consignment, distance (km) between customers and between each customer and terminal. In addition, it would be beneficial to have the information on the dimensions of each consignment or on the type of handling unit for volume-constrained cargo. It is also beneficial if there are various descriptive data, such as the own weight and EURO-class of the truck and identification of the driver and route. Descriptive data is not necessary for carbon footprinting but it enables in-depth analysis of the determinants of carbon footprint and thus actions to reduce it. DEFRA (2010) claims that exact consignment-level allocation of CO_2 emissions would require more data than most transport operators collect, making it theoretically possible but 'certainly not practical'. The shipper and haulier surveys of this study aim to find out how the Finnish shippers and hauliers have taken the environmental issues, including monitoring and reporting, into account in their operations.

3.6. Conclusions

The reviewed literature showed that the previous research on the future of road freight transport energy efficiency and CO_2 emissions has focused mainly on national and transport policy level analysis. However, the future of the issue is largely determined in the interaction between the shippers and hauliers with the policy measures setting the regulatory boundaries for the decisions made in the companies. Hence, it is necessary to gain deeper understanding of the shippers' and hauliers' attitudes, practices and future plans regarding the environmental effects of logistics in order to find out if the policies are seen by shippers and hauliers as factors directing the logistics decisions towards sustainable future.

This chapter aimed primarily at fulfilling the first objective the research by answering the first research question, i.e. *What indicators can be used to analyse the relationship between economic development, road freight transport and its energy use and CO_2 emissions?* Several possible indicators were identified in various frameworks, but based on their previous use in various similar studies the following eight indicators were chosen:

- Gross domestic product (€)
- Value density (€/t)
- Modal split (% of tons transported by road)
- Average length of laden trips (km)
- Average load on laden trips (t)
- Empty running (% of total mileage run empty)
- Average fuel consumption (l/100km)
- Fuel CO_2 content (kg/l)

Also three key indicators for analysing the decoupling of economic growth, road haulage and energy use were presented:

- CO_2 intensity (g/€)
- Transport intensity (tkm/€)
- Energy efficiency (tkm/kWh)

These indicators are used throughout the research as information about their development in Finland is gathered and analysed using the statistics. Also Delphi panellists forecast the future values of the eight indicators and identify and evaluate the reasons for the changes in these indicators. Based on the Delphi forecasts the future scenarios are also developed using these indicators

This chapter also aimed at fulfilling the second objective of the research by identifying a variety of decarbonising measures which can be taken in order to promote the sustainable changes of each indicator. These measures are used later in the research in shipper and haulier surveys as companies are requested to state the level of usage of these measures and the likelihood of their future usage. The measures also served as background information for expert panel workshops and are used in developing the action plan for energy efficient and low carbon road freight transport.

The reviewed literature revealed that the need for consignment-level carbon footprinting of logistics operations has been internationally recognized and there is on-going work to standardize the processes to produce the footprints. Draft standard and other guidelines are quite ambiguous, however. The general principle in the guidelines is to calculate the carbon footprint with tonne-kilometre based allocation, which has been seen very difficult to do.

4. Statistical analysis

This chapter is modified from the following papers:

Liimatainen, H., Pöllänen, M. 2010. Trends of energy efficiency in Finnish road freight transport 1995-2009 and forecast to 2016. Energy Policy, Vol. 38, Issue 12, pp. 7676-7686.

Liimatainen, H., Pöllänen, M. 2011. The impact of economic development on the energy efficiency and CO_2 emissions of road freight transport. 16th International Symposium on Logistics (ISL 2011), July 10-13, Berlin, Germany. 8 p.

Liimatainen, H., Pöllänen, M. 2013. The impact of sectoral economic development on the energy efficiency and CO_2 emissions of road freight transport. Transport Policy, Vol. 27, pp. 150-157.

The aim of this chapter is to answer the second research question: *how have these indicators developed in the past and what kind of a future can be expected in the short-term if the past trends continue?* In order to answer this question, statistical analysis based on secondary data on economic development, road freight transport and truck fuel consumption are performed.

4.1. Data sources

Data of the various factors influencing the energy efficiency and CO_2 emissions of road freight transport are derived from the official Finnish statistics. The two major data sources used in this research are the Goods transport by road -data by Statistics Finland and LIPASTO Unit Emissions of Road Freight Transport -data by VTT Technical Research Centre of Finland.

Goods transport by road -statistics (later GTRS) is part of the official statistics of Finland. It contains data on goods transport volumes and performances as well as its origins and destinations by truck type. The data is collected continuously throughout the year by a survey posted to 8 400 truck owners per year (Statistics Finland 2012a). The owners are asked to provide detailed information on their truck use on two days of survey. This data is then raised to correspond with the sampling frame. There is a coherent time series available from 1995 onwards and the data is comparable with the statistics of other EU countries as it is compiled according to the guidelines stated in the Council Regulation (1172/98) on statistical returns in respect of the carriage of goods by road.

The Council Regulation determines the contents of road freight transport statistics, but it does not define the method to be used to compile the data. National statistics are sent quarterly to Eurostat which then compiles the European road freight transport statistics. The Eurostat database provides information on many of the aggregates, indicators and determinants of the framework, but lacks any information on energy consumption or CO_2 emissions (Eurostat 2010a). The environmental statistics of Eurostat provide some information on transport energy consumption and CO_2 emissions, but this information is only provided by mode of transport and the shares of freight and passenger transport are not indicated (Eurostat 2010b). Therefore energy efficiency comparisons between countries require additional and more detailed information from the original sources.

The LIPASTO traffic emission database contains detailed data on emissions of different transport modes and vehicles. Unit emissions of road freight transport -data provides over 10 000 figures on road unit emissions. Unit emissions define the energy consumptions and emissions per tonne-kilometre and vehicle-kilometre for empty load and full load of vehicles. Unit emissions are defined by using several sources of information, including HBEFA (The Handbook Emission Factors for Road Transport), ARTEMIS (Assessment and Reliability of Transport Emission Models and Inventory Systems) database and VTT's own measurements (LIPASTO 2011b).

The LIPASTO database also provides data on the annual total vehicle mileage and total diesel fuel use by trucks in Finland. Total vehicle mileage data comes from the official road traffic statistics by the Finnish Transport Agency (FTA) and is gathered by traffic flow measurements done manually and automatically on various locations across Finnish road network. Total diesel fuel use data comes from the records of diesel fuel purchases in Finland provided by the Finnish Oil and Gas Federation. Data is provided only on total purchases of diesel fuel and the share of truck diesel use is estimated from this in the LIPASTO database (Mäkelä & Auvinen 2011).

Other sources for average truck fuel consumption data are the Finnish Energy Efficiency Reporting System (PIHI) and the vehicle fuel consumption data by the Network for Transport and Environment (NTM). PIHI is an online tool for freight operators to report the fuel consumption, mileage and haulage for each truck on monthly basis. Operators which adopt the energy efficiency agreement are requested to report to PIHI (Motiva 2008). Currently, about 200 operators with 1500 trucks report to PIHI. PIHI has only been in wider use from the end of 2009 and the annual mileage reported equals only 4-5% of total mileage reported by GTRS (PIHI 2012), so the data cannot be considered representative or very reliable. However, as it provides real-life data on fuel consumption, it may be useful as a comparison with the unit emission data of LIPASTO.

The Network for Transport and Environment NTM is a non-profit organization based in Sweden, which aims at establishing a common base of values for calculating the environmental impacts of transport. NTM publishes reports which, among other things, contain fuel consumption data for heavy-duty vehicles of various size and Euro-class. This data is, similarly to LIPASTO, based on ARTEMIS database and HBEFA handbook as well as Swedish traffic activity data. (NTM 2008)

Data on indicators' past trends come from the GTRS except for energy consumption per vehicle, which is calculated using LIPASTO and NTM vehicle consumption data. Total vehicle-kms and the distribution of those for urban and rural roads are estimated using both GTRS and FTA data. Estimating vehicles' fuel consumption needs a new method, which is discussed in detail in the following section.

4.2. Estimating vehicles' fuel consumption

Vehicle's fuel consumption is determined by the energy losses in power train, the energy needed to work against aerodynamic drag, rolling resistance and gravity (in uphill) to maintain constant speed and the energy needed to accelerate the speed to a chosen level. The relationship between vehicle weight and fuel consumption is fairly linear with a certain type of vehicle (Coyle 2007). Between vehicle types, however, there is dissimilarity due to differences in aerodynamics and rolling resistance. There are differences also between vehicles of diverse age because of improvements in aerodynamics and power train design, which has reduced the energy losses. LIPASTO and NTM provide data on fuel consumption for various vehicle type, Euro-class, loading and road type combinations. Using these datasets, weight - fuel consumption functions are estimated for each Euro-class and road type. The functions reflect to some extent the aerodynamic differences between the trucks of different sizes, but aerodynamic developments between trucks of different age could not be assessed here due to lack of data. It should also be noted that the fuel consumption depends also heavily on the drivers' driving standards, but this factor could not be assessed here due to the lack of data.

Estimation is done by firstly forming a dataset with fuel consumptions for respective vehicle gross weight and Euro-class. Consumptions are given by LIPASTO and NTM for each vehicle type both empty and full. NTM data does not provide information on vehicles' empty weights, but these are assumed to be those used in ARTEMIS database (Rexeis et al. 2005). These datasets are done separately for freeflow rural roads and saturated rural (NTM) or urban (LIPASTO) roads (Table 6).

Table 6. Fuel consumption dataset (based on LIPASTO 2011a, NTM 2008).

			Mass [t]	Fuel consumption [l/100km]											
				Freeflow rural road						Saturated rural or urban road					
				pre-euro	euro1	euro2	euro3	euro4	euro5	pre-euro	euro1	euro2	euro3	euro4	euro5
NTM	Small truck	empty	3.5	12.8	10.6	10.2	10.8	10.1	10.3	14.5	11.7	11.1	11.8	11.1	11.3
		full	7.5	14.6	12.6	12.3	12.8	12.1	12.2	16.8	14.4	13.8	14.5	13.6	13.9
	Medium truck	empty	7.3	17.8	15.4	14.9	15.6	14.7	14.9	22.1	18.8	17.9	19	17.8	18.2
		full	14	22.4	20.2	19.7	20.5	19.2	19.5	28.2	25.4	24.6	25.6	23.8	24.3
	Tractor + semitrailer	empty	15.1	27.6	24	23.2	24.1	22.5	22.9	37	32.4	30.8	32.2	29.9	30.5
		full	40	46.9	42	41.6	42.1	39.2	39.8	62.7	56.6	55.5	56.5	52.1	52.9
	Truck + semitrailer	empty	19.4	35.4	30.4	29.6	30.5	28.6	29.1	47.4	40.9	39.5	41	38.2	39.1
		full	60	73.2	64.5	64.2	64.6	60.5	61.6	98.3	87	86.3	87	80.5	82
	Large truck	empty	11.8	24.6	20.5	19.8	20.7	19.4	19.8	32.6	27	25.8	27.2	25.4	25.9
		full	26	33.8	29.7	29.2	29.9	27.9	28.3	44.8	39.4	38.3	39.6	36.6	37.3
	Tractor + citytrailer	empty	9.2	24.4	21.4	20.4	21.4	20	20.3	32.6	28.6	26.9	28.2	26.2	26.8
		full	28	37.2	33.6	32.9	33.5	31.3	31.8	49.6	45.1	43.5	44.7	41.3	41.9
	Tractor + megatrailer	empty	16	30.4	26.1	25.5	26.4	24.6	25.1	40.8	35.2	34	35.4	32.9	33.6
		full	50	59.1	52.4	52.4	52.7	49.1	49.8	79.1	70.5	70	70.7	65.2	66.3
LIPASTO	Small delivery truck	empty	2.5	10.8	10.9	11.1	11.4	11.1	11.1	11.4	11.6	11.8	12.1	11.8	11.8
		full	6	12.4	12.6	12.8	13.1	12.8	12.8	15.2	15.4	15.6	16	15.6	15.6
	Large delivery truck	empty	6	17.2	17.5	17.8	18.3	17.8	17.8	17.8	18.1	18.3	18.8	18.3	18.3
		full	15	21.1	21.4	21.8	22.3	21.8	21.8	26.4	26.8	27.3	28	27.3	27.3
	Tractor + semitrailer	empty	15	29.1	29.6	30.1	30.9	30.1	30.1	45.1	45.8	46.6	47.8	46.6	46.6
		full	40	39.6	40.2	40.9	42	40.9	40.9	66.3	67.3	68.4	70.2	68.4	68.4
	Truck + trailer	empty	20	31.7	32.2	32.7	33.5	32.7	32.7	49.2	50	50.8	52.1	50.8	50.8
		full	60	48	48.8	49.6	50.9	49.6	49.6	87.2	88.6	90	92.4	90	90
	Large truck	empty	13	25.6	26	26.4	27.1	26.4	26.4	36.9	37.5	38.1	39.1	38.1	38.1
		full	32	34	34.6	35.2	36.1	35.2	35.2	54.3	55.2	56.1	57.6	56.1	56.1

Dataset is then plotted to a graph and trend line is fitted to data to model the fuel consumption (Figure 11). Trend line may be constant, linear, exponential, damped (logarithmic) or polynomial. The best trend line is chosen using the coefficient of determination (R^2) which is the proportion of total sum of squares explained by the least squares trend line. The R^2 can have a value between 0 and 1 and the nearer it is to 1, the better the trend line represents the data. The best form of trend line here is a power-type equation as it has the greatest R^2 value. The R^2 value is close to 1 indicating that the fuel consumption model represents the original fuel consumption data very well. Note that the maximum gross vehicle weight in Finland is 60 tons.

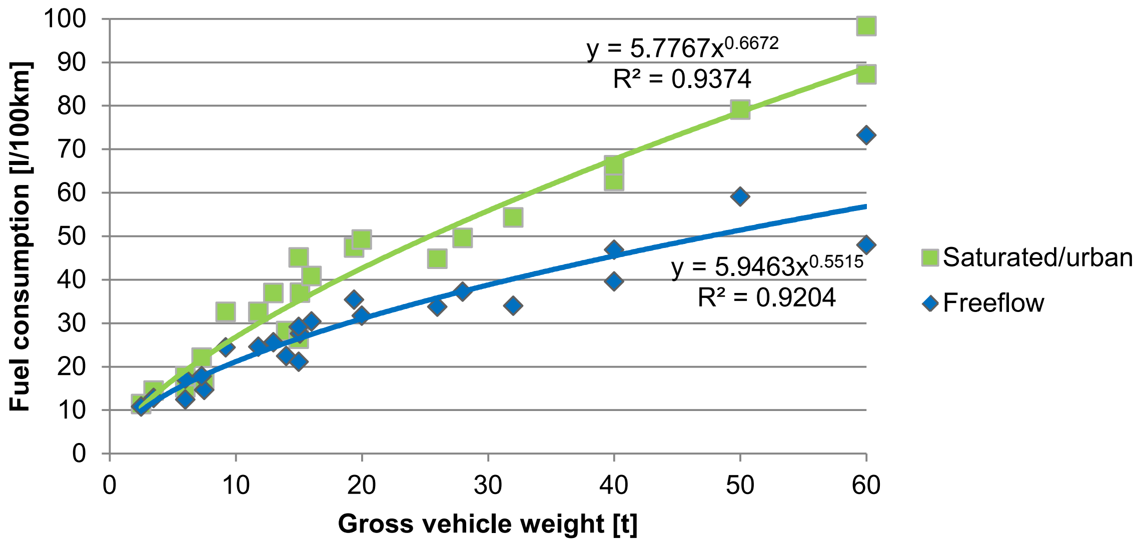

Figure 11. Weight and fuel consumption with trend lines for pre-Euro vehicles in freeflow rural roads and saturated or urban roads (data from LIPASTO 2011a and NTM 2008).

There is a trade-off between the NO_x emissions and the fuel consumption, making it difficult to decrease both of these at the same time (Baert et al. 1999). It has been estimated that fuel efficiency of trucks has historically improved by 0.8-1% annually and that without the Euro-standards for NO_x and PM emissions the fuel consumption of trucks could currently be 7-10% lower (IEA 2007a). However, the truck manufacturers claim to have been able to reduce NO_x, PM and fuel consumption simultaneously (Lingström 2010; Johansson 2008) and some recent measurements seem to confirm this, as far as the developments from Euro 3 to Euro 4 and 5 vehicles are concerned (Erkkilä et al. 2008). However, the new Euro 6 regulation (EC/595/2009), which will be implemented in 2013, sets the maximum level of NO_x emissions to 0.4 g/kWh, which is only one fifth of the current level of 2 g/kWh. This may again cause a rise in fuel consumption.

The views on the effect of the Euro-class on fuel consumption are contradictory between NTM and LIPASTO data (Table 7). The NTM data indicates that the fuel consumption of all Euro-classed vehicles is 10-20% lower than for pre-Euro vehicles. On the other hand, LIPASTO indicates that the consumption for Euro-classed vehicles is 1-6% higher than for pre-Euro vehicles. Furthermore, the results from an extensive European research project suggest differences very similar to those stated by NTM (Rexeis et al. 2005).

Table 7. The average differences in fuel consumption compared to pre-Euro vehicles.

	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5
Rexeis et al.		-15.0%	-11.6%	-17.8%	-16.0%
NTM	-12,9%	-14,9%	-12,2%	-17,8%	-16,5%
LIPASTO	1,6%	3,3%	5,9%	3,3%	3,3%

The difference between the NTM and LIPASTO data can be due to many reasons, but it is possibly mainly due to differences in the age of the vehicles included in the pre-Euro category. However, more important than the differences compared to pre-Euro vehicles are the differences between the Euro-classes. Here again the NTM and Rexeis et al. are more optimistic about the possibilities of power train design, but the sources agree that within the Euro-classes the fuel consumption is the highest with Euro 3 vehicles. The shift from Euro 4 to Euro 5 vehicles seems not to have led to reduced fuel consumption, but to a rise as suggested by NTM (2008), Rexeis et al. (2005) and also by Erkkilä et al. (2008).

In this study the differences between Euro-classes are established by plotting the weight-fuel consumption functions for each Euro-class similarly to that shown for pre-Euro vehicles in Figure 11, using both NTM and LIPASTO data. This ensures an internal consistency of this study. By doing this, it can be said that the differences in fuel consumption between Euro-classes remain fairly stable for all gross weights and also for both road types. Because of this, a single figure for the difference can be used for all weights and for both road types. Euro 1 vehicles' consumption is on average approximately 6.9% smaller than pre-Euro vehicles'. The difference is -7.6% for Euro 2, -5.2% for Euro 3, -10.1% for Euro 4 and -9.1% for Euro 5, respectively (Figure 12). Although these differences to pre-Euro vehicles are smaller than those stated by NTM and Rexeis et al., they reflect the changes between Euro-classes similarly. This estimate of Euro 1 vehicles consuming 6.9% less fuel than pre-Euro vehicles is also better in line with the historical reduction of fuel consumption (0.8-1%/year) than the 12.9% less suggested by NTM.

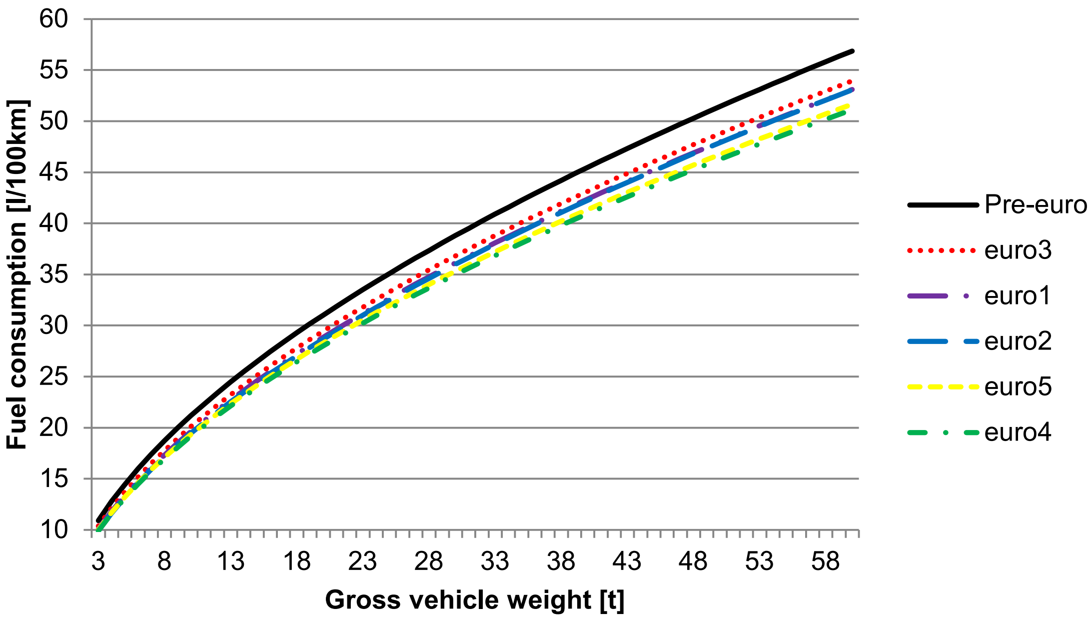

Figure 12. Fuel consumptions for different Euro-class vehicles on freeflow rural roads (data from LIPASTO 2011a and NTM 2008).

These differences in fuel consumptions between different Euro-class vehicles are used in the analysis to determine average fuel consumption for each trip in the GTRS data. Data holds information for each trip on vehicle's own weight and payload as well as on the commissioning date of the vehicle. The commissioning date is used to determine vehicle's Euro-class by assuming all the vehicles to be the newest Euro-class available on the year of commissioning. To describe the effects of Euro-classes on fuel efficiency on a national level with a single figure, a "Euro factor" is calculated for each year based on the differences seen above in Figure 12. The Euro factor is the weighted average of the share of mileage driven with each Euro-class vehicles and the respective fuel efficiency ratio (Equation 1):

$$\text{Euro factor} = m_{\text{pre-Euro}} + 0.931m_{\text{Euro1}} + 0.924m_{\text{Euro2}} + 0.948m_{\text{Euro3}} + 0.899m_{\text{Euro4}} + 0.909m_{\text{Euro5}} \qquad \text{(Eq 1)}$$

where m_x = annual share of mileage with vehicles of Euro-class (x)

The Euro factor is the ratio between the fuel actually consumed annually compared to a situation where all the annual mileage would have been driven with solely pre-Euro vehicles (in which case the Euro factor would be 1).

GTRS data does not directly hold information on the road type. The choice between freeflow rural and saturated/urban consumption function is made based on an assumption that all the trips which start and end within the same municipality and are stated to be delivery trips are considered to be driven on a saturated/urban road. In addition all the trips starting and ending within the Helsinki metropolitan area (including the municipalities of Helsinki, Espoo, Vantaa and Kauniainen) are considered to be driven on a saturated/urban road. By using this definition the share of mileage driven on saturated/urban roads comes close to that estimated in the FTA statistics.

Yet another assumption is made when determining the fuel consumption for each trip. The total fuel consumption is estimated to be 10% smaller on trips with multiple drop off or pick up points than it would be on similar other types of trips. This is because only the maximum payload is stated in the data but on these multiple stop trips the payload is smaller than the maximum during the trip. By using these assumptions, the fuel consumption is calculated for each trip in the GTRS data. The annual total fuel consumption for all the trucks in Finland is then calculated similarly to all other statistical indicators of the GTRS data.

4.3. Trends between 1995-2010

The analysis with the data shows that the energy efficiency of Finnish road freight transport has fluctuated between 1995-2010 from 2.97 to 3.14 tkm/kWh and no clear trend can be found. CO_2 emissions, on the other hand showed an upward trend from 1995 to 2000, after which the emissions have fluctuated between 2.3 and 2.4 million tonnes. The emissions were at the highest 2.4 Mt in 2008, but decreased to 2.14 Mt the next year because of economic downturn, only to increase back to 2.3 Mt in 2010. (Figure 13).

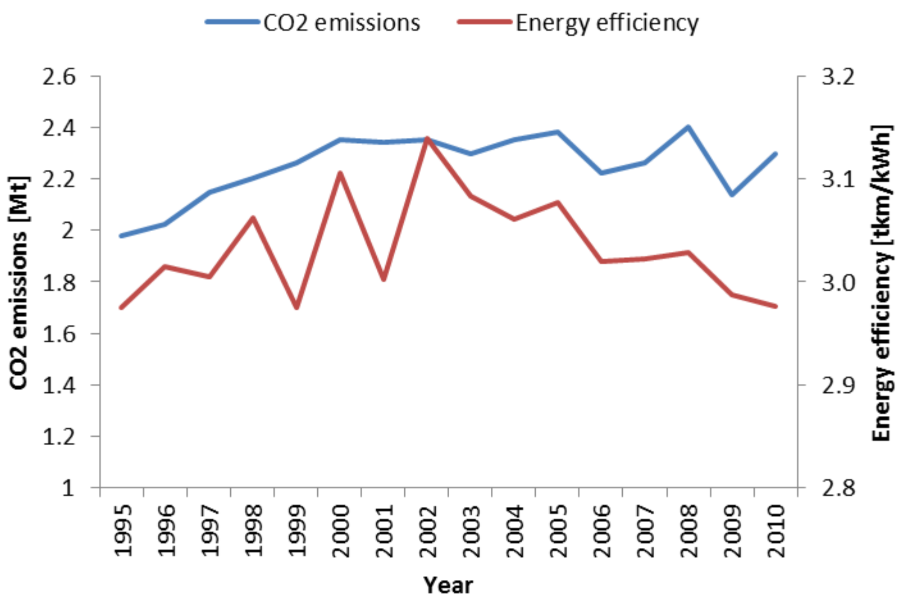

Figure 13. The development of road freight energy efficiency and CO_2 emissions in Finland 1995-2010.

The energy efficiency seems to have had an improving trend from 1995 to 2002, but a declining trend since. However, the energy efficiency in Finland is still on a quite high level compared to the energy efficiency of 3.46 tkm/kWh for Great Britain in 2007, 2.74 tkm/kWh for a sample of German companies in 2003 and 2.42 tkm/kWh for Spain in 2003 (author's calculations based on figures in Piecyk 2010a; Leonardi & Baumgartner 2004; Perez-Martinez 2009). On the other hand, the vehicles' energy intensity in Finland has been from 13 to 14 MJ/km, compared to approximately 11.8 MJ/km in Great Britain, 11.5 MJ/km in Germany and 10.9 MJ/km in Spain.

These differences are possibly mainly due to the extensive use of long (up to 25.25 meters) and heavy (up to 60 tons) vehicles in Finland, which is best illustrated by the average truck loading calculated by dividing the tonne-kilometres by vehicle-kilometers. The average payload in Finland has been from 15.3 to 13.3 tons whereas in Great Britain and Spain it was about 9.8 and 7.3 tons respectively. The average fuel intensity in Great Britain is close to that of Finland even though long and heavy vehicles are not used in Great Britain. However, tall and high capacity double deck vehicles are used in Great Britain, which may have an effect. Neither of these high capacity vehicles is used in Germany or Spain, which leads to better fuel intensity but worse energy efficiency in these countries than in Finland and Great Britain.

Another explanation for the high energy efficiency in Finland might be found in the product mix carried. Fairly high share of Finnish freight transport is heavy goods, such as wood, paper, metals and machinery. Heavy goods enable good vehicle utilization in terms of weight. The utilization rate on laden trips is 81-74% in Finland, compared to 80% in Spain, 57% in Great Britain and only 44% in the German sample. However, it is most likely that there are also other affecting factors and the data and calculation methods are different. It could also be that the liberation of road transport markets in different EU countries is still affecting also the energy efficiencies, for instance by adding empty runs. A European comparison of energy efficiency using similar data and calculation methods would be necessary to further analyze the reasons for differences between countries.

4.3.1. Transport intensity

Transport intensity is the ratio of road haulage and GDP (tkm/€), which is affected by four indicators: GDP, value density, modal split and average length of laden trips on road. Transport intensity remained at around 0.24 tkm/€ in Finland in 1995-2000, but decreased since to 0.18 tkm/€ in 2007 and is now 0.19 tkm/€. The modal split has been very stable during this time and it has not affected the transport intensity (Figure 14).

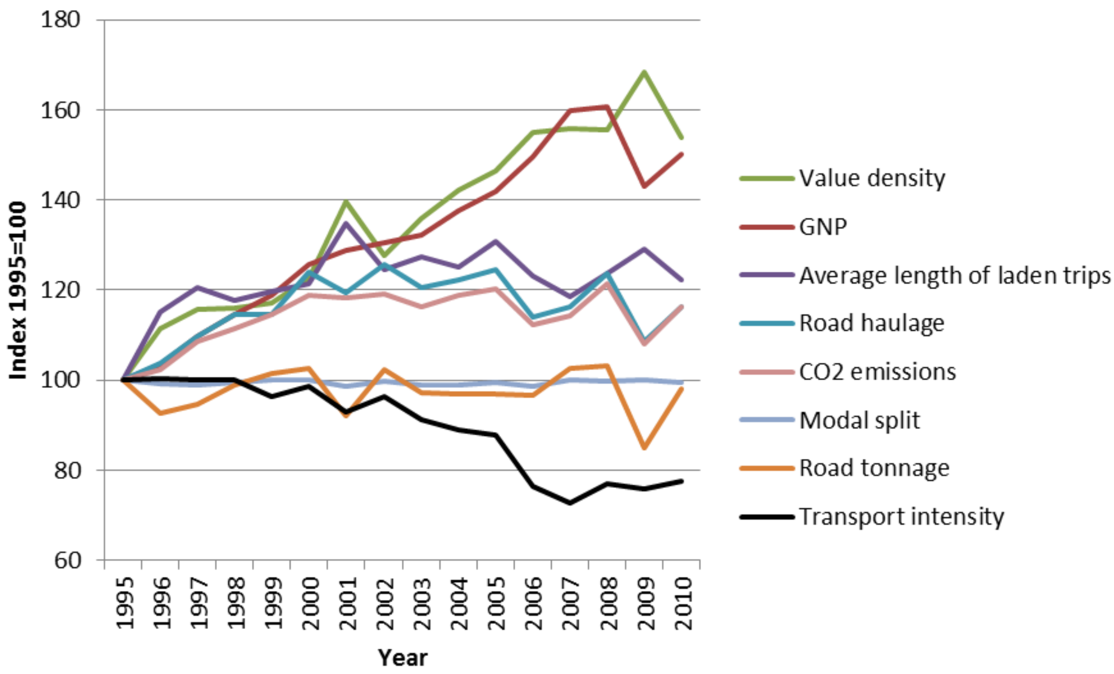

Figure 14. The changes of aggregates and indicators affecting transport intensity, with CO_2 emissions, 1995-2010.

Transport intensity has been affected by the changes in value density and average length of laden trips which have had opposite effects. The increase in the value density has decreased the total tonnage and hence decreases the transport intensity. Increase in the average length of laden trips, on the other hand, increases the total haulage and thus also the transport intensity. Until year 2000 these two indicators increased at the same pace, so the transport intensity did not change. After that, value density has continued to increase, but average length of laden trips has stabilised, causing the transport intensity to decrease. Value density has increased at approximately the same pace with the GDP, so the road tonnage has remained at the 1995 level, except for the few years. Thus the increase in the road haulage in 1995-2002 has been due to lengthening trips.

4.3.2. Energy efficiency

Energy efficiency is the ratio of road haulage and energy consumption (tkm/kWh), which is affected by three indicators: average load on laden trips, empty running and average fuel consumption. Energy efficiency increased in Finland 1995-2002, but has since decreased almost back to 1995 level (Figure 15).

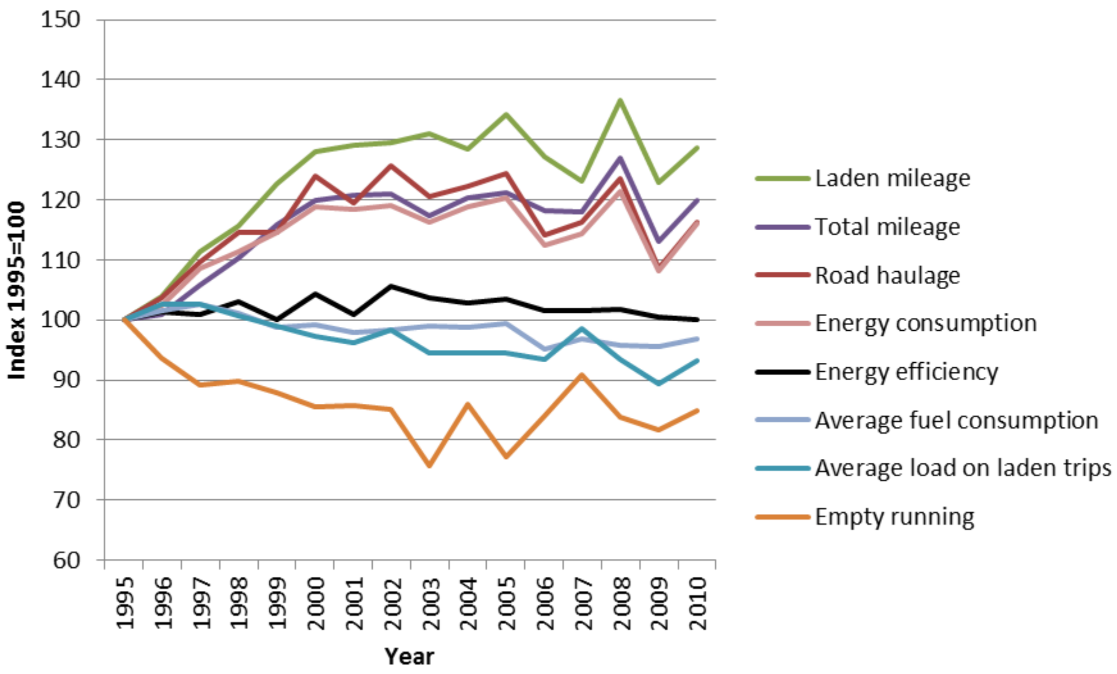

Figure 15. The changes of aggregates and indicators affecting energy efficiency 1995-2010.

The values of all indicators affecting energy efficiency have decreased since 1995. However, decreasing indicator values change energy efficiency in opposite directions. Decrease in the average load on laden trips means that more laden mileage is needed to perform the same amount of road haulage, so more energy is consumed and the energy efficiency decreases. Decrease of empty running, on the other hand, decreases the total mileage if laden mileage remains stable and thus increases the energy efficiency. Decrease in the average fuel consumption means that less energy is needed to drive the same total mileage, so energy efficiency increases. The effects are not as straightforward, however. This is because vehicle loading also affects the fuel consumption, hence part of the decrease in energy efficiency caused by decrease in average load is offset by decrease in average fuel consumption. It has to be kept in mind also that fuel consumption is greatly affected by driver behaviour which is not taken into account here due to lack of data.

The increase in energy efficiency until year 2002 was caused mainly by the decrease in empty running seen in Figure 15. The empty running was actually at the lowest in 2003, but then also the average load was considerably lower than in 2002, so energy efficiency was also lower than in 2002. Since 2003 empty running has fluctuated but average load has continued to decrease, causing the energy efficiency to decrease. Average fuel consumption has also decreased slightly and this has restrained the decrease in energy efficiency caused by decreasing average loads.

The eight indicator, fuel CO_2 content, was not considered here as it was assumed to be constant (2.66 kg/l for diesel) in 1995-2010.

4.4. Defining the Finnish energy efficiency target for 2016

The energy efficiency target for 2016 was defined in the energy efficiency agreement as “9% saving in energy use compared to the average energy use in 2001-2005, if the total haulage (in tonne-kilometres) remains at the 2008 level” (Motiva 2008). However, the agreement does not specify what statistics should be used to determine this target. The only available statistics for total energy use for Finnish road freight transport prior to this study has been the LIPASTO emission database and the only available statistics for total haulage the Goods transport by road -statistics (GTRS). The difficulty is that these have a significant difference in total mileage. The total mileage in GTRS is 17-30% smaller than that provided by Finnish Transport Agency (FTA) which is used in LIPASTO.

A similar difference in mileage has been found in the United Kingdom with road-side traffic counts (NRTS) and postal questionnaire survey of truck operators (CSRGT). Major reasons for this were identified to be the exclusion of foreign trucks from the survey, under-reporting of distances by truck operators and misclassification of trucks in road-side counts. (McKinnon & Piecyk 2009.) The same reasons apply also for Finland, although the effect of foreign trucks is likely to be smaller in Finland than in the UK.

The difference in total mileage leads to a difference in total energy consumption, hence the energy efficiency target of the Finnish Energy Efficiency Agreement for Freight Transport and Logistics 2008-2016 is best defined by using these calculations for energy use and energy efficiency. The method used in this research ensures that the energy use is calculated consistently with the total haulage. This also enables detecting the main drivers of energy efficiency and forecasting it by using these drivers. In the calculations done here the average total energy consumption in 2001-2005 was 8904 GWh which sets the target of 9% energy savings to approximately 8103 GWh in 2016, if the total haulage remains at the 2008 level of 27.6 billion tkm. This results in the energy efficiency target of 3.41 tkm/kWh in 2016. From the energy efficiency level of 3.03 tkm/kWh in 2008 this actually means a 12.5% improvement to meet the target, not the 9% improvement which is the original target interpreted from energy efficiency agreement.

Quite interestingly, because of the global economic crisis that began in 2008 and the following drop in the amount of road haulage also in Finland, the total energy consumption in 2009 was 8122 GWh. Consequently, the total energy consumption was in 2009 close to the target, but the energy efficiency, which is the key issue in the agreement, was even further away from the goal (2.99 tkm/kWh in 2009, 14% increase needed to meet the target for 2016) than in 2008.

The energy consumption target of 8104 GWh is 2.13 Mt in terms of CO_2 emissions for year 2016. In 2009 the CO_2 emissions were at 2.14 Mt, so the target was almost achieved, even though in terms of energy efficiency the target was far from achieved. However, 7% decrease in CO_2 emissions from the 2010 level of 2.3 Mt is required to achieve the target. The case of year 2009 highlights that energy efficiency and CO_2 emissions do not necessarily change in the same direction, so the other target can be achieved while the other is even further away. Because of this, transport policy should not be based on only one indicator, but the energy efficiency and CO_2 emissions of road freight should be analysed as an entity using the eight indicators and starting from the changes in sectoral GDP.

4.5. Sectoral analysis

In the national-level analysis of the Finnish energy efficiency agreement above it was seen that the energy efficiency improvement and CO_2 reduction targets for road freight transport can in fact be contradictory. As an outcome of the economic downturn in 2009 the GDP (Gross domestic product) in Finland decreased by 8.5% (Statistics Finland 2012b) and the energy use – and the directly related CO_2 emissions – decreased close to the target, but the energy efficiency in tkm/kWh also decreased, i.e. worsened, and was actually further away from the target. As these results indicated a strong impact of economic development on the energy efficiency and the CO_2 emissions, a sectoral analysis was seen necessary to study these findings further.

Research on the impact of economic development on freight transport has focused mainly on national-level or international comparisons (see e.g. Stead 2001; Tapio 2005; McKinnon 2007a; Kamakate & Schipper 2009). A few studies have also been made on sectoral level and Kveiborg and Fosgerau (2007) note that distinction between industries is important, but further distinction between commodities within industries is not necessary. Sorrell et al. (2009) on the other hand study the road freight movements by commodity groups and conclude that the trends in each commodity group influence the aggregate trends greatly and may result in misleading conclusions on aggregate level. A common goal in these researches has been to find out whether decoupling – the slower growth of either tonne-kilometres, energy consumption or CO_2 emissions compared to the growth of GDP or added value – has occurred and what changes have contributed to this. Most of the studies found out that decoupling has happened and it has mainly been due to off-shoring industrial production, reduction in empty running and reduction in the fuel consumption of trucks.

It seems that economic development in different sectors of economy has a considerable effect on the development of energy efficiency and CO_2 emissions of road freight transport. Understanding these relations is essential when national and also international energy efficiency targets are set and evaluated. The key to this understanding is a detailed sectoral analysis. The purpose of this chapter is to analyse what are the effects of differences between the branches of economy on energy efficiency and CO_2 emissions of road freight transport. This analysis is done by combining statistical data related to road freight transport, energy use, CO_2 emissions and economic activity.

4.5.1. Data and classifications

The sectoral analysis here is based on grouping the types of commodities of road freight and national accounts sectors under chosen business sectors as presented in Table 8. The main source for information on road freight transport in Finland is the continuous goods transport by road statistics, GTRS, which is compiled according to the European guidelines (Council Regulation 1172/98) and is thus comparable with the statistics of other European countries. For Finland there are comparable annual statistics available from 1995. It should be noted that, because of the sampling in the GTRS, the data is limited at the branch-level and this may cause some random variation to this analysis, which is the case even at the national level. The random variation may occur because the data consist of 11000 to 17000 journeys annually and the smallest sectors in analysis only have 100-200 journeys annually. The amount of journeys in the smallest sector may vary considerably because the GTRS survey is not sampled according to sectors. Because of this a sector may have 150 journeys one year and 200 journeys the next year. This 33% increase in the number of journeys also changes the amount of tonne-kilometres, mileage and energy consumption considerably, even though no such change could not be detected if all the journeys made by every truck in Finland would be recorded and analysed. Statistics Finland (2010b) estimates the margin of error to be 5-7% for the overall values of tonnes and tonne-kilometres in GTRS, so for sectoral values the margin of error may be larger. Because of this sectoral year-on-year analysis should not be made but longer time series should be analysed.

There were 40 types of commodities in the GTRS in 1995, 42 between 1996 and 2007 and 45 in 2008-2010. The changes in the commodity classifications are minor and mostly divide previous commodity types to sub-categories, which still belong to the same sector, but can cause some inaccuracy in the analysis. Data on the added value by sector is available in the national accounts statistics provided by Statistics Finland (2012b). The sectors are established from the ones used in the national accounts. These categories have also changed between 1995 and 2010 but the statistics have been adapted by Statistics Finland to ensure comparable time series.

Matching the types of commodities used in the GTRS to sectors used in the national accounts statistics for a sectoral analysis is not an unambiguous task. Some commodities can be assigned to both manufacturing and trade sectors (these commodities appear in bold in Table 8). The solution is to divide those commodities amongst the sectors according to the answer the hauliers have given in the GTRS questionnaire regarding its primary customer: is it industry, trade or public sector? For each commodity type the share of journeys for which the primary customer is stated to be trade is assigned to trade and the rest to the corresponding manufacturing sector. However, most GTRS commodities clearly belong to one sector as can be seen from Table 8.

Table 8. Assigning the commodity classes in the GTRS and the national accounts sectors to the eight business sectors analysed in this research.

Business sector	Commodity classes in the GTRS	National accounts sectors
Forest cluster	Raw wood, wood products and paper	Forestry, manufacturing of wood products, mfg of paper products
Food cluster	Agricultural products, animals, **food products**	Agriculture, hunting, fishing, mfg of food products
Energy cluster	Solid and liquid fuels	Mfg of oil, coke and nuclear fuel; supply of electricity, gas and water
Construction cluster	Asphalt, gravel, building materials	Construction
Technology cluster	Ore, scrap metal, metal products, machines, **appliances**, vehicles, **furniture, clothes, glass** and plastic products, **unidentified goods**	Mining, mfg of metal products, machines, appliances, electrotechnical products, vehicles, clothes, leather, rubber and plastic products, non-metallic mineral products
Chemical cluster	Chemicals, medicines	Mfg of chemicals and chemical products
Waste and maintenance	Waste, empty containers, packaging materials, maintenance	Waste collection and recycling, other environmental services
Trade	Fruits, **furniture, food products, appliances, clothes, glass**, empty containers, packaging materials, **unidentified goods**	Trade; wholesale and retail, repairs of vehicles and household appliances

Also the service sector is problematic as none of the commodities can be assigned solely to services except of trade, which is its own sector also in this analysis, as well as waste and maintenance services. Excluding other services from this analysis means that a large share of economical output measured by Gross domestic product (GDP) is excluded from the study. These other services consist of sectors such as health and social services, public administration, education, financial and insurance activities, arts, entertainment and recreation, which by their nature have very little freight transports absolutely, i.e. in terms of tons, and relatively, i.e. compared to their contribution to GDP. This approach is similar to Sorrell et al. (2012), where services are considered to be ‘weightless’ and transports with heavy goods vehicles are assumed to be determined by manufactured goods. For Finland the share of services other than trade and waste and maintenance services was 50 per cent of the GPD in 2010.

4.5.2. Combining fuel consumption data and road freight statistics

The GTRS in Finland lack direct data on energy consumption or CO_2 emissions, unlike e.g. the respective statistics in the UK (DfT 2010b). In order to analyse the energy efficiency and CO_2 intensity in Finland, the road freight statistics are enhanced with fuel consumption data as shown in section 4.2. In this method each journey reported in the GTRS is given an estimated fuel consumption based on the gross vehicle weight, age of the vehicle and the type of road on each journey. Thus energy consumption and CO_2 emissions can be analysed in the same way as other indicators in the statistics, allowing comparative sectoral analysis.

The results of a survey (see Chapter 7.3.3) on the average fuel consumption of hauliers revealed that the estimated fuel consumption, based on the Goods Transport by Road Statistics (GTRS) from year 2010, underestimate the fuel consumption in some sectors. The reasons for the lower figures are most likely that, firstly, idling could not be taken into account in the estimates, and secondly, the travel speed could not be taken into account. The transport in forest, construction and waste and maintenance clusters typically include long periods of idling when loading and unloading the vehicle. Also, some of the mileage in these sectors is driven on small rural roads at low speed and on urban roads with constant stops as in case of waste transport.

Because the analysis based on GTRS significantly underestimated the fuel consumption on some sectors compared to the results of the survey, an adjustment to the method and therefore the figures presented earlier was seen necessary (Table 9). In this study the revised fuel consumption data is used. The fuel consumption of the trips in forest cluster was increased by a factor of 1.3, in construction cluster by 1.2 and in waste and maintenance sector by 1.6.

Table 9. Average fuel consumption on sectors based on responses of 2011 haulier survey (Chapter 7.3.3) and GTRS data from 2010, with revised 2010 GTRS data.

	2011 survey	2010 GTRS data	Revised 2010 GTRS data
Forest cluster	51.1	40.3	49.4
Energy cluster	43.4	42.7	42.7
Construction cluster	42.4	31.7	40.7
Chemical cluster	40.7	40.8	40.8
Waste and maintenance	40.6	26.9	37.7
Food cluster	37.7	39.6	39.6
Technology cluster	35.1	29.3	29.3
Trade	33.5	31.8	31.8
Total	**39.6**	**33.7**	**37.2**

4.5.3. Analysing the empty running by sector

Empty running is one type of commodity in the commodity classification of the GTRS and thus it cannot be directly assigned to any sector. Sorrell et al. (2012) highlighted this as an important deficiency of national statistics as it prevents the analysis of empty running by commodity group and vehicle type. In this analysis the empty running is, however, studied by sector and vehicle type. To enable this, the amount of vehicle kilometres run empty and run laden are divided to vehicles with different types of cargo space and cargo handling equipment (there are 15 types in the GTRS in total, e.g. curtainsided, refrigerated box, flatbed or waste compactor). The share of empty running is thus calculated for each type of cargo space. Laden and empty kilometres driven with each type of cargo space are then divided to the eight sectors used in this analysis. Each sector utilises the types of cargo space differently (e.g. timber trucks are used only in forest cluster) so the overall level of empty running varies between sectors according to the laden and empty kilometres driven with different types of cargo space.

The sectoral levels of empty running calculated as described above are shown in Table 10 and compared with the levels of empty running which the hauliers stated in a survey (see Chapter 7.3.3). The comparison shows that the method based on GTRS data gives somewhat lower figures for empty running in bulk transport and somewhat greater for trade and technology sectors, when compared to the results of the company survey. However, the overall share of empty running is very similar in the survey and in the GTRS data. Because of this, and the lack of other reliable methods for determining the sectoral empty running in the past, the sectoral shares of empty running are determined in this study using the GTRS data as described above.

Table 10. The level of empty running [empty mileage divided by total mileage] by sector according to the 2011 haulier survey (Chapter 7.3.3) and 2010 GTRS data.

	2011 survey	2010 GTRS data
Energy cluster	40%	32%
Construction cluster	40%	36%
Forest cluster	38%	34%
Waste and maintenance	34%	27%
Chemical cluster	28%	30%
Food cluster	23%	21%
Technology cluster	22%	24%
Trade	15%	21%
Total	**28%**	**27%**

4.6. Decoupling by sector

Results from the decoupling analysis, using the decoupling definitions introduced in Figure 6, are presented in Table 11. Overall, there has been weak decoupling of transport volume and CO_2 emissions from the economic development in Finland between 1995 and 2010. The Finnish economy currently has considerably lower road freight CO_2 intensity than 16 years ago (48 g/€ in 1995, 33 g/€ in 2010). Yet, in terms of energy efficiency there has been no improvement (2.97 tkm/kWh in 1995, 2.98 tkm/kWh in 2010), i.e. there has been expansive coupling between energy use and transport volume.

The overall situation conceals dramatic changes between and within the sectors. These changes can largely be attributed to the shift of balance from transporting bulk goods (e.g. paper, gravel and fuels) to transporting parcelled goods (e.g. machinery, appliances, clothes and food products). Bulk transport clusters such as forest, construction, energy, and chemical, are responsible for the majority of freight transport demand in Finland, but their transport is also relatively energy efficient. Road freight transport in these sectors produces considerably less CO_2 per tonne-kilometre than e.g. transport in technology cluster, trade or waste and maintenance. This shift has been driven by diminishing importance of forest cluster and growing importance of technology cluster and trade. The forest cluster had 20%, 31% and 25% share of added value, transport volume and CO_2 emissions, respectively, in 1995. By 2010 these shares had dropped to 14%, 26% and 20%. Note that these figures of value added do not include the share of services other than trade and waste and maintenance cluster.

Technology cluster is the third biggest in terms of tonne-kilometres and second biggest in terms of energy use and CO_2 emissions in 2010. The analysis shows that technology cluster has seen 159%, 38% and 41% increase between 1995 and 2010 in added value, transport volume and CO_2 emissions, respectively. This means that weak decoupling of transport volume and CO_2 emissions from the economic development and expansive coupling between energy use and transport volume has taken place in the technology sector, similarly to the overall decoupling development in Finland. However, some of the growth of transport volume in technology cluster may be explained by the economic growth in other sectors. This is because in this analysis technology cluster includes transport of unidentified goods, e.g. containerised goods and mixed pallet loads, and other sectors use increasingly these kinds of unitised transports with valuable small goods. In GTRS, unidentified goods comprised 6% of total tonne-kilometres in 1995 but as much as 11% in 2010.

The greatest growth in transport volume and energy use has occurred in the waste and maintenance sector. This growth is likely to be due to increased and more segregated recycling of waste, which has been recognised e.g. in an enquiry done in Helsinki metropolitan area in Finland (HSY 2011). However, some of the growth may also be due to harsh winter Finland experienced in 2010 (see e.g. FMI 2012) as snow clearance and road maintenance is a part of this sector. The other sector which has grown in importance is trade. Trade has almost doubled its transport volume from 1995 to 2010 and increased its share of transport volume from 8% to 13%. This growth is likely to be partly due to a shift of the control of logistics and transport operations from industry to trade (see e.g. Fernie and Sparks 2004). For example the wholesale trade is managing the transport to groceries that was previously controlled by the food industry. This increases trade's share of the transport volume, because the volume is allocated between industry and trade based on the respondents' choice of the primary customer (sector) that they serve.

Table 11. Decoupling of road freight transport volume from economic growth; energy use and CO_2 emissions from economic growth as well as energy use and CO_2 emissions from transport volume in Finland by sector 1995–2010. The number before the arrow (→) indicates the value for year 1995 and after the arrow for year 2010.

	Forest cluster	Food cluster	Energy cluster	Construction cluster	Chemical cluster	Technology cluster	Waste and maintenance	Trade	**Total w/o services**
Share of added value 1995 → 2010	20% → 14%	9% → 7%	5% → 4%	16% → 14%	6% → 5%	22% → 34%	1% → 1%	21% → 22%	**100%**
Share of tkm 1995 → 2010	31% → 26%	14% → 10%	7% → 6%	18% → 19%	6% → 5%	15% → 17%	3% → 5%	8% → 13%	**100%**
Share of energy use and CO_2 1995 → 2010	25% → 20%	13% → 10%	5% → 4%	17% → 16%	4% → 3%	16% → 19%	8% → 13%	11% → 15%	**100%**
Change in added value in constant prices 1995–2010	19%	20%	27%	46%	54%	159%	57%	75%	**50%**
Change in tkm 1995–2010	-3%	-12%	-4%	21%	-5%	38%	129%	86%	**16%**
Change in energy use and CO_2 emissions 1995–2010	-11%	-9%	-7%	7%	-17%	41%	100%	64%	**16%**
CO_2 intensity gCO_2/€ 1995 → 2010	62 → 47	66 → 50	55 → 42	52 → 38	35 → 19	35 → 19	686 → 876	25 → 24	**48 → 33**
	strong decoupling	strong decoupling	strong decoupling	weak decoupling	strong decoupling	weak decoupling	expansive negative decoupling	expansive coupling	**weak decoupling**
Transport intensity tkm/€ 1995 → 2010	0.85 → 0.70	0.79 → 0.58	0.79 → 0.61	0.61 → 0.50	0.60 → 0.37	0.36 → 0.19	2.51 → 3.67	0.21 → 0.22	**0.55 → 0.38**
	strong decoupling	strong decoupling	strong decoupling	weak decoupling	strong decoupling	weak decoupling	expansive negative decoupling	expansive coupling	**weak decoupling**
Energy efficiency tkm/kWh 1995 → 2010	3.6 → 3.9	3.2 → 3.1	3.8 → 3.9	3.1 → 3.5	4.5 → 5.2	2.7 → 2.7	1.0 → 1.1	2.2 → 2.5	**2.97 → 2.98**
	recessive decoupling	recessive negative decoupling	recessive decoupling	weak decoupling	recessive decoupling	expansive coupling	weak decoupling	weak decoupling	**expansive coupling**

4.7. Reasons for decoupling

The decoupling of energy use and CO_2 emissions of road freight transport from the economic output can be further analysed through the eight indicators of the decarbonisation framework presented in Figure 10. The sectoral values of these indicators are summarised for 1995 and 2010 in Table 12. The changes of six indicators are analysed here because the modal split could not be analysed sectorally and the fuel CO_2 content was kept at the fixed value for diesel (2.66 $kgCO_2/l$), so the possible use of biofuels was not taken into account in this study.

4.7.1. Indicators affecting transport intensity

The term 'transport intensity' is used in many contexts and different meanings, e.g. in relation to the amount of transport volume or tonnage and energy use or economic output (GDP), both for passenger and freight transport (Stead 2001). Transport intensity in this study means the relationship between transport volume and economic activity. Here the road freight transport volume is measured in tonne-kilometres (tkm), and the economic activity as value added (€), which is a sectoral value connected to the GDP. Thus the unit measuring transport intensity is here tkm/€. Transport intensity has decreased in Finland from 1995 to 2010 as was seen in Table 11.

Transport intensity is determined by three indicators: value density, modal split and average length of laden trips on road. Another possible indicator is handling factor, i.e. the ratio of the weight of goods produced and the weight of goods transported (McKinnon 2007b), but there is no information available to calculate the handling factor in Finland. Modal split could not be determined by sector either, because there were no sectoral statistics for maritime, rail or air transport available. On national level modal split has been very stable in Finland during the studied period. Road's share of transported tons has been between 88.6% and 90.0% (Statistics Finland 2010c). Thus the modal split has had virtually no effect on the development of transport intensity.

Value density is here the ratio between value added and road tons moved (€/t). Increasing value density in all sectors is the main reason for the decreasing transport intensity. Value density has increased in all sectors of the economy in Finland from 1995 to 2010. Overall the value density has increased by 73% and the development has been driven by the 118% increase in the value density of the technology cluster.

The average length of laden trips has increased slightly in all sectors except food cluster, in which it has decreased by 11%. The overall average length of laden trips has increased by 22% from 1995 to 2010. In construction and trade the increase has been 30%, but construction still has by far the shortest length of haul at 19 km on average (Table 12). Lengthening trips in construction are mostly due to gravel being transported further than before. In trade the lengthening is caused by centralisation of warehouses to the Helsinki metropolitan area and distribution of goods from there to all of Finland. Longer trips increase transport intensity, but the effect of this is negated by the huge increases in value densities.

Table 12. Changes in the indicators for analysing economy and road freight transport by sector in Finland 1995–2010.

	Forest cluster	Food cluster	Energy cluster	Construction cluster	Chemical cluster	Technology cluster	Waste and maintenance	Trade	**Total w/o services**
Value added (billion €) 1995 → 2010	8.1 → 9.7	3.8 → 4.6	1.9 → 2.4	6.5 → 9.5	2.3 → 3.5	9.0 → 23.2	0.2 → 0.3	8.6 → 15.1	40.4 → 68.3
Value density (€/t) 1995 → 2010	109 → 129	172 → 202	118 → 139	29 → 48	264 → 400	292 → 637	15 → 17	601 → 907	**100 → 173**
Modal split (% of tons carried on road) 1995 → 2010	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	**90% → 90%**
Avg. length of haul (km) 1995 → 2010	83 → 94	131 → 116	105 → 110	15 → 19	128 → 143	77 → 86	39 → 44	96 → 125	**48 → 59**
Avg. load (t) 1995→2010	24.5 → 28.5	15.3 → 13.5	29.5 → 27.8	16.5 → 17.7	23.4 → 26.0	9.0 → 7.9	5.6 → 5.5	6.8 → 8.0	**14.9 → 13.9**
Empty running (% of total mileage) 1995→2010	35.2% → 34.4%	25.6% → 21.1%	38.0% → 32.4%	38.9% → 35.9%	33.8% → 29.7%	29.7% → 24.4%	35.3% → 27.1%	25.8% → 20.7%	**32.2% → 27.4%**
Fuel consumption (l/100km) 1995→2010	48.8 → 49.4	37.1 → 39.6	42.6 → 42.7	39.8 → 40.7	41.9 → 40.8	31.2 → 29.3	35.1 → 37.7	29.9 → 31.8	**38.4 → 37.2**
Fuel CO_2 content (kg/l) 1995 → 2010	2.66 → 2.66	2.66 → 2.66	2.66 → 2.66	2.66 → 2.66	2.66 → 2.66	2.66 → 2.66	2.66 → 2.66	2.66 → 2.66	**2.66 → 2.66**

Green means the change has improved the energy efficiency and/or reduced the CO_2 emissions

Red means the change has decreased the energy efficiency and/or inceased the CO_2 emissions

4.7.2. Indicators affecting energy efficiency

Energy efficiency is the ratio between total road freight haulage and energy consumption (tkm/kWh). It it affected by three indicators: average load on laden trips, the level of empty running and average fuel consumption. These indicators are interrelated as the loading of a vehicle affects its fuel consumption greatly.

Sectoral differences are evident in terms of average loads and empty running. The sectors carrying mostly bulk goods (construction, energy, chemical and forest clusters) are characterised by high average loads, but also high level of empty running. On the other hand, small loads and fairly low level of empty running are typical for sectors carrying general cargo (technology cluster and trade). Food cluster is between the two aforementioned types with average loads but low empty running. The waste and maintenance sector has very low loads and average empty running. In Table 12 a clear trend towards lower empty running can be seen on every sector. For average loads there is more mixed development, as for some sectors the loads have dropped, e.g. food and technology cluster, and for some raised, e.g. chemical cluster and trade.

Vehicle fuel consumption determines how much energy is used and CO_2 emitted in driving the total mileage. Besides the payload, fuel consumption is a result of many interacting determinants, including vehicle's own weight, engine and transmission technology, aerodynamics, driver's behaviour, and traffic conditions. However, there is data on only some of these attributes. In this analysis the fuel consumption is calculated based on vehicle's gross weight and Euro-class and type of road. The overall average fuel consumption has reduced in Finland from 38.4 l/100km in 1995 to 37.2 l/100km in 2010. The overall average fuel consumption has reduced even though the average fuel consumption has increased in all sectors except chemical and technology clusters. The reduction in overall average consumption is mostly due to the decreasing mileage in bulk transport sectors which have high average consumption (forest, energy and chemical clusters) and growing mileage in general cargo sectors which have low average fuel consumption (technology cluster and trade). It can be concluded that the decrease in empty running and in average fuel consumption is negated by decreasing payloads, and thus the energy efficiency has improved only marginally in Finland.

4.8. Forecast to 2016

A forecast to the year 2016 by using different economic developments further highlights the effect of economic development on the road freight transport and CO_2 emissions. There are some organisations providing sectoral economic forecasts, which can be used in forecasting the energy efficiency and CO_2 emissions of road freight by extrapolating the trends of the indicators and determinants. Here three forecasts to the year 2016 are made. The first forecast is done with national average figures and is an update to the trend extrapolation forecast presented in Liimatainen and Pöllänen (2010). The new features are the data from 2010 and the revised fuel consumption estimates discussed earlier. These forecasts can be used to indicate whether the national energy efficiency and emission targets will be achieved or not.

4.8.1. National trend forecast

The forecast for energy efficiency to the year 2016 was performed by fitting the best trend function illustrated by the R^2 value for each determinant in the model and extrapolating the trend of 1995-2010 to the year 2016. The forecasts of future values are done using trend extrapolation tools provided in the Excel software. Simple trend extrapolation is done by fitting a trend line to the time series and calculating the future values using the trend line equation. Trends may be constant, linear, exponential, damped (logarithmic) or polynomial. The best trend line is chosen using the coefficient of determination (R^2) which is the proportion of total sum of squares explained by the least squares trend line. The R^2 can have a value between 0 and 1 and the nearer it is to 1, the better the trend line represents the data. Figure 16 presents as an example the trend extrapolation used for empty running in this study.

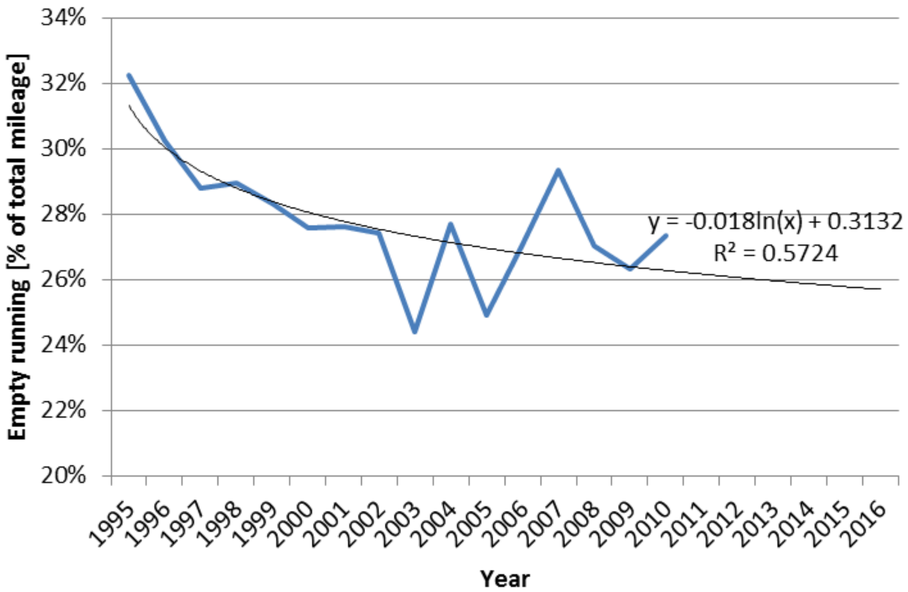

Figure 16. An example of trend extrapolation: empty running.

The trend functions are summarised in Table 13. Most of these trends are, like empty running, logarithmic or power-type functions which level in time. Also, most indicators have fairly clear trend, which is captured well by the function. This results in high goodness of fit illustrated by the R^2 values. In the forecasting the modal split is assumed to be constant 90%, so the value density is forecasted directly as the ratio between GDP and road tonnage. Also the fuel CO_2 content is assumed to be constant 2.66 kg/l in the forecast. Average load on laden trips and average fuel consumption are not directly extrapolated, but calculated from the trend extrapolation of their determinants. Average load on laden trips is forecasted using the extrapolations of average capacity on laden trips and lading factor. Average fuel consumption is calculated using the extrapolations of vehicle own weight, payload, Euro factor and the shares of mileage on distribution trips and on urban/saturated roads. This is done to be able to capture the effects of these determinants.

Table 13. Extrapolated indicators, their trend functions and R^2 values.

Indicator	Trend functions (x=# of year; 1995=1, 2016=22)	R^2 value
Added value [€]	85180*x^0.1773	0.907
Value density [€/road t]	9.1226*x+228.97	0.924
Modal split [road share of total tonnage)	assumed constant 90%, so value density directly €/road tons	-
Average length of laden trips [km]	52.173*x^0.0634	0.561
Average load on laden trips [t]	vehicle carrying capacity*lading factor	
Vehicle carrying capacity [t]	18.925*e^(-0.002*x)	0.324
Lading factor [%]	-0.0035*x+0.8089	0.761
Empty running [% of total mileage]	-0.018*ln(x)+0.3132	0.572
Average fuel consumption [l/100km]	calculated based on vehicle own weight, payload, Euro factor, share of distribution trips and share of mileage on urban/saturated roads	
Vehicle own weight [t]	12.688*x^0.0072	0.309
Payload [t]	-0.0442*x+8.5912	0.674
Euro factor	-0.02*ln(x)+0.991	0.956
Share of distribution trips [% of total mileage]	0.2178*x^0.0091	0.015
Share of mileage on urban/saturated roads [%]	0.0308*ln(x)+0.1009	0.812
Fuel CO_2 content [kg/l]	assumed constant 2.66	-

Figure 17 and Table 14 summarise the changes in the indicators, aggregates, key indicators and determinants in the decarbonisation framework from 1995 to 2010 and the forecast to 2016. The forecasted figures for 2016 are based on extrapolating the development of indicators and determinants between the years 1995 and 2010 as shown in Table 13. The key indicators and aggregates are calculated based on the indicators and determinants.

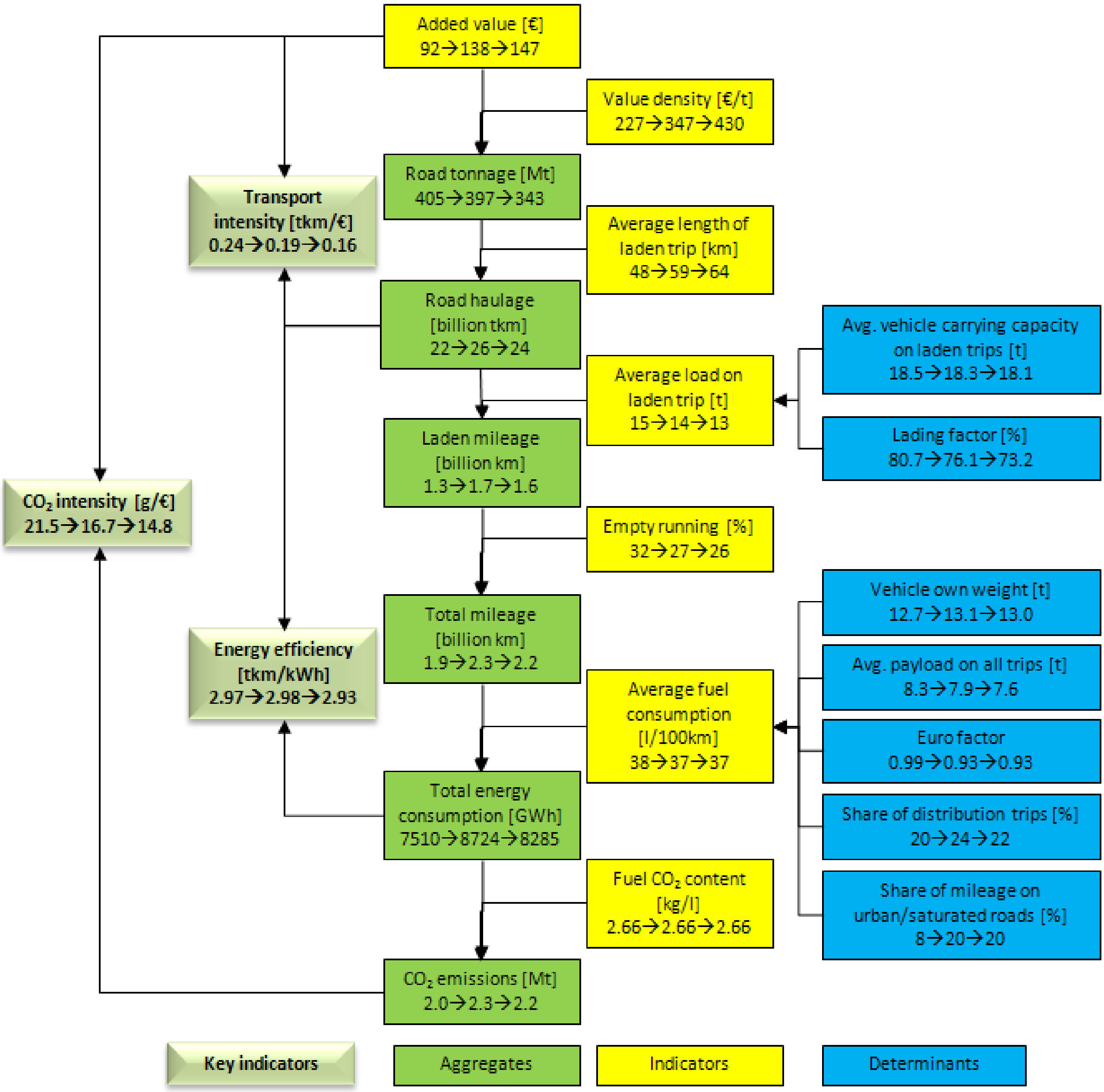

Figure 17. The decarbonisation framework presented with the changes in indicators, aggregates, key indicators and determinants 1995→2010→2016.

Based on the trend forecast, the CO_2 emissions of road freight transport is forecasted to decrease from the 2.3 Mt in 2010 to 2.18 Mt in 2016 (Figure 17). The change is driven by the rapid increase in value density which causes the road tonnage to decrease from 397 Mt in 2010 to 343 Mt in 2016. Average length of laden trips increases slightly, but the road haulage still decreases from 26 billion tkm in 2010 to 24.2 billion tkm in 2016. Hence, the transport intensity decreases from 0.19 to 0.16 tkm/€.

The trends have contradicting effects on energy efficiency. Declining empty running and average fuel consumption affect for improving energy efficiency, but their effect is met by counteracting trend of decreasing average load on laden trips. As a result the level of energy efficiency is forecasted to decline to 2.93 tkm/kWh by 2016 (Figure 17).

If the current statistical trends continue until 2016, the energy efficiency and CO_2 emission targets set in the Finnish energy efficiency agreement will not be achieved. However, achieving the target would not require great changes to any of the determinants. For example, if all the other determinants are kept at the forecasted level, but the average vehicle utilization rate on laden trips rises from 76.1% in 2010 to 76.5% in 2016 and the average vehicle fuel consumption decreases from the 2010 level of 37.2 to 32.8 l/100km, the energy efficiency target would be met. The change in the average vehicle fuel consumption would be -11.8%, which could be achieved by e.g. improvements in vehicle aerodynamics, lighter vehicles (i.e. reduced own weight), use of hybrid electric vehicles in urban operations and wide adoption of ecodriving. Other examples for reaching the energy efficiency target could be established for instance by reducing the amount of empty running by developing the logistic systems or by raising the average load by combining loads.

4.8.2. Sectoral trend forecasts

The second forecast is a sectoral trend forecast, which is done with a similar method as the national forecast but separately for each sector. National figures are then summed up from the sectoral figures. The third forecast is otherwise similar to the second, but the forecast for the added value are not trend forecast, but forecast from the Research Institute of the Finnish Economy, ETLA. The ETLA forecast (ETLA 2011) published in October 2011 covers the years up to 2015, and to reach the year 2016 it is assumed that the sectoral economic development, i.e. the percentage change, is the same from 2015 to 2016 as it is forecasted to be between 2014 and 2015. Other determinants than the added value are the same as in the second forecast. The results of these forecasts are presented in Table 14.

Table 14. Indicator, aggregate and key indicator values in 1995, 2010 and the forecasted values for 2016 with the target for 2016.

	1995	2010	Previous forecast (Liimatainen & Pöllänen 2010)	National trend forecast	Sectoral trend forecast	Sectoral forecast with ETLA added value forecast	Target
					2016		
Added value [mrd. €]	92	138		**147**	**161**	**163**	
Value density [€/t]	227	347		**430**	**421**	**375**	
Road tons [million t]	405	397		**343**	**385**	**433**	
Average length of laden trips [km]	48.3	59.1		**63.5**	**60.6**	**58.1**	
Road tonne-kms [billion tkm]	22.3	26.0	**24.2**	**24.2**	**26.0**	**28.0**	
Average load on laden trips [t]	14.9	13.9	**12.9**	**13.3**	**12.5**	**13.1**	
Vehicle kms on laden trips [billion km]	1.31	1.69	**1.68**	**1.64**	**1.87**	**1.92**	
Empty running [% of total mileage]	32.2%	27.4%	**26.0%**	**25.7%**	**25.2%**	**23.6%**	
Total vehicle kms [billion km]	1.93	2.32	**2.27**	**2.21**	**2.49**	**2.51**	
Average fuel consumption [l/100km]	38.4	37.2	**33.2**	**37.1**	**36.0**	**36.1**	
Total energy consumption [GWh]	7510	8724	**7619**	**8285**	**9079**	**9175**	**8103**
Fuel CO_2 content [kg/l]	2.66	2.66	**2.66**	**2.66**	**2.66**	**2.66**	
Total CO2 emissions [million t]	1.98	2.30	**2.01**	**2.18**	**2.39**	**2.42**	**2.13**
CO_2 intensity [g/€]	21.5	16.7		**14.8**	**14.8**	**14.8**	
Transport intensity [tkm/€]	0.24	0.19		**0.16**	**0.16**	**0.17**	
Energy efficiency [tkm/kWh]	2.97	2.98	**3.18**	**2.93**	**2.87**	**3.06**	**3.41**

The differences between the indicators of the sectoral trend forecast and the sectoral forecast with ETLA added value forecast highlights the great impact that the economic development has on the energy efficiency and CO2 emissions of road freight transport. The only difference between these forecasts is in the added value in different sectors. It is worth to note that the sums of sectoral added value are close to each other in the sectoral trend and ETLA forecasts but the sectoral shares of added value are slightly different (Table 15).

Table 15. Sectoral shares of added value in the history according to the national accounts statistics and in the two forecasts.

	1995	2002	2010	**Sectoral trend forecast 2016**	**ETLA forecast 2016**
Forest cluster	8.8%	8.4%	7.0%	**6.5%**	**8.0%**
Food cluster	4.2%	3.5%	3.3%	**3.2%**	**3.2%**
Energy cluster	2.5%	2.4%	2.1%	**2.0%**	**1.5%**
Construction cluster	7.1%	6.4%	6.9%	**6.0%**	**7.1%**
Technology cluster	9.8%	14.4%	16.8%	**18.1%**	**20.9%**
Chemical cluster	2.5%	3.0%	2.5%	**2.3%**	**3.1%**
Waste and maintenance	0.2%	0.2%	0.2%	**0.3%**	**0.3%**
Trade	9.4%	10.0%	10.9%	**12.9%**	**9.0%**
Services	55.5%	51.6%	50.1%	**48.8%**	**47.0%**
Total [billion €]	92	120	138	**161**	**163**

Although the added value is only 0.8% bigger with ETLA forecast than with the sectoral trend forecast, the amount of road tons transported is 12.5% greater. This is caused by the greater share of transport intensive and low value density forest and construction clusters. Transport volume in tkm in ETLA forecast is 7.7% greater than in the sectoral trend forecast. The difference is smaller than in terms of tons because the average length of haul is very small in the construction cluster so its increasing effect is proportionately smaller with tonne-kilometres than with tonnes.

Interestingly, the forecast with ETLA added value gives rather similar estimate for laden and total vehicle mileage to the sectoral trend forecast. This is because the forest, construction and chemical clusters have high average loads and thus larger transport volume is produced with fewer kilometres than in the sectoral trend forecast. The sectoral empty running affects the difference in the total mileage. Here the greater importance of technology cluster in the ETLA forecast becomes the most influential factor, as its share of added value is significantly bigger than in the sectoral trend forecast (Table 15), while the empty running is quite low in that sector.

Furthermore, the energy consumption and CO_2 emissions are just 1% higher in the ETLA forecast than in the sectoral trend forecast. The difference is approximately the same as with the total mileage. This is due to the fact that the increasing importance of forest and construction clusters, which have high average fuel consumption, is counteracted by the growing importance of technology cluster, which has the lowest average fuel consumption. In terms of the energy efficiency, on the other hand, the difference between the two forecasts is again greater, because of the difference in tonne-kilometres discussed above.

4.9. Conclusions

A new method for analysing the energy efficiency of road freight transport was presented in this chapter. This method is based on a unique way to determine the fuel consumption for each vehicle and trip in the Finnish Goods Transport by Road -statistics. In this way, the total energy consumption can be calculated and decoded similarly to other indicators in the statistics, thus making it possible to analyse the impact of different factors affecting the energy efficiency and CO_2 emissions of road freight transport on national and sectoral level. The sectoral analysis gives highly dissimilar values of CO_2 emissions and energy efficiency between sectors, as the transport needs and thus the freight operations are very varying in different fields of industry and trade.

Though the method was tested using Finnish statistics, it can possibly be applied to other countries which gather goods transport data using continuous company surveys. Statistics on the carriage of goods by road are reasonably similar within EU member states (following the Council Regulation 1172/98) and at least a European comparison of energy efficiency by using this method could be possible. It could also be highly interesting as it might give more insight of the differences between countries and possibly some indications of good or best practices in energy efficiency of road freight transport. However, such comparison would require access to primary data of national continuous goods transport surveys as the currently available Eurostat data is not sufficient for this purpose.

The energy efficiency forecast produced in this research is based on several assumptions and simplifications. To gather more accurate energy efficiency data, a question of fuel consumption for each trip could be added to GTRS-survey, although already the current load on the respondents has been evaluated to be high and there might be difficulties in determining and reporting the actual fuel consumption of each journey. Another possibility to gather more accurate data in Finland is the PIHI system, though it requires higher amount of reporting companies to produce more reliable data. Furthermore, PIHI does not withhold much data on tonne-kilometres, because most truck operators have difficulties in reporting this data. This means that further research on accurate and reliable ways to measure and report also tonne-kilometres is needed.

The purpose of the analysis was to answer the second research question: *How have these indicators developed in the past and what kind of a future can be expected in the short-term if the past trends continue?* As an answer to the first part of the question, the results show that the energy efficiency of Finnish road freight transport improved from 1995 to 2002, but has declined since. The major drivers have been the trends in empty running as well as in fleet composition, indicated by the Euro factor. Empty running hit its lowest level in Finland in 2003 and has since fluctuated considerably. Euro factor decreased quickly during the 1990s but the pace of that decrease has slowed down since, most likely due to emphasizing strict Euro-standards for particulate matter and NO_x emissions in power train design.

As an answer to the second part of the research question, the energy efficiency target for the year 2016 set by the Finnish government was defined as a single figure of 3.41 tkm/kWh for the first time in this research. The energy efficiency target will not be achieved if the current trends continue as extrapolated. However, the target could be achieved with a combination of small changes in the determinants of energy efficiency. Because of the economic crisis, this target is now even further away than it was in 2008, when it was set. The economic crisis started in the last quarter of 2008, so years 2007 and 2009 can be analyzed to see its effects, which are clear. The energy efficiency decreased from 3.02 to 2.99 tkm/kWh. The decrease was mostly caused by the drop in average payload and vehicle utilization rate from 14.7 tons and 77.6% to 13.3 tons and 73.8%. However, the empty running also decreased from 29.3% of total mileage to 26.3% and average vehicle fuel consumption also decreased slightly from 37.2 l/100km to 36.8 l/100km. These last two changes should increase the energy efficiency, but the adverse changes in vehicle utilization resulted in the decrease in energy efficiency. This also highlights the importance of making decisions that promote energy efficiency on every level of logistics management. Planning the supply chains efficiently, optimizing the vehicle utilization, minimizing the empty running, choosing the vehicle of the right size and type for each operation and motivating the drivers to drive economically have a much greater potential to increase the energy efficiency than the technological measures which enhance the fuel economy of trucks.

This chapter focused solely on quantitative analysis of energy efficiency. This approach was necessary to determine the energy efficiency trends in the past and to determine the target for the future. However, quantitative approach has several limitations and data describing many determinants of energy efficiency cannot be found for analysis. Because of this, a qualitative analysis is necessary to better understand the past development and the trends shaping the future. Qualitative analysis combined with the quantitative framework make it possible to have factors not available as statistical data analysed for example with the help of expert views.

The research confirmed that the sectoral economic development has a great impact on the energy efficiency and CO_2 emissions of road freight transport. Bulk goods sectors (forest, construction, energy and chemical) are transport intensive and energy efficient, because they carry heavy loads mostly on rural roads. A shift in balance towards these sectors would improve the energy efficiency of road freight operations but also rapidly increase the overall CO_2 emissions. A shift towards sectors transporting general cargo (technology cluster and trade) would result in worsening energy efficiency and more slowly increasing or even decreasing CO_2 emissions. The economic development in Finland from 1995 to 2002 was characterised by growth in all sectors, which led to growing CO_2 emissions and, at the same time, improving energy efficiency. Economic development from 2002 to 2010, on the other hand, saw diminishing importance of forest cluster and growing importance of technology cluster and trade. This has led to diminishing CO_2 emissions but also diminishing energy efficiency.

The future of road freight energy efficiency and CO_2 emissions is greatly affected by the economic development in each sector. In the short term policymakers have only limited means to affect the economic drivers (such as private investments, labour and energy costs, access to raw materials, level of technology and know-how), which in the end determine the sectoral economic development and also the need for, and to some extent the efficiency of, freight operations. However, the policymakers can affect for instance the modal split (e.g. investments in rail or port infrastructure), average length and load on laden trips and empty running (e.g. fuel taxation, land use planning, urban or regional co-operative distribution centres and regulation of distribution times), and average fuel consumption (e.g. dissemination of best practices, introducing subsidies for energy efficient vehicle technologies and improving the traffic flow).

The research presented a new method for analysing the relations between economic activity, transport demand, energy efficiency and carbon dioxide emissions with a high level of detail in different economic sectors. This was done by using the statistics that are available in many countries and are gathered in a harmonised manner in the EU member states. Hence, the method is applicable in other countries and enables in-depth comparison between countries. Though it should be noted that there are national differences in collecting the statistics, and thus the method may need to be adjusted. Energy consumption data might be available directly from the statistics or there might not be weight based vehicle utilisation data available as highlighted by (McKinnon 2010b). Comparisons between countries would give more understanding on the dynamics of the economy, freight transport, energy consumption and CO_2 emissions. With the method a sector can gain knowledge of its transports and compare the energy efficiency and CO_2 emissions of the transport operations with other operations, and prioritise the actions for improvements. The approach also enables sectoral analysis between countries; e.g. a question can be set that, what is the energy efficiency in a specific sector in different countries. Also the road freight sectors in different countries could be compared to each other which could lead to recognising best practices and gaining international benefits when sharing the experience and knowledge in different sectors and countries. This could for example bring new information in respect to vehicle sizes and weights, e.g. what is the effect of long and heavy trucks currently permitted in Sweden and Finland.

5. Delphi survey

This chapter is modified from the following paper:

Liimatainen, H., Kallionpää, E., Pöllänen, M., Stenholm, P., Tapio, P., McKinnon, A. 2013. Decarbonising road freight in the future – Detailed scenarios of the carbon emissions of Finnish road freight transport in 2030 using a Delphi method approach. Technological forecasting and social change. DOI: 10.1016/j.techfore.2013.03.001.

5.1. Delphi panel

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

In this research the invited Delphi panel consisted of 135 experts representing a variety of stakeholders of road freight transport. The largest share of the experts is from logistics service providers (LSP). The representatives of the 20 largest LSP in Finland were invited to participate, along with 39 LSPs which had answered the haulier survey and said that they would be willing to participate in the Delphi survey. The second largest group of experts invited to the panel were the logistics managers of 32 companies of trade, industry and construction. These experts were selected because they had answered the shipper survey or because they were members of the regional boards of the Finnish Association of Purchasing and Logistics (Logy). Representatives of research organisations were selected from the professors and researchers of the VTT Technical Research Centre of Finland and the Finnish universities which do research on logistics. Representatives of the largest trade associations of road freight transport and logistics were also invited to the panel along with state officials from the ministry of transport and the Finnish Transport Agency. Also a few experts from companies that sell trucks and non-governmental organisations (NGOs) specialised on environmental issues were asked to join the panel, but none of them completed the survey.

The Delphi survey consisted of two rounds. The first round was carried out in September and the second in October 2011. 24 experts completed the survey in the first round and 20 experts 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, so there were 29 panellists in total and the response rate was thus 21%. Responses were received from almost all of the invited stakeholder groups, except from truck sellers and NGOs.

5.2. Selection of questions

The Delphi survey aims to answer the third research question: *What factors affect the long-term future development of the indicators and will the long-term emission targets be achieved?* Two types of data are needed to answer this question, (1) experts' insight on the factors affecting the future development and (2) forecasts of the future values of the eight indicators of the decarbonisation framework. Both types of data provide background information for building the long-term scenarios.

The survey was carried out using a spreadsheet file which consisted of an introduction sheet, eight sheets for forecasting the future of the eight indicators and a concluding sheet. The introduction sheet contained a description of the survey and the framework of the analysis. 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:

- Gross domestic product (GDP)
- value density
- modal split
- average length of haul on laden trips on road
- average load on laden trips on road
- share of empty running of total mileage
- average fuel consumption
- share of biofuels of total energy

A figure of the indicator, its determinants 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 and onwards to 2016 and 2030 based on the forecast by the expert. In the first round the experts were asked to answer these questions for each eight indicators:

- What factors explain the historical development of the indicator?
- What is the probable value of the indicator in 2016 and why this development will happen?
- What is the probable value of the indicator in 2030 and why this development will happen?

In the second round the median value of the forecast for 2016 and 2030 for each indicator was shown to the respondent as well as the respondent's own estimates, if he had answered in the first round. In the figure of the development of the indicator all the estimates from the first round were shown enabling the respondents to see the dispersion of the estimates. In the second round the respondents were given a list of statements about the factors 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 these questions for each eight indicators:

- What is the probable value of the indicator in 2016 and 2030?
- Will the given factor affect the development of the indicator? (-2=totally disagree ... +2=totally agree)
- How will the given factor change the development of the indicator? (Because of the factor the value of the indicator will -2=decrease a lot ... +2=increase a lot)

5.3. Analysis techniques

Three types of analysis of the gathered material were made in this study. First, the responses of the impact of the factors affecting the indicators were analyzed. This was done in a standard manner by reporting the median values of each key indicator and factors affecting it. Standard deviations of the key indicators are calculated for both rounds to see whether the views became closer to each other.

Second, cluster analysis of the key indicators was carried out. Hierarchical cluster analysis with the furthest neighbour -method was performed with the SPSS software. Since each variable was presented in its own natural form in relative scale to the respondents, the variables were standardized to the scale of 0...1 for the cluster analysis. The maximum response of each variable was set the value of 1 and the other responses relatively downwards. Cluster analysis sums up the differences of each variable between the responses and groups similar response totalities together. Normal Euclidean distance was used as a measure of similarity/dissimilarity. Furthest neighbour algorithm starts by grouping two closest responses together and then uses the furthest case in each group as a reference case when calculating the similarity of a response (or already established group) to the group (Milligan 1996; Everitt et al. 2001).

Third, scenarios were built and written. The arithmetic mean values of each indicator in each cluster were used as the cluster centre. The snapshot images of the future in 2016 and 2030 were enriched to describe the rationale of the drivers of change. Materials from all the phases of the research were combined for this work. The resulting scenarios are described in Chapter 9.

With the future statements about the factors that affect the future development of the indicator the qualitative information from the first round could be transformed to quantitative data which enabled more detailed analysis of these factors. This analysis is presented for each indicator in the following chapters. A table of the expert forecasts and a figure of the factors affecting the development of each indicator are shown. The tables summarize the median values of expert forecast for 2016 and 2030 from both rounds separately and combined in overall median. If the panellist gave a forecast on both rounds (15 panellists), the answer from the second round is included in the overall median and answer of each round is included in the median of the respective round. If the panellist gave a forecast only on the first round (9 panellists) or only on the second round (5 panellists), their answer is included in the overall median and the median of the respective round. Although there were 29 answers in total, some panellists did not give values for every indicator. The evaluation of the factors presented in figures was done in the second round with 20 panellists, but here again some panellists did not give values for every factor.

5.4. Gross domestic product

The Delphi panellists forecast the GDP to grow moderately in the future. The median value of the expert forecasts for GDP is 170 billion Euros in 2016 and 200 billion Euros in 2030 (Table 16). The median remained almost the same between the two rounds, although one third of the experts who responded on both rounds changed their forecast between the rounds for 2016 and 40% changed their estimate for 2030. The standard deviation decreased significantly between the rounds.

Table 16. Expert forecast for GDP

Year	**1995**	**2009**	**2016**	**2030**
Historical development (billion €)	105	153		
1. round (N=22) median (billion €)			168	200
1. round standard deviation			33.8	46.6
Overall (N=27) median (billion €)			**170**	**200**
2. round (N=20) standard deviation			12.9	22.7
Share of experts changing their estimate between rounds			33%	40%

The rapid growth of the GDP from 1995 to 2009 was seen to be due to the expansion of the technology industry, lead by Nokia. Also the growth of the export industry and private consumption were seen to have an effect. However, the GDP decreased from 2008 to 2009 due to the global financial crisis and the experts saw that the crisis still affects the GDP until 2016 and even further on. Because of this the GDP is forecasted to be at 2008 level only in 2015 and grow much more slowly than before. Figure 18 shows how the experts saw the different factors to affect the development of GDP in the future.

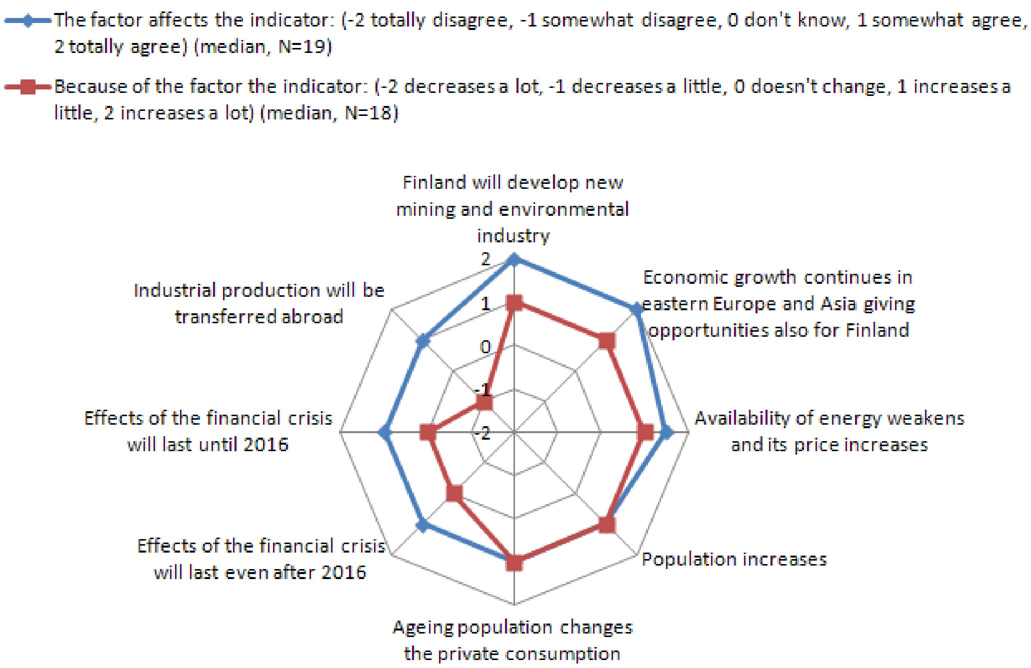

Figure 18. The factors affecting the GDP in the future and their effect.

It can be seen from Figure 18 that the experts agree that all the factors identified in the answers in the first round will affect the development of GDP. Mostly these factors are seen to increase the GDP, but the effects of the financial crisis tend to keep the GDP stable and as an effect of the industrial production transferring abroad the GDP is seen to decrease.

5.5. Value density

The experts forecast the value density to continue its growth, but much more slowly than from 1995 to 2009 when it grew by 73% (Table 17). Median value for the year 2030 forecast a 20% growth from 2009 level. The median remained the same between the rounds, even though 40% of experts changed their estimate between rounds. Standard deviation decreased very much between rounds.

Table 17. Expert forecast for value density

Year	**1995**	**2009**	**2016**	**2030**
Historical development (€/t)	232	401		
1. round (N=23) median (€/t)			430	480
1. round standard deviation			95.1	217
Overall (N=28) median (€/t)			**430**	**480**
2. round (N=20) standard deviation			22.9	91.6
Share of experts changing their estimate between rounds			40%	40%

Delphi panellists stated the historical development to be due to a shift in the Finnish economy from producing bulk goods such as paper to producing valuable goods such as mobile phones. Also the efficiency of logistics was seen to have increased and this development was seen to continue in the future (Figure 19). Increasing efficiency of logistics means in this context mainly that the goods are handled fewer times than before in the supply chain.

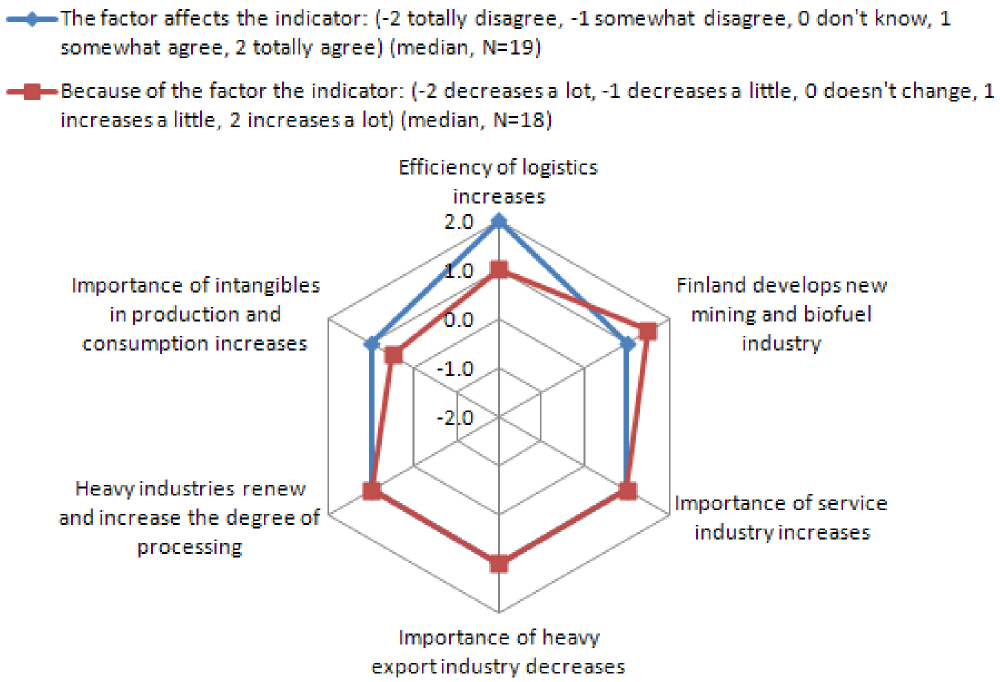

Figure 19. The factors affecting the value density in the future and their effect.

The experts agreed that all the factors have an effect on the value density and the value density will increase as a result. It seems surprising that the development of new mining and biofuels industry is seen to increase the value density considerably. These sectors are not considered to have a high degree of processing, but maybe the experts see the production of biofuels to be more valuable than the production of fossil fuels. Mining industry may also enable new metal industry with high degree of processing.

5.6. Modal split

Modal split will not change significantly according to the experts. In 2016 the share of road freight of overall freight is the same as in 1995 and in 2009 (Table 18). In the 2030 its share is forecasted to decrease by just 2 percentage points. The median of expert forecasts did not change between rounds and the standard deviations decreased only a little for 2030 as only 7% of respondents changed their estimate for 2016 between rounds and 20% for 2030.

Table 18. Expert forecast for the share of road freight of overall freight within Finland.

Year	1995	2009	2016	2030
Historical development (%)	90%	90%		
1. round (N=23) median (%)			90%	88%
1. round standard deviation			0.03	0.07
Overall (N=28) median (%)			**90%**	**88%**
2. round (N=20) standard deviation			0.03	0.06
Share of experts changing their estimate between rounds			7%	20%

The experts said that the modal split has been established in Finland for a long time. Rail or water transports are used when there is sufficiently strong and regular flow of goods. However, other modes than road don't have the necessary flexibility or willingness to increases their share.

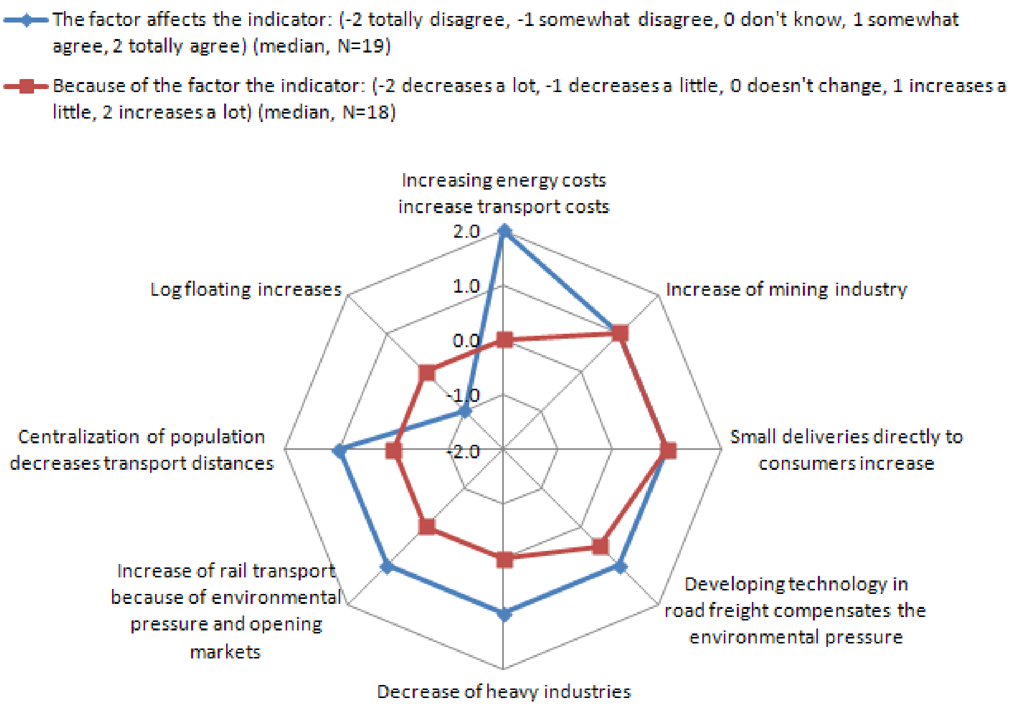

Figure 20. The factors affecting the modal split in the future and their effect.

Once again the panellists agree with the factors that were mentioned in the first round of the Delphi to affect the modal split (Figure 20). Experts only disagree with the view that the log floating would increase. Even though the share of road transport was seen to slightly decrease until 2030, the experts did not consider any factor to decrease it. However, the median of experts is zero for many factors which shows that these factors will not at any rate increase the share of road transport. New mining industry is seen to increase the share of road transport, which indicates that the experts do not think that new rail connections will be build. Also an increase in direct customer deliveries (e.g. due to online shopping) is seen to potentially increase road's share as well as developments in technology which help to compensate the environmental pressure towards reducing road transports.

5.7. Average length of haul on laden trips on road

The average length of haul is forecasted to increase by 2016, but just slightly and only to decrease back to current level by 2030 (Table 19). There were only minor changes in the median and standard deviation between rounds.

Table 19. Expert forecast for the average length of haul on laden trips on road.

Year	**1995**	**2009**	**2016**	**2030**
Historical development (km)	48.3	62.4		
1. round (N=23) median (km)			64.0	63.0
1. round standard deviation			6.9	12.6
Overall (N=28) median (km)			**64.0**	**62.0**
2. round (N=20) standard deviation			6.4	12.5
Share of experts changing their estimate between rounds			20%	33%

Lengthening trips in the history were seen to be due to a centralisation of logistics and decrease in the number of industrial facilities in the rural areas. However, the average length of haul has fluctuated considerably and this was seen to be due to a large number of soil transports, which are very short and volatile.

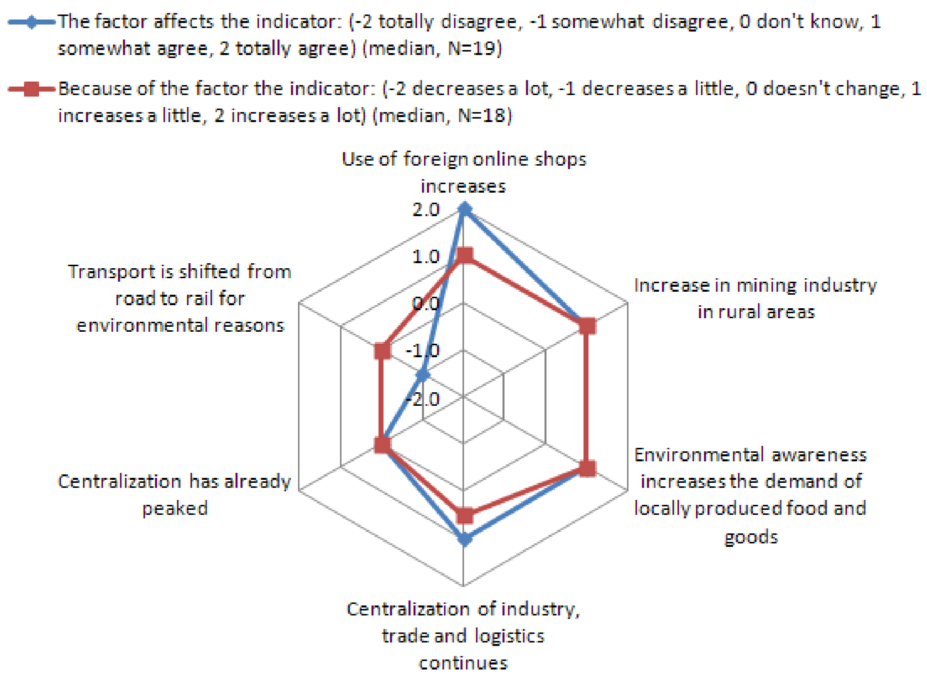

Figure 21. The factors affecting the average length of haul in the future and their effect.

The future of the average length of haul was seen to be affected by increased use of foreign online shops as well as increased mining industry, environmental awareness and centralisation (Figure 21). All of these were seen to increase the length of haul, which is rather peculiar especially in the case of environmental awareness which could be seen to increases the demand of locally produced food and goods. However, the expert views varied a lot on this and the most common value was actually -1, which would mean that the average length of haul would decrease.

5.8. Average load on laden trips

The average load on laden trips has decreased in Finland in 1995-2009, but the panellists forecast this development to break and the average load to increase almost to the 1995 level by 2030 (Table 20). The median of the estimates changed only slightly between the rounds, but this indicator was one of the two in which the standard deviation actually increased between rounds.

Table 20. Expert forecast for the average load on laden trips

Year	**1995**	**2009**	**2016**	**2030**
Historical development (t)	14.9	13.3		
1. round (N=23) median (t)			13.8	14.5
1. round standard deviation			0.9	2.9
Overall (N=28) median (t)			**13.7**	**14.5**
2. round (N=20) standard deviation			1.7	3.1
Share of experts changing their estimate between rounds			13%	20%

The decrease in the average load in the history was seen to be due to the spreading use of just in time and outsourcing principles in every sector of economy. These have increased the frequency of transports while decreasing the average size of shipments. Also the shift in the economic structure in Finland from heavy industries to technology industries was seen to have decreased the average load.

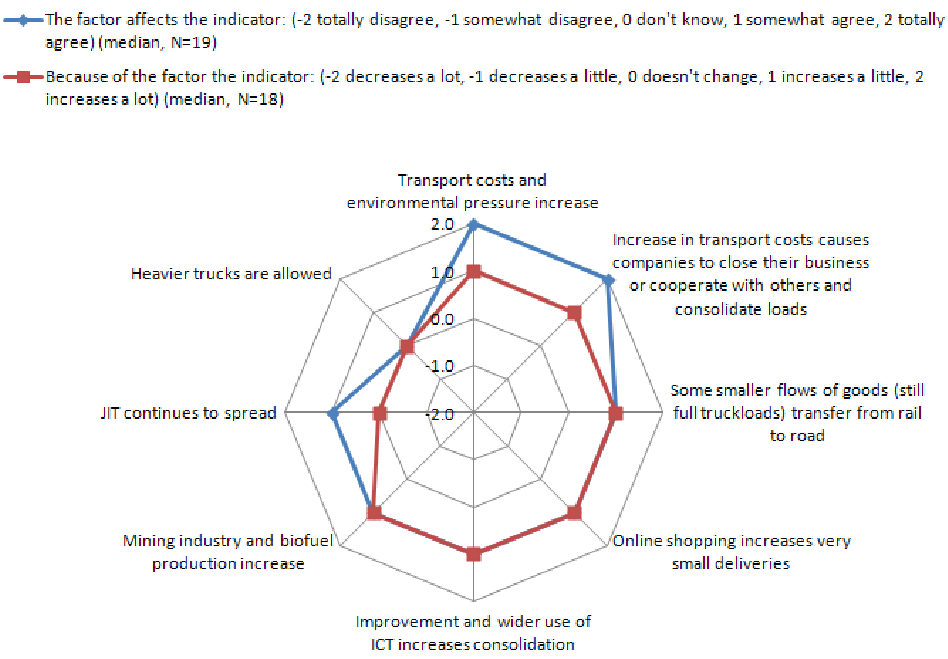

Figure 22. The factors affecting the average load in the future and their effect.

The forecasted increase in the average load was seen to be mainly due to increasing transport costs and environmental pressure which enforces companies to cooperate and consolidate loads (Figure 22). Improvement and wider use of ICT is seen to enable the consolidation, but heavier vehicles are not needed to do this.

5.9. Empty running

Experts forecast the empty running to continue decreasing in the future (Table 21). Median and standard deviation did not change between the Delphi rounds and none of the experts changed their estimate for 2016 between the rounds. However, 20% of experts changed their estimate for 2030 between the rounds, but this did not have an effect on the median or standard deviation.

Table 21. Expert forecast for the share of empty running of total mileage

Year	1995	2009	2016	2030
Historical development (%)	32%	26%		
1. round (N=23) median (%)			25%	21%
1. round standard deviation			0.02	0.03
Overall (N=28) median (%)			**25%**	**21%**
2. round (N=20) standard deviation			0.02	0.03
Share of experts changing their estimate between rounds			0%	20%

The panellists stated that reducing empty running has been necessary in order to maintain the competitiveness in the road freight sector. Control over the haulage has also transferred to large

LSPs, retailers or manufacturers which have better chance and tools to arrange the hauls efficiently. Also the economic shift from the sectors with large share of structural empty running (e.g. forest industry) to sectors with smaller share (e.g. technology industry) have accounted for the decrease in empty running.

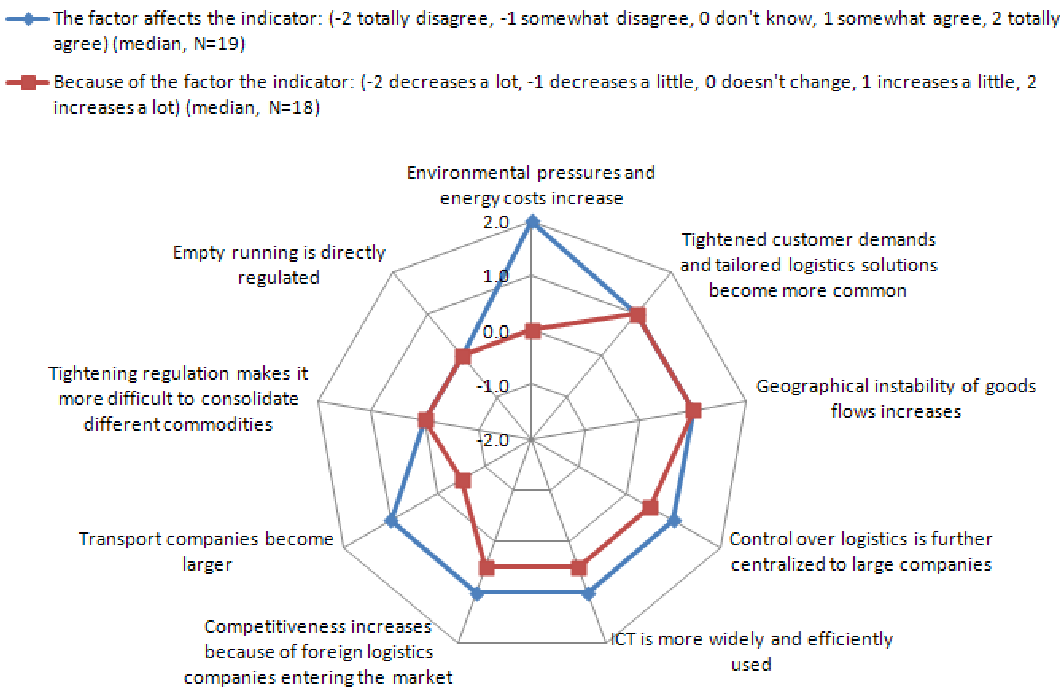

Figure 23. The factors affecting the empty running in the future and their effect.

Only one expert forecasted the empty running to increase in the future, but still the median of the experts seems to estimate that majority of the factors increase the empty running slightly (Figure 23). This result may be because of a misinterpretation of the question by some experts as the mode of the answers shows a decreasing effect for the environmental pressures and energy costs, more centralised control over logistics and wider use of ICT. Only the tightened customer demands and geographical instability of goods flows are seen to increase the empty running if mode is considered. Anyhow, the experts do not believe that empty running will be regulated directly in the future.

5.10. Average fuel consumption

Average fuel consumption is expected to decrease further in the future and the decrease is seen to be faster than in the history (Table 22). The median forecast of the panellists did not change between the rounds, but the standard deviation increased slightly for 2030 in the second round.

Table 22. Expert forecast for the average fuel consumption

Year	1995	2009	2016	2030
Historical development (l/100km)	38.4	37.0		
1. round (N=23) median (l/100km)			35.4	32.1
1. round standard deviation			1.1	4.8
Overall (N=28) median (l/100km)			**35.4**	**32.1**
2. round (N=20) standard deviation			1.1	5.0
Share of experts changing their estimate between rounds			20%	33%

The decrease in the average fuel consumption in the history was seen to be mostly due to development of vehicle technology. Environmental pressure and rising costs also force the companies to focus on ecodriving. The same factors are expected to have an effect also in the future (Figure 24). In the history the decrease of average load was seen to have decreased the fuel consumption (l/100km), but also to have decreased the energy efficiency (tkm/kWh). In the future the increasing average loads are seen to not have a significant effect on the fuel consumption. New emissions regulations, on the other hand, are expected to increase the average fuel consumption.

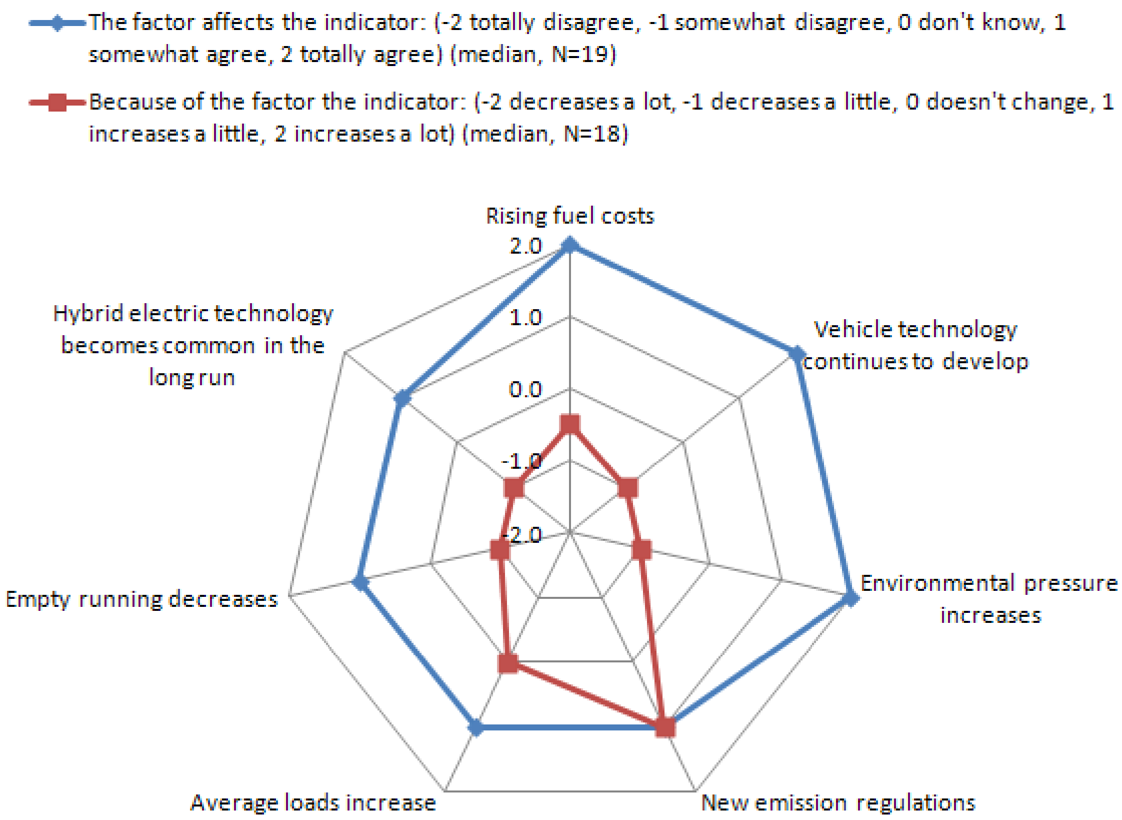

Figure 24. The factors affecting the average fuel consumption in the future and their effect.

5.11. Biofuels

Biofuels have only become widely available during the last few years, but experts forecast them to be much more significant in the future (Table 23). The median and standard deviation change slightly between the rounds.

Table 23. Expert forecast for the share of biofuels of total energy

Year	1995	2009	2016	2030
Historical development (%)	0%	3%		
1. round (N=23) median (%)			5%	18%
1. round standard deviation			0.03	0.12
Overall (N=28) median (%)			**6%**	**20%**
2. round (N=20) standard deviation			0.03	0.11
Share of experts changing their estimate between rounds			13%	20%

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.

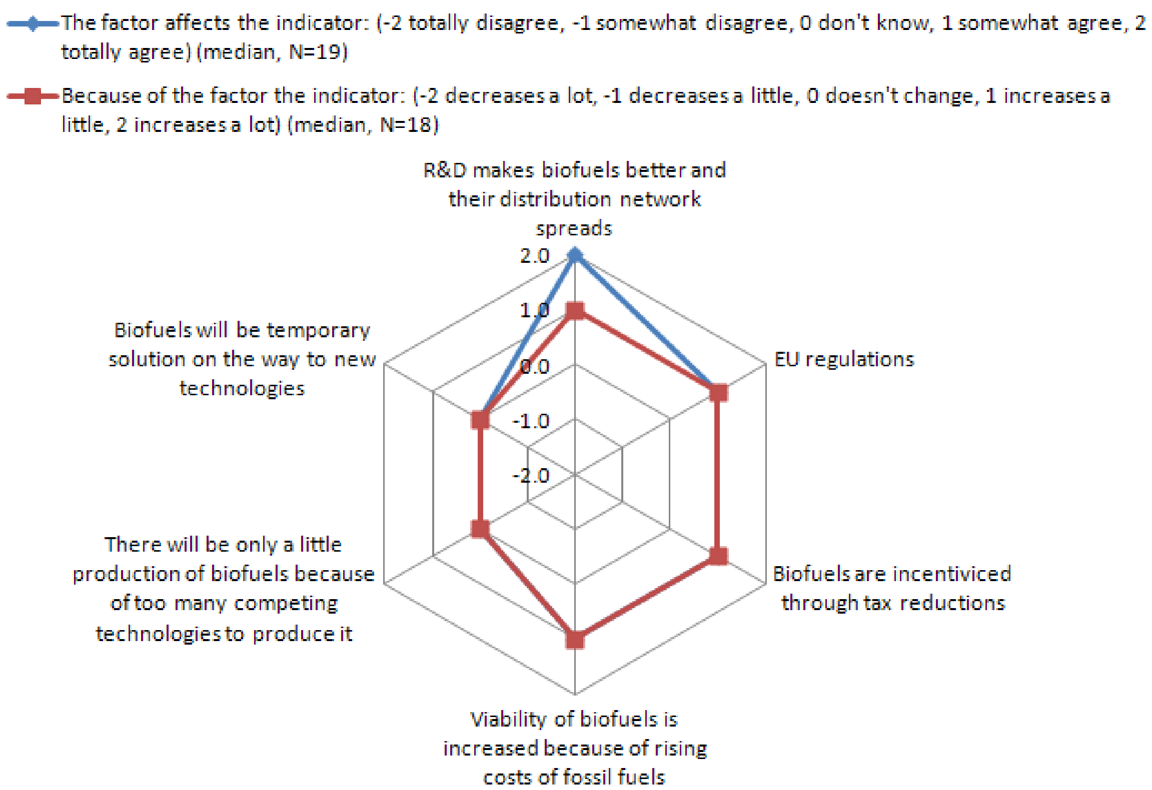

Figure 25. The factors affecting the biofuels in the future and their effect.

Research and development of biofuels and their distribution network is forecasted to increase the use of biofuels in the future (Figure 25). The EU policy and regulations are also seen to continue to have an effect. Rising costs of fossil fuels and tax incentives for biofuels are also believed to promote wider use of biofuels.

5.12. Megatrends

Based on the views of the experts, there were many same or similar factors affecting the development of the indicators reported above. Hence these factors can be grouped into five megatrends (Table 24):

- structural change of the economy
- changes of regional structure
- changes of consumer habits
- concerns of energy and environment
- efficiency of road freight transport.

Many factors which belong to the same megatrend may affect an indicator and their effect may be opposite. The overall effect of the megatrend is the average of the effects of these various factors.

Table 24. Grouping of factors into megatrends

	GDP	Value density	Modal split	Average length of haul	Average load	Empty running	Average fuel consumption	Biofuels
Structural change of the econmy	Industrial production will be transferred abroad	Importance of service industry increases	Decrease of heavy industries		JIT continues to spread			There will be only a little production of biofuels because of too many competing technologies to produce it
	Effects of the financial crisis will last until 2016	Importance of heavy export industry decreases	Increase of mining industry					
	Effects of the financial crisis will last even after 2016	Heavy industries renew and increase the degree of processing						
	Economic growth continues in eastern Europe and Asia giving opportunities also for Finland							
	Finland will develop new mining and environmental industry	Finland develops new mining and biofuel industry	Increase of mining industry	Increase in mining industry in rural areas	Mining industry and biofuel production increase			R&D makes biofuels better and their distribution network spreads
Changes of regional structure	Population increases		Centralisation of population decreases transport distances	Centralisation of industry, trade and logistics continues		Geographical instability of goods flows increases		
				Centralisation has already peaked				
Changes of consumer habits	Ageing population changes the private consumption	Importance of intangibles in production and consumption increases		Environmental awareness increases the demand of locally produced food and goods				
			Small deliveries directly to consumers increase	Use of foreign online shops increases	Online shopping increases very small deliveries	Tightened customer demands and tailored logistics solutions become more common		
Concerns of energy and environment	Availability of energy weakens and its price increases		Increasing energy costs increase transport costs		Transport costs and environmental pressure increase	Environmental pressures and energy costs increase	Environmental pressure increases	Viability of biofuels is increased because of rising costs of fossil fuels
			Increase of rail transport because of environmental pressure and opening markets	Transport is shifted from road to rail for environmental reasons			Rising fuel costs	Biofuels are incenticived through tax reductions
			Log floating increases				New emission regulations	EU regulations
Efficiency of road freight transport		Efficiency of logistics increases	Developing technology in road freight compensates the environmental pressure		Improvement and wider use of ICT increases consolidation	Competitiveness increases because of foreign logistics companies entering the market	Vehicle technology continues to develop	Biofuels will be temporary solution on the way to new technologies
					Increase in transport costs causes companies to close their business or cooperate with others and consolidate loads	Tightening regulation makes it more difficult to consolidate different commodities	Average loads increase	
					Some smaller flows of goods (still full truckloads) transfer from rail to road	Empty running is directly regulated	Hybrid electric technology becomes common in the long run	
					Heavier trucks are allowed	Transport companies become larger	Empty running decreases	
						ICT is more widely and efficiently used		
						Control over logistics is further centralised to large companies		

5.12.1. Structural change of the economy

The megatrend structural change of the economy is forecasted to transfer the heavy export industry away from Finland. The remaining industries renew and increase their degree of processing. Mining and bioindustries, on the other hand, are seen to grow, as are the service sectors. The economic growth in the Eastern Europe and Asia will benefit also the Finnish economy, but the global financial crisis will restrain the economic growth in Finland. These changes will have an effect on all indicators except empty running and average fuel consumption (Figure 26). This megatrend is seen 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, also average length of haul and average load are seen to increase due to this megatrend. Biofuels will also be used more as the bioindustry increases.

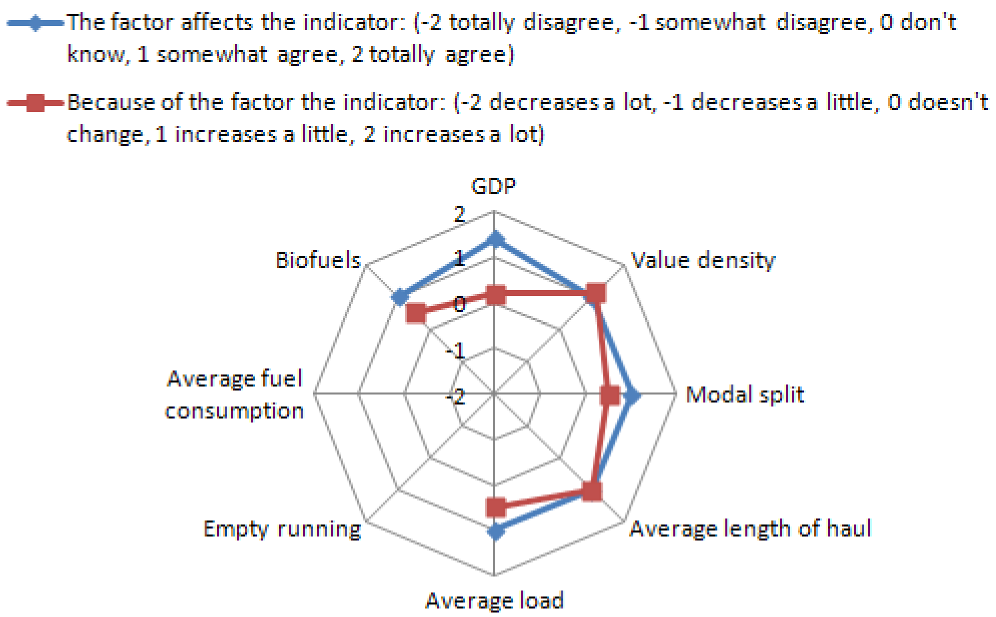

Figure 26. The effects of the structural change of the economy on the indicators.

5.12.2. Changes of regional structure

Changes of regional structure include the growth and centralisation of population, due to which also industry, trade and logistics centralise to few large metropolitan areas in Finland. This leads to a regional imbalance of goods flows and an increase in empty running (Figure 27). Increasing population is seen to increase the GDP. This megatrend is also seen to have a minor increasing effect on the average length of haul on laden trips, but modal split will not change.

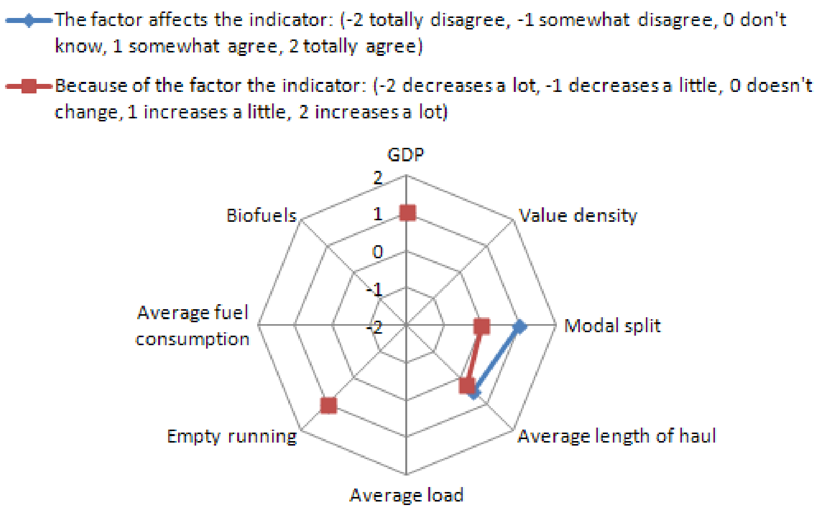

Figure 27. The effects of the changes of regional structure on the indicators.

5.12.3. Changes of consumer habits

Changes of consumer habits are caused by the ageing population of Finland, increasing awareness of environmental issues and increasing variety of goods and services available online. Due to these changes, logistics is seen to shift more and more towards distribution of small shipments directly to the consumers. The goods will also be more often produced either more locally or further away than today. Changes of consumer habits are forecasted to increase the GDP and value density (Figure 28). The share of road transport and the average length of haul are also seen to increase. Rather surprisingly also the average load would increase although the online shopping and direct deliveries to consumers become more frequent. Empty running is also seen to increase because of this megatrend.

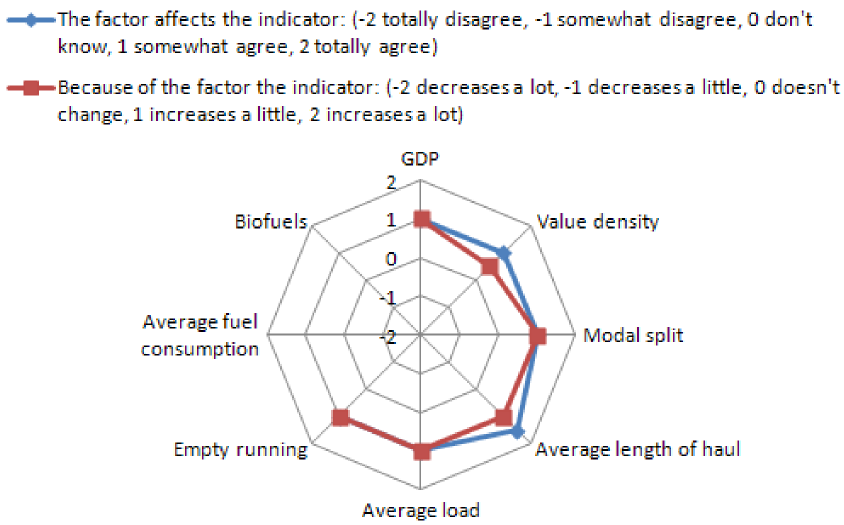

Figure 28. The effects of the changes of consumer habits on the indicators.

5.12.4. Concerns of energy and environment

Concerns of energy and environment are forecasted to affect the indicators most widely. Value density is the only indicator this megatrend is seen not to affect. The most important factor in this megatrend is the increase of the price of fossil fuels. Another factor is the growing awareness about the environmental issues and the related policy objectives, e.g. to promote biofuels. Concerns of energy and environment are seen to affect the GDP, but the effect is not a decrease because of increasing costs but rather an increase due to new opportunities of environmental business (Figure 29). This megatrend is not seen to change the modal split, the average length of haul on laden trips or the share of empty running of total mileage. Average load on laden trips, on the other hand, is forecasted to increase because of the increasing environmental concerns and energy costs. These changes are also seen to have a decreasing effect on the average fuel consumption. Utilisation of biofuels is also seen to increase due to the strong policy objectives and measures such as tax reductions.

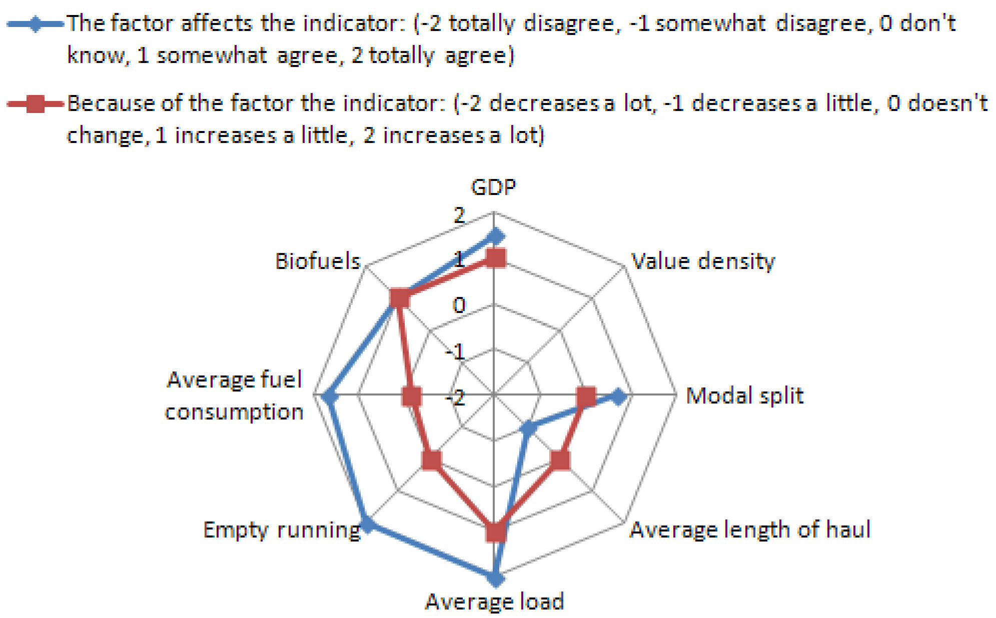

Figure 29. The effects of the concerns of energy and environment on the indicators.

5.12.5. Efficiency of road freight transport

The efficiency of road freight transport is seen to increase because of developments in vehicle technology and related ICT, but also because of changes in the operational methods of logistics service providers. Especially the cooperation between the companies is seen to increase and improve the efficiency. This leads to increasing average loads, reducing empty running and decreasing average fuel consumption (Figure 30).

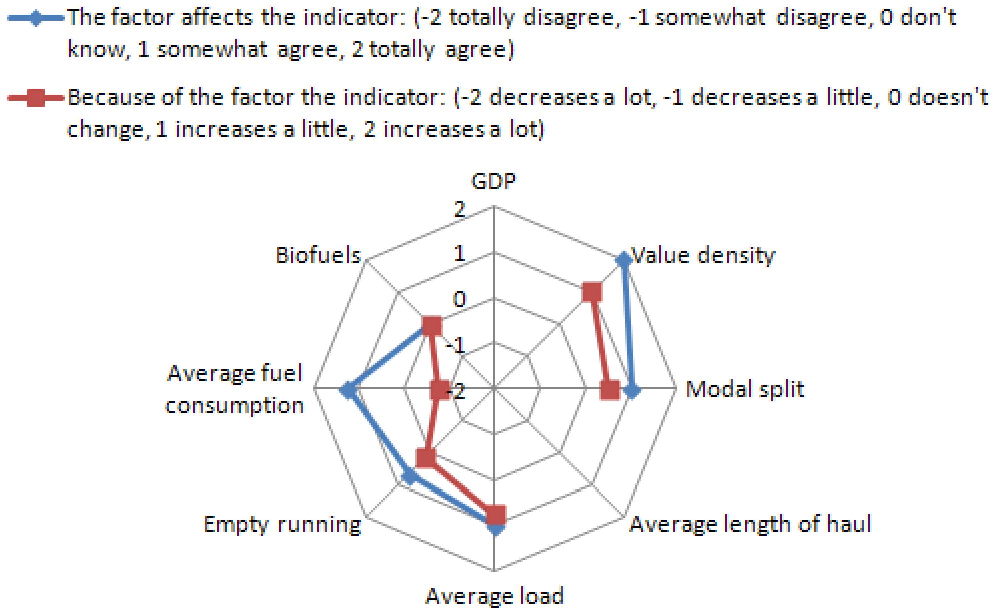

Figure 30. The effects of the efficiency of road freight transport on the indicators.

5.13. Conclusions

The Delphi survey aimed to answer the third research question: *What factors affect the long-term future development of the indicators and will the long-term emission targets be achieved?* As an answer to the first part of the question, five megatrends affecting the long-term development of the energy efficiency and CO_2 emissions were identified from the factors identified and evaluated by the Delphi panellists:

- structural change of the economy
- changes of regional structure
- changes of consumer habits
- concerns of energy and environment
- efficiency of road freight transport.

Each indicator is affected by many factors within the megatrends and the effects may be contradictory.

Rather clear clusters of indicator values could be identified from the forecasts of the Delphi panellists, which enabled the various scenarios, answering the second part of the research question, presented in Chapter 9. It should be noted that the number of panellists was rather small and the results of the Delphi may be very different if other panellists would have answered. However, the panellists did represent a variety of expertise from university professors to owners of small haulage companies.

This study utilized a method for making the qualitative data from the first round of the Delphi study quantitative in the second round using historical trends, visual feedback and calculation options in an Excel form. This enabled finding out the importance and the effects of the statements given in the first round. However, there seemed to be some confusion about the effects of the statements, which is probably because the direction viewed as “improvement” varied from indicator to indicator.

The research helps the Finnish Ministry of Transport and Communications in planning the future transport policy as it gives the understanding about how the changes of one indicator affect the total CO_2 emissions. The study also highlighted several trends which affect the future development of the emissions and this enables the policy makers to find measures to affect these trends.

6. Shipper survey

This chapter is modified from the following paper:

Liimatainen, H. 2010. Shippers' Views on Environmental Reporting of Logistics and Implications for Logistics Service Providers. Logistics Research Network Conference 2010 Proceedings. September 8-10, Harrogate, United Kingdom. 7 p.

6.1. Selection of questions

Despite of the ambiguous carbon auditing practices and the critique towards product-level carbon auditing, there seems to be a clear and growing need to develop the environmental reporting of logistics, based on the literature review in Chapter 3.5. The purpose of this survey is to describe the current state of environmental reporting of logistics and answer the fourth research question: *How do the shippers take the environmental issues into account in their operation and are they going to change their operations because of environmental policy targets?* The results of the survey are primarily used as an input to the expert panel workshops and for building the short-term energy efficiency action plan.

The questionnaire consist of five sets of questions: background, environmental issues in general, current and wanted environmental reporting of logistics service providers (LSPs), environmental reporting in transport purchasing decisions and views of the future. The background questions include questions on the branch of the company, its turnover, transport costs, volume and modal split. These questions enable analysis of variations between sectors and company sizes. Questions about the environmental issues in general include five 'yes or no' questions and open questions for further description about these. These questions aim to find out what environmental expectations the shippers experience from outside the company and how these expectations affect the environmental target-setting, monitoring and auditing within the company as well as the requirements for the suppliers of the company.

The questions about the environmental reporting of LSPs to shippers aims to find out what kind of information the shippers currently receive or would like to receive about the indicators related to the energy efficiency of freight transport. Shippers can choose what information they get or would like to get from a given list of indicators and how they get it from lists of attributes concerning the frequency, level of detail and format of reporting. The fourth set of questions aims to find out how the environmental reporting is taken into account when making transport purchasing decisions. The final set of questions aims to find out how the environmental issues are seen to change in the short-term future.

6.2. Respondents

The survey was targeted to Finnish companies from the sectors of trade and industry, which have more than 20 employees. The trade and industry sectors were selected, because these sectors are mainly responsible for freight transport. The service sectors were left out because the service companies mostly have the role of freight receiver in the supply chain and thus do not affect the logistics decisions as much as trade and industry sectors. The companies with less than 20 employees were left out because there are too many of them, it was difficult to find contact details for them and they have minor role in purchasing logistics services compared to the companies included in the survey. There were 3670 companies of trade and industry with more than 20 employees in Finland in the end of year 2009 (Statistics Finland 2012c). The number of companies is small enough to include all companies in the survey, so no sampling is required. However, an email address is required, because an online survey tool is used. Many marketing contact companies provide email contact lists made according to specifications. Using the above specifications MicroMedia provided the contact list of 2273 executives. The list covers sufficient amount of companies and no resources were available for finding more contact details, so this list was used in the survey.

The survey was carried out by using web-based survey software and invitations with a link to the survey were sent via email to 2273 executives in mid-January 2010. The executives were told that they could send the link forward in their organisation. 2009 invitations were delivered to recipients successfully. After one week a reminder was sent to recipients who had not yet answered the survey. During a two and a half week period usable responses were received from 115 companies, setting the response rate to 5.7%. The response rate is fairly low, which is probably mainly due to sending the invitations to busy executives. In total 159 persons opened the survey, so 44 persons opened but did not complete the survey, indicating that the survey may have been too extensive and time-consuming. Due to low response rate and considerable number of unfinished surveys there is a possibility that especially persons that are more environmentally conscious than average completed the survey and the results are thus more environmentally friendly than is the reality among all companies.

60% of respondents were CEOs, 20% logistics managers and the rest other managers, such as environmental managers or production managers. The turnover of the companies ranged from 400 k€ to 6 billion Euros. Although the response rate is quite low, the responses cover wide range of sectors and on most sectors there is usable amount of responses to make sector-specific analysis possible. Figure 31 shows the respondents by sector and size.

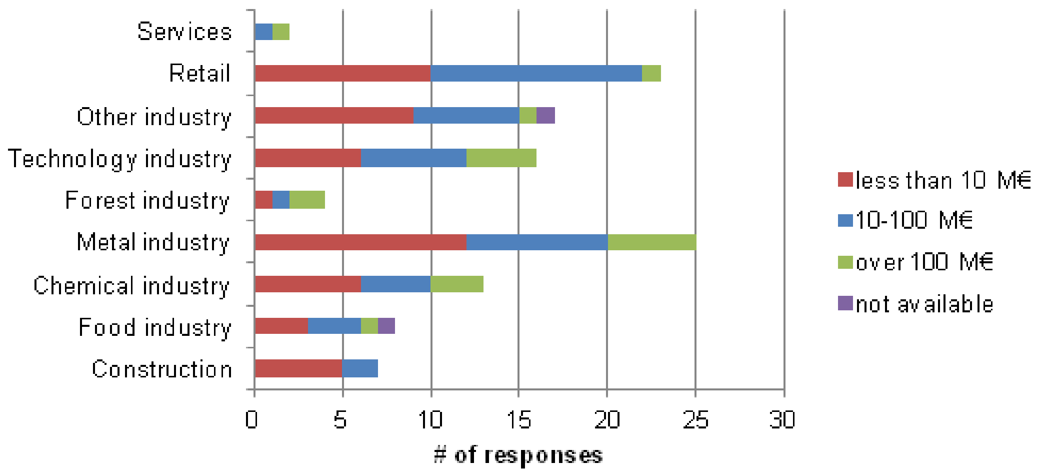

Figure 31. Number of responses by sector and turnover

The transport costs equal on average 4% of the companies' turnover. 84% of companies have outsourced all transport operations, 12% have outsourced them partly and only 4% have not outsourced them. Around two thirds of the companies operate at European market and 16% are global companies operating also outside Europe. 84 companies stated their annual volume of transport, which totalled 13.5 million tons, i.e. 4% of the overall goods transported by road in Finland in 2009.

6.3. Environmental aspects in general

The first part of the survey explores shippers' views on environmental aspects in general. 30% of the companies stated they had experienced requirements and expectations on environmental aspects from outside the company, e.g. from customers. Half of the biggest companies, with over 100 M€ turnover, had experienced this, as had three quarters of companies from forest industry. The most common forms of expectations were legal requirements and environmental certificates.

Environmental reporting is currently performed in 42% of the companies; yet again this is more common in the biggest companies (78%), in forest industry (75%), and also in chemical industry (69%). Environmental reporting is the least performed in retail sector (22%). The reported aspects varied greatly from one company to other, but the amount of waste, recycling and energy consumption were mentioned by many companies. The future prospects of environmental reporting were explored by asking companies to choose on five-point scale (very unlikely-very likely), how likely they considered the statement "our company reports its environmental impacts annually" to be true by 2016. A quarter of the companies considered the statement very likely and 37% likely, whereas only 5% considered it very unlikely. Nearly all of the biggest companies considered it likely or very likely. Most positive sectors towards this statement were forest and chemical industry and most sceptical construction with 43% of companies answering unlikely or very unlikely.

Product-level carbon auditing has been done or is on-going in 15 companies (13%). Interestingly, companies from every sector except technology industry have done carbon auditing. Carbon auditing is mainly done in biggest companies with 39% of them having done it, as opposed to 9% of medium sized (turnover from 10 M€ to 100 M€) and 6% of small (turnover less than 10 M€) companies. Many companies noted that their carbon auditing project is at an initial stage. Experiences from audits have been mixed and problems with scoping the audit, acquiring reliable data and lack of standards are common. Future statement "our products have carbon labels" (by 2016) divided the opinions of companies. 31% of companies couldn't decide whether it is likely or unlikely. 23% of companies regarded it likely and the same percentage regarded it unlikely. Similarly, very unlikely and very likely got 11% of responses both. On the future statement responses were very similar from companies of all sizes. Forest industry and other industry considered the statement most likely to happen with 75% and 53% of likely or very likely responses, respectively. Food industry, on the other hand was remarkably puzzled with 63% of companies choosing "neither likely nor unlikely".

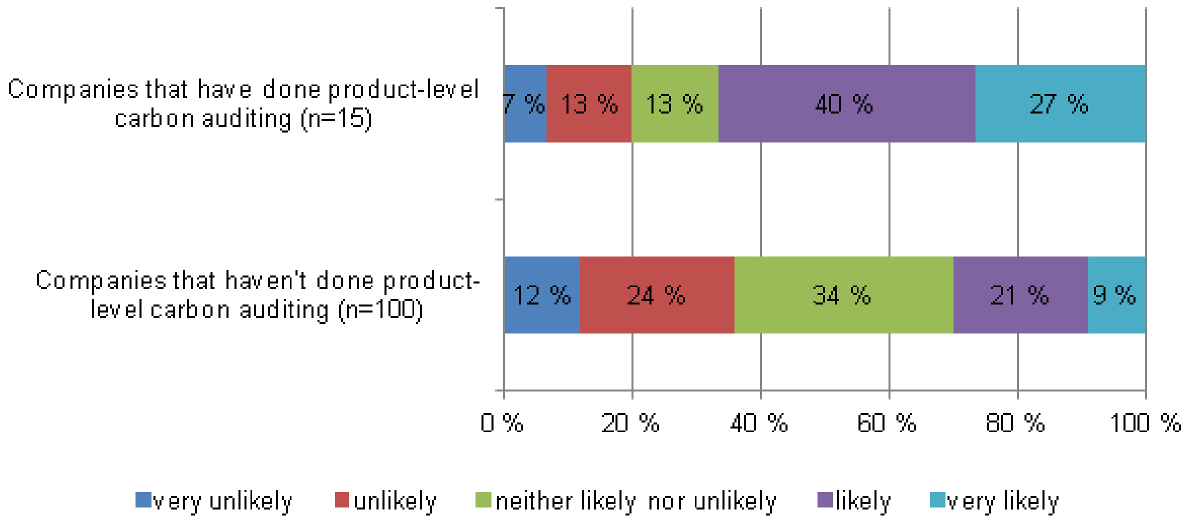

Figure 32. Responses to the future statement: "Our products have carbon labels by 2016."

Despite of the mixed and problematic experiences from carbon audits, 67% the companies who have done product-level carbon auditing considered carbon labels on their products in the future likely or very likely (Figure 32). On the other hand, one in five of those considered it unlikely or very unlikely.

Targets for reducing the environmental effects have been set in 54% of the companies. Among the biggest companies over three quarters of the companies have done so, as have all of the companies in forest industry sector. The targets focused mostly on reducing waste and energy consumption. The related future statement was "our company is committed to an energy saving target". 59% of the companies considered this likely or very likely and only under one fifth unlikely or very unlikely. The biggest companies considered this more likely than smaller ones and every company from forest and chemical industries considered it likely or very likely.

6.4. Environmental reporting of logistics

Currently only 4 companies out of 115 (3.5%) are receiving environmental reports from their logistics service providers (LPSs) and three out of these four would want to improve the current reporting. Also 43% of the companies which do not currently get environmental reporting would want to have it in some form or another. Nearly a half of the respondents are not satisfied with the current state of the environmental reporting from their LSPs. Again, there is variation in this with companies of different sizes. Two thirds of the biggest companies would like to improve the reporting, whereas two thirds of the smallest companies do not see a need for improvement. The need for improvement is greatest in the chemical industry, with 69% of the companies wanting better environmental reporting. The future statement “our company will require environmental reporting from the LSPs”, was considered likely or very likely by 40% of the companies and unlikely or very unlikely by one fourth of the companies. The statement was considered likely or very likely by a half of the biggest companies but only by a third of the smallest companies. From the sectors, food industry was the one with most likely or very likely answers. Answers to the two questions indicate clearly that there is a great need for improving the environmental reporting of the LSPs.

To help the LSPs to develop sufficient reporting practices, questions considering the indicators, frequency, scope and format of reporting were asked from the 53 companies that stated they would want to improve environmental reporting. The amount of carbon dioxide emissions was clearly the most wanted indicator to be included in environmental reporting, followed by fuel consumption per haulage and vehicle utilization rate on laden trips. It is remarkable that all three most wanted indicators are those which LSPs have difficulties to produce, especially allocated to each customer. The indicators and shares of companies wanting them to be included in environmental reporting of the LSPs are summarized in Figure 33.

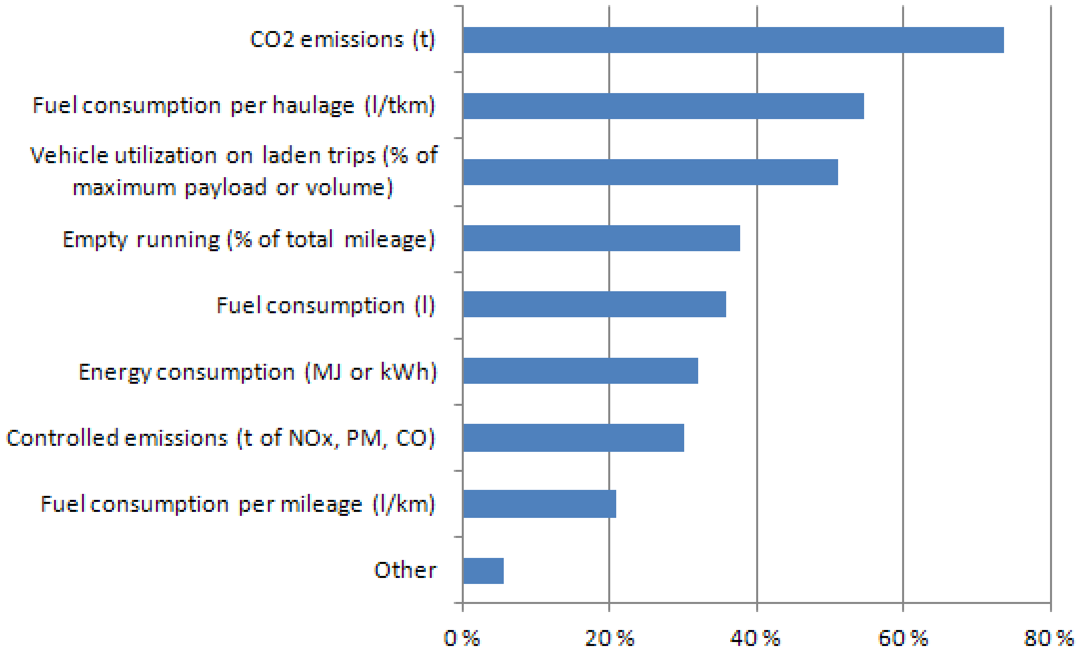

Figure 33. Shares of companies wanting indicators to be included in the environmental reporting of the LSPs (n=53).

The order of the most wanted indicators is similar for medium and large companies, but the percentage of companies wanting CO_2 reporting is 63% of the smallest companies and the next four indicators are equally wanted at 37%. The CO_2 emissions are also most wanted across all branches except the chemical industry, where the fuel consumption per haulage is the most wanted. Also, in the food industry vehicle utilization is equally wanted with CO_2 emissions and in the other industries CO_2, fuel consumption per haulage and vehicle utilizations are equally wanted.

The most suitable frequency of reporting for nearly two thirds of the companies is quarterly reports, but annual reports would be sufficient for one third of the companies. Only 4% of the companies would want monthly reports. As to the scope of reporting, 59% of companies would be satisfied with total figures of all their logistics operations, but 13% of the companies, and one fourth of the biggest companies, would want product-level reports. Consignment-level reporting is wanted by nearly one fifth of the companies. The most usable format of reporting is a spreadsheet file, with 69% of the companies stating that would do. Many respondents commented that a standard should be formed for the environmental reporting to enable comparisons of the environmental performance of the LSPs.

6.5. Environmental aspects in purchasing logistics services

Logistics service provider's ability of environmental reporting is currently taken into account by 17% of all 115 companies, but by 44% of the biggest companies. Food industry is the most active sector in this respect, whereas within chemical industry and other industry sectors not a single company takes this into account. However, taking it into account does not mean that companies are willing to pay for environmental reporting when purchasing logistics services. In fact, only 4.5% of the companies are ready to pay extra for reporting and 7% of the companies currently require the ability from all LSPs. Still over a half of the companies prefer a LSP with the ability of environmental reporting, if the costs are not higher. About a third of the companies do not take reporting into account when making purchasing decisions.

Taking LSP's current level of energy efficiency into account is very similar to the figures above. One in five take it into account and 44% of the biggest companies do so. Responses within sectors are similar to previous question. The future statement "our company uses energy efficiency criteria in purchasing logistics services", was considered likely or very likely by 38% and unlikely or very unlikely by one fourth of the companies. In contrast to most other future statements, this was considered most likely among medium-sized companies. Food and forest industry were once again the most positive in their views.

6.6. Views of the future

Several future statements have already been analysed above with respective questions of the current practices. In addition to these there were four more future statements about planning and delivering energy efficient logistics in 2016. The first statement was: "our company's supply chains are planned according to energy efficient practices". This statement was considered likely or very likely by 34% of the companies and it was considered most likely among medium-sized companies and companies from food and forest industry sectors.

Companies considered the next statement, "our company's supply chains are planned in cooperation with LSPs", more likely than the previous statement. Just over a half of the companies considered this likely or very likely and the answers were similar in companies of all sizes. Between sectors there was more variation in responses. Nearly all food and forest industry companies considered this statement likely or very likely, but only 31% of the technology industry companies did so.

The future statement considered most unlikely was "our company uses less road transport because of environmental reasons". Only 7% of the companies considered this likely or very likely, whereas nearly two thirds considered it unlikely or very unlikely. Most positive responses came from food, metal and other industry sectors, but within them still only about 12% considered this likely or very likely. Currently 97.6% of the respondents' haulage in Finland is done by road and only 12% of companies use rail transport to some extent. Within the companies using rail transport, its share is 8.4% of total haulage and the share of road haulage is 90.4%. These sceptical attitudes towards reducing road transport indicate that there is very little potential for modal shift from road to rail. Modal shift is one of the most commonly stated goals for building a low-carbon future, so these attitudes should be considered when e.g. government assesses the possibilities for modal shift.

Even though there seems to be a little potential for modal shift, there is a considerable potential for reducing environmental effects by improving road transport operations. In the light of this survey, shippers also encourage LSPs to this direction. The future statement, “our company requires continuous improvement of energy efficiency from LSP”, was considered likely or very likely by 44% of the companies. Over three quarters of the biggest companies considered this likely and food and forest industry were once again the most positive in their answers.

6.7. Conclusions

The shipper survey aimed to answer the fourth research question: *How do the shippers take the environmental issues into account in their operation and are they going to change their operations because of environmental policy targets?* Based on the survey results the shippers would like to have more information on the environmental effects of their logistics than they currently have, as long as it does not induce extra costs. Most companies stated that legislative requirements and industry standards rather than customers set the requirements for environmental issues. Some companies have been proactive in developing their practices to prepare to possible future environmental policy measures.

There is growing critique towards product-level carbon auditing and carbon labelling because of the complexity and high costs of these actions. In Finland, 15 companies have done or are currently doing product-level carbon auditing. The experiences from these companies confirm the problematic issues identified in the literature. Most of all there is a great need for clear guidelines and standards on how to perform carbon auditing. Despite of the problems, most companies who have done carbon auditing expect to be doing it in a wider scale in the future. Companies are confused about the future of product-level carbon auditing and same uncertainty was noticeable from answers to other future statements, too, as a fairly big share of the companies chose the option “neither likely nor unlikely”. Nevertheless, it can also be seen from the answers that many companies are actively reducing their environmental effects and improving their reporting, even though demands from outside the companies are not yet that common.

Carbon auditing on a supply chain or company level are expected to have a great potential for identifying opportunities for carbon reductions. However, information from logistics service providers is needed to perform supply chain carbon audits, and currently environmental reporting of the LSPs is nearly non-existing. Almost a half of the companies want to improve the environmental reporting of their LSPs. Reporting of the CO_2 emissions, fuel consumption per haulage and vehicle utilization rate are mostly wanted, but all of these are currently difficult for the LSPs to produce. Active LSPs could gain competitive advantage by improving their environmental reporting, as many shippers prefer a company which can do that.

However, shippers are not willing to pay any extra for environmental reporting and this fact may effectively undermine improvement efforts of the LSPs. Also, if each LSP begins to develop environmental reporting that fits their own business best, there will be various environmental reports, none of which would have any relevant information to shippers because they have all been done differently. Therefore there is a great need for collaborative effort by LSPs, shippers and researchers to develop measuring methods and reporting standards to be commonly used for environmental reporting of logistics services to ensure transparent and comparable results.

7. Haulier survey

This chapter is modified from the following paper:

Liimatainen, H., Stenholm, P., Tapio, P., McKinnon, A. 2012. Energy efficiency practices among road freight hauliers. Energy Policy, vol. 50, pp. 833-842.

7.1. Selection of questions

The survey aims to answer the fifth research question: *How do the hauliers take the environmental issues into account in their operation and are they going to change their operations because of environmental policy targets?* The results of the survey are primarily used as an input to the expert panel workshops and for building the short-term energy efficiency action plan. Results are also used for evaluating the correctness of the fuel consumption and empty running estimates made based on the statistics in Chapter 4.

The survey consists of seven sets of questions: background, monitoring of fuel consumption, level of energy efficiency, energy efficiency actions, energy efficiency agreement, energy efficiency in haulier-shipper interface and views of the future. The background questions include questions on the sector the haulier serves, haulier's turnover, number of trucks and employees. These questions enable analysis of variations between sectors and company sizes. The questions about the monitoring of fuel consumption aim to find out how the environmental issues are monitored and do the companies have necessary data in order to provide the reporting the shippers want.

The questions about the current level of energy efficiency include questions about fuel consumption and empty running which enable the comparison between the stated indicator values and those calculated based on the statistics in Chapter 4. Questions on the energy efficiency actions also builds on previous research phases as a list of 16 actions is built based on the literature review and the level of knowledge and usage of the actions is surveyed. Furthermore, the aim of the research is to *support the initiatives of the Finnish government for improving the energy efficiency and reducing the CO_2 emissions of freight transport*, the most important of these initiatives being the Finnish energy efficiency agreement, which the next set of questions covers. The level of knowledge about the agreement is asked, along with the usefulness of some possible features of the agreement.

While the shipper survey covered their view of the environmental issues in purchasing logistics services, the haulier survey aims to provide the view from the other side of negotiations. Shippers' interest toward the energy efficiency of haulier and the usefulness of some possible requirements from shippers to hauliers are surveyed. Also an open question about the best ways that shippers could promote the energy efficiency of hauliers is presented. Finally, questions about the views of the future aim to find out the likelihood of improvements in fuel monitoring, energy efficiency actions and shipper-haulier collaboration.

7.2. Respondents

The survey was targeted to Finnish hauliers. There were 10923 road freight hauliers in Finland in the end of year 2010 (Statistics Finland 2012c). Survey was directed to the members of the trade association Finnish Transport and Logistics SKAL which has around 6600 members (SKAL 2010). The sample comprised of firms with known email address and SKAL had an email list of 3174 member companies. The number of companies is small enough to include all companies in the survey, so no sampling is required. The list covers sufficient amount of companies and no resources were available for finding more contact details, so this list was used in the survey.

The survey was conducted from March 21st to April 4th 2011 with Webropol online survey software. Invitations were sent on March 21st and reminders on March 24th and March 30th. Before the first reminder there were 106 responses, and this rose to 234 responses before the second reminder and finally to 303 responses by the end the survey period. 295 of the 303 responses were usable, giving a response rate of 9.3%. The fleet sizes of respondents compared to all Finnish hauliers were as follows (Figure 34).

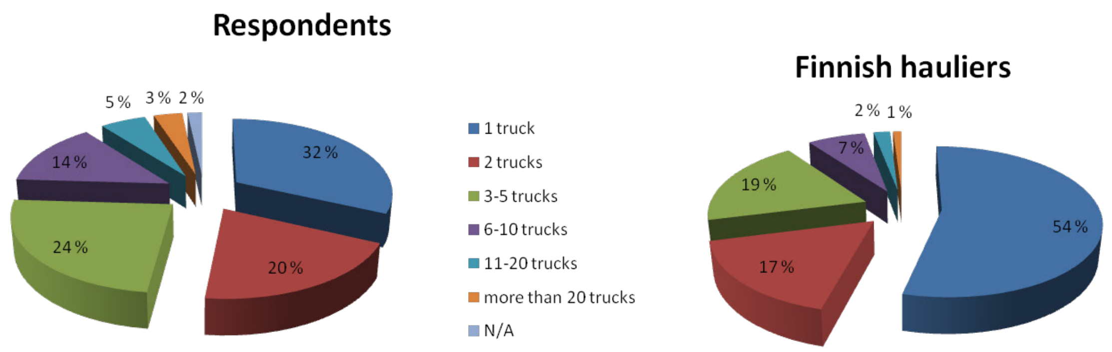

Figure 34. Company sizes of the respondents and all Finnish road freight hauliers (SKAL 2011a).

As can be seen from Figure 34, companies with just one truck are slightly under-represented among the respondents while larger companies are over-represented to some degree. By acknowledging this it is selected to present nonweighted numbers. The respondents were also requested to indicate which sector of economy is their primary customer (Figure 35).

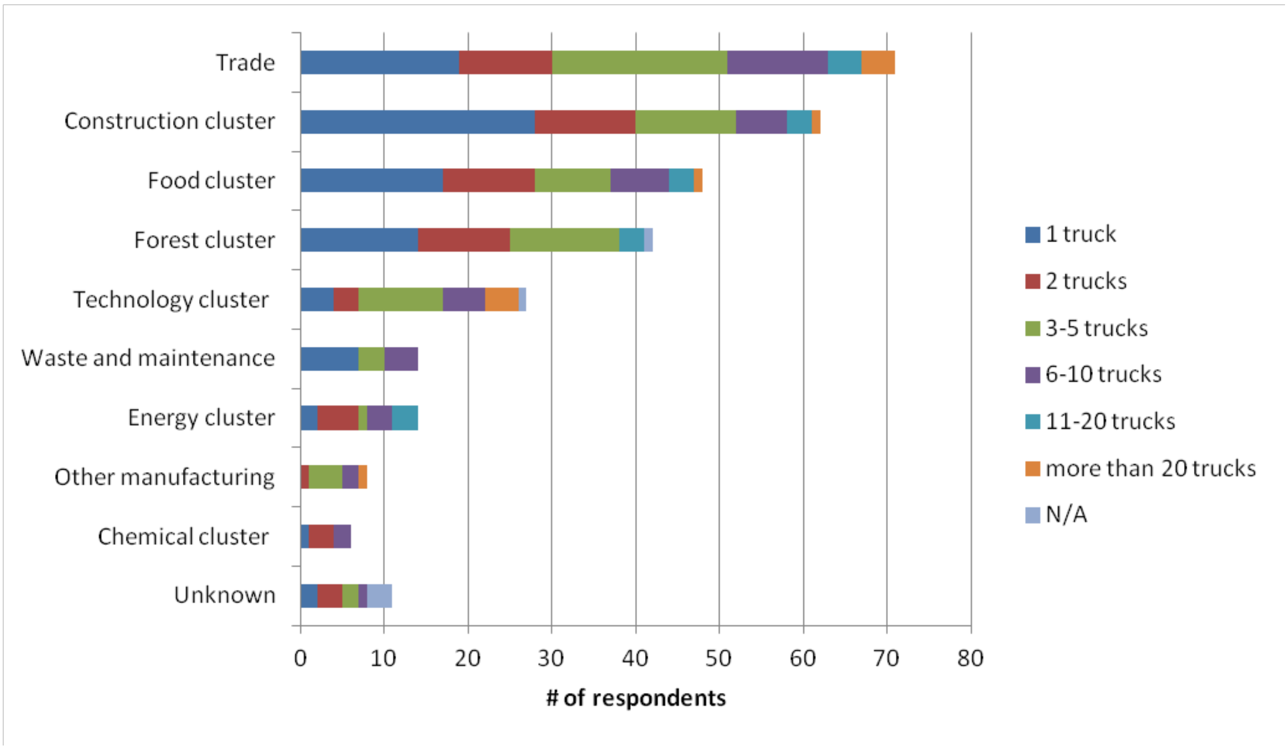

Figure 35. The number and fleet size of respondents by primary sector.

The companies serving technology and other manufacturing sector as well as energy and chemical clusters are mostly larger companies, while the construction cluster is mostly served by companies with only one or two trucks.

The measures related to energy efficiency were further analysed with descriptive statistics and, when possible, with cross-tabulations.

7.3. Monitoring the current level of energy efficiency

The respondents are active in monitoring and managing their fuel consumption. About 60% of companies have set targets for reducing their fuel consumption, while 13% do not actively monitor their fuel consumption. Although 13% is not much, it is still rather surprising that any company does not actively monitor their fuel consumption. After all, fuel consumption is the second biggest cost for the hauliers, accounting for 23% of total costs (SKAL 2011b). The Finnish results are aligned with their British peers (small hauliers), of which 50% run a fuel efficiency programme (AECOM 2010). Operational key performance indicators were monitored by 72% of small British hauliers. Among British hauliers the barriers for not running a fuel efficiency programme or monitoring key performance indicators were: no time or lack of staff, lack of know-how and too high costs. A fuel efficiency programme and key performance indicators might be considered as a larger set of actions than just setting a target for reducing fuel consumption and monitoring it, but still the basic principle remains the same. Thus, the barriers for not doing such activities are probably the same in Finland as in Britain.

7.3.1. Energy efficiency related activity and company size

A categorization was created on the firms' activity related to energy efficiency. Category was created based on simultaneous presence of targets for energy efficiency and monitoring the fuel consumption. An 'active' company has set a target for reducing fuel consumption and monitors the fuel consumption regularly. Out of 295 hauliers 166 belong to the category of 'active' companies. When this categorization is studied further the results show that activity in energy efficiency is related to the size of the company (Table 25). Based on their self-assessment, 56% of respondents are 'active' and 44% are not. The 'inactive' companies are smaller than the active ones (Table 25).

Table 25. Energy efficiency related activity and company size.

	Active in energy efficiency?	n	avg.	s.d.	t-test sign.
How many trucks do you operate?	Yes	161	6.3	11.934	p<0.01
	No	128	3.5	3.698	
How many employees do you have?	Yes	161	11.4	23.427	p<0.01
	No	129	6.2	7.885	
What is your annual turnover? (million euros)	Yes	156	1.5	3.443	p<0.05
	No	122	0.9	1.549	
What share of your turnover comes from your biggest customer? (%)	Yes	158	65.3	30.482	n.s.
	No	126	65.8	30.441	

In addition to setting targets and monitoring their fuel consumption, the 'active' companies have also implemented more energy efficiency actions than the 'inactive' ones. Only with implementation of hybrid vehicles the difference was not significant. The motivation to become active in terms of energy efficiency seems to be mostly due to increasing fuel costs as the 'active' companies stated the fuel price as a motivation for the energy efficiency actions more often than the 'inactive' companies.

7.3.2. Monitoring practices and level of detail

Most of the studied companies (44%) keep manual records of their fuel consumption by recording the mileage and amount of fuel when filling the tank. On the other hand, 27% of companies keep the records on computer while still manually collecting the data. Automatic recording of fuel and mileage at the pump is used by 6.5% of companies and 9.6% of companies use advanced on-board monitoring equipment. Implementation of fuel consumption recording technologies seems to be similar also in other countries. Only one company out of eight interviewed British small hauliers used automatic monitoring at the pump, while others emphasised the use of simple spreadsheets (AECOM 2010). On-board monitoring equipment was used by only one of ten interviewed German large hauliers (Tacken et al. 2011). The monitoring practices reveal the slow adoption of new technologies by hauliers. This may hinder the participation in the Finnish energy efficiency agreement, because the entire system is internet-based. This fact should be taken into account while trying to enhance the fuel consumption monitoring among the hauliers. Thus, educating and supporting the computer usage and possibility for manual reporting should be emphasised.

About 78% of respondents monitor their fuel consumption on at least truck-level, while 30% assess the consumption at driver-level. Truck-level monitoring is required in the energy efficiency agreement, so there should be adequate data available, although much of it is not in electronic form. Most companies monitor the development of fuel consumption monthly, but 20% do it on weekly basis and some even daily.

Monitoring the total haulage in tonne-kilometres seems to be too difficult or impractical for the hauliers according to the results. Only 11% of respondents said that they monitor tonne-kilometres. However, even this may be an overestimate, because only 8% of respondents gave a reasonable figure for their annual total haulage in tonne-kilometres, when asked. Annual total haulage was considered reasonable if it gave an average load of 1–50 tons when divided by the annual laden kilometres stated by the respondent. The low level of tonne-kilometre monitoring causes difficulties for the assessment of the energy efficiency agreement because information on both fuel consumption and total haulage in tonne-kilometres are needed. If the energy efficiency database does not provide information on tonne-kilometres, the data must be taken from the national Goods Transport by Road statistics (GTRS) and reliability of the assessment is weakened when data from different sources are combined.

7.3.3. Current level of fuel consumption

The respondents were also requested to provide data on their annual fuel consumption and the share of empty running. The following information was calculated based on these responses (Table 26).

Table 26. Average fuel consumption and empty running on sectors based on responses of this survey and GTRS data from 2009.

	This survey		2009 GTRS data	
	Fuel consumption [l/100km]	Empty running	Fuel consumption [l/100km]	Empty running
Forest cluster	51.1	38%	39.1	33%
Energy cluster	43.4	40%	43.6	32%
Construction cluster	42.4	40%	35.3	36%
Chemical cluster	40.7	28%	39.7	28%
Waste and maintenance	40.6	34%	25.4	30%
Food cluster	37.7	23%	37.0	21%
Technology cluster	35.1	22%	31.8	26%
Trade	33.5	15%	30.7	21%
Other manufacturing	33.3	19%	30.5	23%
N/A	30.4	17%		
Total	39.6	28%	34.4	28%

The results indicate a variance between the road transport hauliers serving different sectors of the economy. The fuel consumption and empty running are higher in the bulk goods sectors than in other sectors. It can also be seen that the estimated fuel consumption, based on the Goods Transport by Road Statistics (GTRS), underestimate the fuel consumption in some sectors. The reasons for the underestimates are most likely that, firstly, idling could not be taken into account in the estimates, and secondly, the speed of transport could not be taken into account. The transports in forest, construction and waste and maintenance clusters typically include long periods of idling when loading and unloading the vehicle. Also, some of the mileage in these sectors is driven on small rural roads at low speed and on urban roads with frequent stops in case of waste transport. The empty running seems to be underestimated in statistics in bulk transport and overestimated in other sectors. Quite remarkably, however, the overall share of empty running is the same in the survey and in the GTRS data. These findings have been taken into account in the statistical analysis in Chapter 4.

7.4. Current energy efficiency actions

The respondents were given a list of 16 energy efficiency actions and asked to indicate their familiarity or level of usage for each action. Responses are reported in Figure 36.

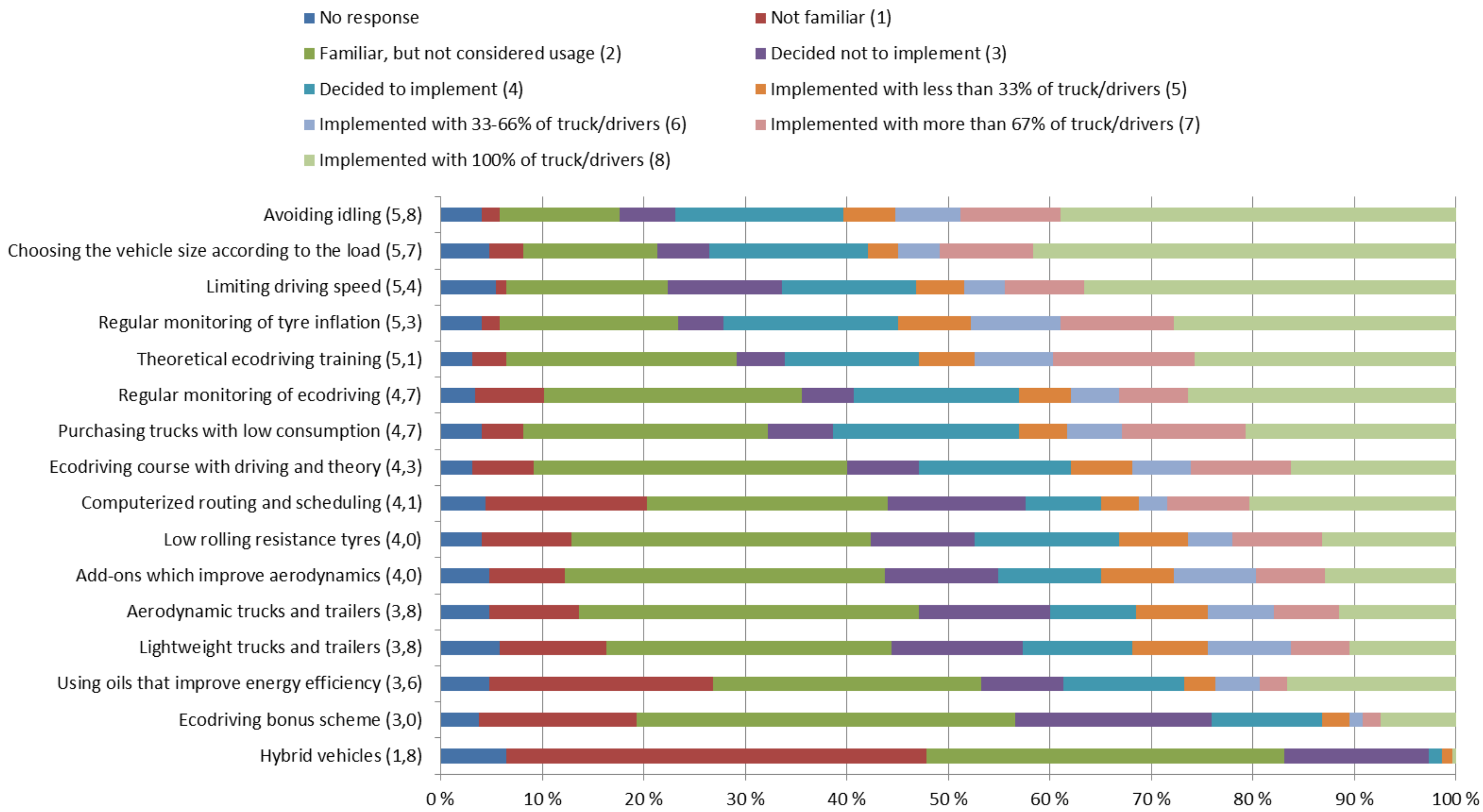

Figure 36. Energy efficiency actions by Finnish hauliers (n=295).

Studied road freight hauliers are very familiar with the energy efficiency actions. The share of respondents unfamiliar with the action is less than 10% with 11 out of 16 energy efficiency actions. Interestingly, their perceptions are again similar to their British peers, most of who stated that they have excellent or good knowledge on fuel efficiency (AECOM 2010). Knowledge on technology was claimed by the British hauliers as their weakness what comes to operational knowledge, as 57% of hauliers claimed to have some, poor or even no knowledge on technology. However, computerized vehicle routing and scheduling (CVRS) was used by only around 15% of British small hauliers, while the same share among Finnish hauliers is 20–30%. This suggests that the Finnish hauliers have better technological knowledge, at least on CVRS systems. However, its utilization seems to be highly dependent of company size, as 8 out of 10 large German hauliers use CVRS (Tacken et al. 2011). The survey indicates potential gaps in the technological knowledge among Finnish hauliers, too. More than 40% of respondents are not familiar with hybrid vehicles. However, there aren't many hybrid trucks available yet and those available are mainly for urban distribution and waste collection, and thus inappropriate for many hauliers.

The companies have not considered the usage of many actions, though. This may indicate that they do not have enough knowledge and information on the actions to do a thorough cost-benefit analysis or they are simply lacking resources for focusing on more than a few actions. If the company has considered the implementation of a particular action, in most cases it has implemented it. Only in some cases, like with ecodriving bonus schemes, many companies who have considered the usage of that action have decided not to implement it. Quite many companies are in the process of implementing measures, the share of companies which have decided to implement but have not yet done it is 10–20% in nearly all actions (Figure 36).

7.4.1. Barriers for implementing energy efficiency actions

The most utilised actions are the inexpensive and simple ones. For example actions like idling avoidance, speed limitation and monitoring tyre pressures have no investment cost but can yield great savings. Choosing the right vehicle for each operation is also business-as-usual if the company operates with more than one vehicle. On the other hand, actions that require greater investments or enough knowledge on many alternatives are not widely used. A comprehensive analysis on the fuel saving measures by the Danish Transport and Logistics Association (DTL 2009) showed that most measures have an expected payback period of less than 2 years and many even less than 1 year. The short payback periods still do not seem to motivate hauliers to implement the actions. An explanation to this is suggested by Ogburn & Ramroth (2007) who point out that a wide variety of energy efficiency actions with promises of significant savings have been pushed to the hauliers for decades, but the hauliers need a proof of the savings in their own operations and lack the resources for carrying out sufficient tests. Hence a clear signal from a reliable source for verified fuel savings may provide the assurance the hauliers need to make the investment decision. This is illustrated by the case of an 810% increase in auxiliary power unit (APU) sales in

Canada following the rebate scheme which decreased the investment cost by only up to 19% (Ogburn & Ramroth 2007).

Lightweight vehicles and aerodynamic profiling increase the costs of vehicle purchase and the companies may not be able to carry any extra investment costs, even though savings would be achieved later on. Finnish hauliers may also have less incentive to implement lightweight trucks and trailers than other European hauliers. This is because Finland has a maximum vehicle gross weight limit of 60 tonnes and thus there is less need for the extra payload weight that lightweight trucks could yield than in the countries with lower maximum weight limit. However, low utilization of aerodynamic profiling and lightweight vehicles is even more the case with large German hauliers, of which none use lightweight vehicles and only a few uses aerodynamic profiling, aerodynamic add-ons and low rolling resistance tyres (Tacken et al. 2011).

There are huge varieties of motor oils and tyres, which may explain why their energy efficient versions are not preferred. The companies simply do not have enough objective information on the different oils and tyres nor the resources to find that information. This is a problem which the national energy efficiency database could address. The database would be an excellent tool for disseminating information on the most energy efficient oils, tyres and other fuel saving spare parts and add-ons. Following the example of SmartWay Technology Program (USEPA 2012) the Finnish government should set up scheme in which the manufacturers could give their products to be tested by an independent research centre which would verify the potential fuel saving of that particular product. Advertising the verified product would then be allowed on the website of the energy efficiency database.

Ecodriving training will become mandatory because of the European directive (2003/59/EC) on the periodic training of truck drivers, but it has not been fully implemented in the companies yet. It is understandable that the owner-operators are reluctant to participate in the training because the time spent in training is directly away from profitable work. Many companies that have implemented ecodriving training have also implemented related monitoring system which enhances the effect of training. However, ecodriving bonus schemes are not widely in use. In many cases ensuring the fairness of such scheme in varying operations is perhaps considered too difficult (Liimatainen 2011). Ecodriving bonus schemes also often require sophisticated driver-specific monitoring and related investments. Naturally bonus schemes are not applicable in companies with only a few trucks and drivers. This fact concerns also computerized routing and scheduling systems. The interviews of large German hauliers seem to give further evidence of this as 9 out 10 companies do driver training and 3 have a driver incentive scheme (Tacken et al. 2011). However, on-board fuel monitoring is used by only one of the 3 German companies that have an incentive system, so incentives can be applied without investments in monitoring equipment.

7.4.2. Objectives and results of energy efficiency actions

The companies were also asked, what had been the primary objective for energy efficiency actions. The most common objective was unsurprisingly cost reduction, which was stated by 82% of respondents. The second objective, on the other hand, is slightly surprising. Environmental concern was mentioned as primary objective by 9% of respondents, far more often than fulfilling customer expectations (4%) and improving company image (3%). Some altruistic, 'soft' environmental values can therefore be found in the supposedly 'hard' technical haulier business.

Some of the studied freight hauliers reported additional energy efficiency actions that were not mentioned among the listed 16 actions. Improving backhauls was mentioned many times, as well as pre-heating the motor during winter. The companies which have implemented energy efficiency actions reported to have gained fuel savings of 5–15%, but only a few companies gave such estimate. The companies also pointed out that they have not been able to fully assess the effects because of varying operations. Some companies also reported safety improvements.

The total fuel savings acquired through the energy efficiency actions of the respondents was estimated based on the reported utilization rate of each action in the respondents' fleets and estimates of average saving for each action (Table 27). The utilization is calculated by first determining that the action is utilized in 17% of respondents vehicles if the respondent said the action is implemented with less than 33% of trucks/drivers, 50% if the respondent said the action is implemented with 33-66% of trucks/drivers and 83% if the respondent said the action is implemented with more than 67% of trucks/drivers and then multiplying the number of vehicles the respondent reported to operate with this percentage. Then each respondents' number of vehicles utilizing each action are summed to calculate the utilization in the total fleet of 1459 vehicles the respondents operate.

The fuel saving in respondents' fleets for each action is then calculated by multiplying the average saving and utilization. The total fuel savings is then calculated with the following equation where the s_i is the saving in respondents' fleets for each action. Also the maximum saving is calculated using this principle to illustrate the potential savings if each action would be fully utilized in the respondents' fleets.

$$Total\ saving = 1 - \prod_{i=0}^{17}(1 - s_i)$$

In order to avoid double accounting of savings in calculations, some adjustments were made. The respondents could choose in the survey four levels of ecodriving, from theoretical training to bonus scheme, but in the savings calculation only the highest level of ecodriving practice is taken into account, i.e. the respondent is calculated to use only ecodriving bonus scheme although he would have marked to use also theoretical ecodriving training, ecodriving courses and regular monitoring, which are here considered as prerequisites for the bonus scheme. Also with the aerodynamics the respondents could choose that they use aerodynamically designed trucks/trailers and aerodynamic add-ons, which may both have great savings, but if the respondent uses both, the savings are likely to be less than the sum of the individual savings. Thus the utilization of aerodynamics is divided in the three groups in the calculation.

The energy efficiency actions are also divided into two groups in Table 27 to make a distinction between "tactical measures" and "operational measures". Tactical measures are considered to be more subjectively defined by each respondent and the average savings are also more difficult to determine than with the operational measures. Hence, the fuel saving estimation of tactical measures should be interpreted with caution.

Table 27. Estimated fuel savings gained by the respondents. The average saving estimations are made based on DfT (2010a), FTA (2012), RICARDO (2009), RASTU (2009) and DTL (2009).

		Average saving	**Utilization**		**Saving in respondents' fleets**	**Maximum saving with 100% utilization**
	Energy efficiency action		**# of vehicles**	**% of all vehicles (n=1459)**		
Tactical measures	Hybrid vehicles	15%	6	0.4%	0.1%	15%
	Purchasing trucks with low consumption	5%	669	46%	2.3%	5%
	Lightweight trucks and trailers	5%	436	30%	1.5%	5%
	Choosing the vehicle size according to the load	10%	863	59%	5.9%	10%
	Computerized routing and scheduling	8%	457	31%	2.5%	8%
	Total tactical fuel savings				*11.8%*	*36%*
Operational measures	Ecodriving					
	- Theoretical ecodriving training	2%	102	7%	0.1%	
	- Ecodriving course with driving and theory	4%	92	6%	0.3%	
	- Regular monitoring of ecodriving	6%	420	29%	1.7%	
	- Ecodriving bonus scheme	8%	142	10%	0.8%	8%
	Avoiding idling	2%	868	60%	1.2%	2%
	Limiting driving speed	5%	662	45%	2.3%	5%
	Aerodynamics					
	- Aerodynamic trucks and trailers	7%	86	6%	0.4%	
	- Add-ons which improve aerodynamics	7%	67	5%	0.3%	
	- Both design and add-ons	10%	324	22%	2.2%	10%
	Low rolling resistance tyres	3%	512	35%	1.1%	3%
	Using oils that improve energy efficiency	2%	533	37%	0.7%	2%
	Regular monitoring of tyre inflation	1%	725	50%	0.5%	1%
	Total operational fuel savings				*11.0%*	*27%*
	Total fuel savings				**21%**	**54%**

It is thus estimated that the respondents currently consume 21% less fuel than they would consume without their energy efficiency actions. This equals approximately 13 million litres of fuel and 34 thousand tons of CO_2 annually, based on the total reported annual fuel consumption of the respondents (48 million l). The estimate is indicative, because the estimates for the average saving of each action cannot be verified to be true in the respondents' fleets. The actual saving that has been gained with an action varies from company to company, especially with the tactical measures. This is because each respondent is likely to perceive the actions differently than another and differently than the researcher has perceived them and thus the average saving may not reflect the actual saving. Furthermore, the actions have interrelations that may diminish the impact of individual actions (e.g. limiting driving speed decreases the savings of improved aerodynamics). The current fuel consumption is also different in each company and this affects the potential savings. It should also be noted that there may be overlap between some actions, especially with the ecodriving and avoiding idling, limiting driving speed and monitoring tyre inflation, all of which can be considered to be a part of ecodriving, but can also be done using automated equipment. In this survey these distinctions were not made so the respondents may have interpreted these actions differently.

7.5. Shippers' expectations

Many of the respondents are very much dependent on one shipper. The share of the biggest shipper is based on a self-reported assessment. The share of the largest shipper was on average 65% of the turnover. In food, chemical and forest clusters the share was on average over 75%, while in construction and other manufacturing the share was on average less than half of the turnover. In such operational environment the expectations of the most important shipper has a considerable influence on how the company manages, monitors and reports its energy efficiency. 18% of the respondents stated that they report the development of their fuel consumption to their stakeholders. However, when asked which stakeholders they report to, only 5% mentioned shippers. 10% did not specify the stakeholders, so 5–15% of respondents report fuel consumption to their shippers. Other stakeholders mentioned by the respondents included drivers, owners and managers.

Companies were also asked, have their shippers been interested in their energy efficiency actions or participation in the energy efficiency agreement (Table 28). 18% of companies agreed with this question, which suggests that at least to some degree the shippers are interested in the energy efficiency of the hauliers. In the energy, technology and chemical sectors over one third of companies have had such interest from their shippers. In the other manufacturing sector, on the other hand, no respondents have had such requests. The differences across sectors are statistically significant. However, in the previous survey to the shippers (Chapter 6) there seemed to be much greater interest towards the environmental effects of logistics operations. The shipper survey showed that almost half of the companies of trade and industry stated that they would like to get environmental reports from their logistics service provider, but only 3.5% of the companies did actually get such reports at the time. One explanation for such a gap may be that the customer expectations are directed at the larger logistics service providers and not transferred to the small contract hauliers. This view is validated by the fact that the sectors mostly experiencing such interest from their customers were also the sectors with the biggest share of large hauliers, i.e. energy, technology and chemical clusters (Table 28). However, other manufacturing sector also has a great share of big companies which have not experienced such interest from their shippers.

Table 28. Share of companies experiencing customer interest for energy efficiency and share of companies with more than 5 trucks by sector.

	Have your customers been interested in your energy efficiency actions?			Share of companies with more than 5 trucks
	N/A	Yes	No	
Energy cluster	*0%*	43%	57%	43%
Technology cluster	*0%*	37%	63%	33%
Chemical cluster	*0%*	33%	67%	33%
Food cluster	*0%*	21%	79%	23%
Trade	*3%*	20%	77%	28%
Waste and maintenance	*0%*	14%	86%	29%
Forest cluster	*2%*	12%	86%	7%
Construction cluster	*5%*	6%	89%	16%
Other manufacturing	*13%*	0%	88%	38%
N/A	*0%*	36%	64%	9%
Total	***2%***	**18%**	**79%**	22%

$\chi^2(9)$ 21.3, $p<0.05$

The respondents could also comment on how the shippers could promote the energy efficiency of logistics operations. The most common wish was that the customers would pay more on energy efficient services so that the hauliers could invest in more energy efficient vehicles. Customers could also use other criteria than just the price when they purchase logistics services. Better planning leading to less empty running and bigger shipments was also frequently mentioned. In addition, easing the time-windows for the deliveries or pick-ups and thus reducing the pressure towards the hauliers that leads to speeding was a frequent wish. Cooperative planning of logistics operations was seen desirable, but this would require longer contracts which are usually not preferred over the low price of the carrier. The same desire for longer contracts, which would enable the logistics service providers to implement green actions with long payback period has also been seen in Sweden (Martinsen et al. 2009). Cooperation seems not to be any easier for larger hauliers: Three out of ten interviewed large German hauliers stated that they collaborate with their customers to improve efficiency and two more hauliers have formed a logistic alliance with other hauliers (Tacken et al. 2011).

7.6. Perceptions on the energy efficiency agreement

The road freight haulage companies have a key role in achieving the emission reduction targets. Therefore awareness raising campaigns and best practice programmes have been set up in various countries. Successful long-term initiatives include SmartWay in the USA (USEPA 2012), FleetSmart in Canada (NRCan 2012) and Freight Best Practice (FBP) in the UK (Welsh Government 2012). FleetSmart and Freight Best Practice initiatives mostly focus on disseminating information on fuel saving measures and promoting ecodriving trainings. SmartWay takes a more holistic approach with finance program issuing loans for fuel saving investments, technology program testing fuel saving technologies and partnership providing tools for tracking and benchmarking fuel consumption. These initiatives have achieved some great results. FleetSmart gave information to about 3000 hauliers and trained almost 500 ecodriving trainers during its first six years of operation (NRCan 2003). Freight Best Practice programme achieved wide awareness and level of use, especially among large hauliers. The users were satisfied with the FBP and the implemented measures resulted in attributed savings of 0.24 Mt of CO_2 and £83 million over a two year period (Databuild 2007). SmartWay currently has more than 2700 logistics or haulier partners and it has resulted in saving 23.6 Mt of CO_2 and $6.5 billion in fuel costs since 2004 (USEPA 2012). RARE Consulting (2011) examined these three initiatives with other past or current initiatives to identify the key success factors of truck fuel saving initiatives. These factors include e.g. clearly defined objectives, demonstrated value to industry, a national focus, addressing skills and knowledge disparity, use of performance measures and engaging potential stakeholders.

The Finnish energy efficiency agreement fulfils some of the success factors identified by RARE Consulting (2011). It has a national focus, engages potential stakeholders and states the objective of improving the knowledge of hauliers. However, the agreement fails to define its objectives clearly. The target of improving the energy efficiency by 9% is set but the sources of information for monitoring this are not specified. Also the target of involving 60% of companies or of trucks is obscure and selecting only one target would have been clearer. It can be argued that involving 60% of trucks is easier to achieve if mostly large companies engage to the agreement, as may well be the case based on the experiences from British Freight Best Practice (Databuild 2007). However, involvement of large companies may also benefit the industry as a whole if these companies encourage or require their subcontracting small hauliers to implement best practices.

The survey results, however, suggest that involving 60% of companies or trucks is going to be quite difficult goal to achieve (Figure 37). Almost one third of the respondents claimed that they have not even heard about the agreement. Further, almost a similar share of studied hauliers had no intentions to participate in the agreement even though they were aware of it.

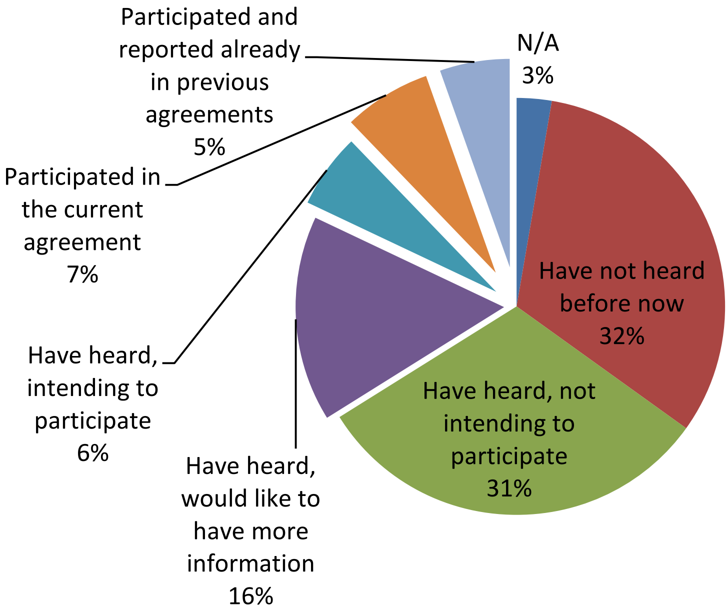

Figure 37. Participation in the energy efficiency agreement.

One of the most likely explanations for the low level perceptions about the energy efficiency agreement is that it has not been very actively marketed so far. These companies could be convinced of the agreement's benefits and be persuaded to get involved. 31% of companies seem to be lost or they would require a great deal of effort to be convinced to participate in the agreement. The 16% who are already interested could be more easily encouraged to join. Thus, achieving the 60% coverage target would require highly successful recruitment campaigns. Even more so because it is likely that the respondents of the survey are more interested in the environmental issues than the companies who did not respond.

It is clear that participation in the agreement should benefit the company or be an answer to shippers' requirements. The results on the low share (18%) of companies the customers of which are interested in energy efficiency suggest that shippers should be approached as well. After all, the share of hauliers indicating shippers' interest in energy efficiency is much higher among the companies who are already participating the agreement than among the companies that have not heard or are not intending to participate. Thus, it seems evident that shippers' interest motivates hauliers to participate in the agreement.

The respondents were given a list of some possible features of the monitoring database to which participating companies are required to report their fuel consumption and energy efficiency actions. Figure 38 shows how useful these features are seen by the hauliers.

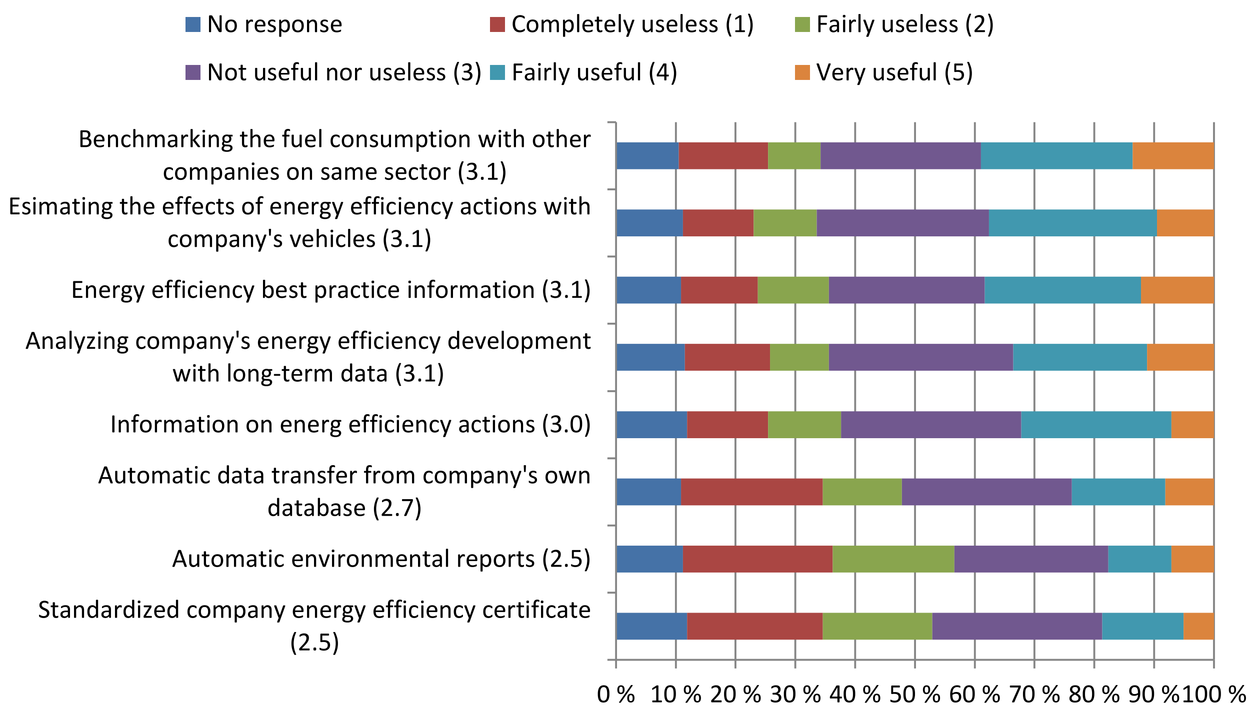

Figure 38. Usefulness of some possible features of the energy efficiency database.

It seems to have been quite difficult for the respondents to assess the usefulness of the features. This is understandable keeping in mind that one third heard about the agreement for the first time when responding the survey. The level of knowledge on the agreement is reflected clearly in the views of usefulness. For example, benchmarking the fuel consumption was considered very useful by 44% of the companies that have participated and reported to the database already in the previous agreements, but only by 9% of companies that had not heard of the agreement. The percentages considering benchmarking to be totally useless were 0% and 24%, respectively. However, it seems that information, best practices, benchmarking, long-term analysis and estimating the effects are seen by a majority of the companies as useful rather than useless. This suggests that these particular features should be developed and fostered to the companies as they have the potential to convince some companies to participate in the agreement.

This view is supported by the findings from the British survey, in which the British government supported Freight Best Practice programme for educating the hauliers on fuel management was seen as the second most important source of knowledge, right after trade press and before trade associations and colleagues (AECOM 2010). The importance of Freight Best Practice programme for British small hauliers shows that the Finnish energy efficiency agreement and database also has potential of becoming an important source of information. To gain such a position, it is important to have a good website, good coverage in trade press and it should also be promoted by trade associations. The agreement may also get positive publicity by word of mouth when good results are gained by hauliers. Participation in the agreement should become inviting if such promotion is achieved.

7.7. Views of the future

Hauliers' views of the future were explored in 13 statements of which the respondents were asked to indicate the likelihood of the fulfilment of the statement by the year 2016 (Figure 39). The year 2016 was chosen because the current energy efficiency agreement ends then.

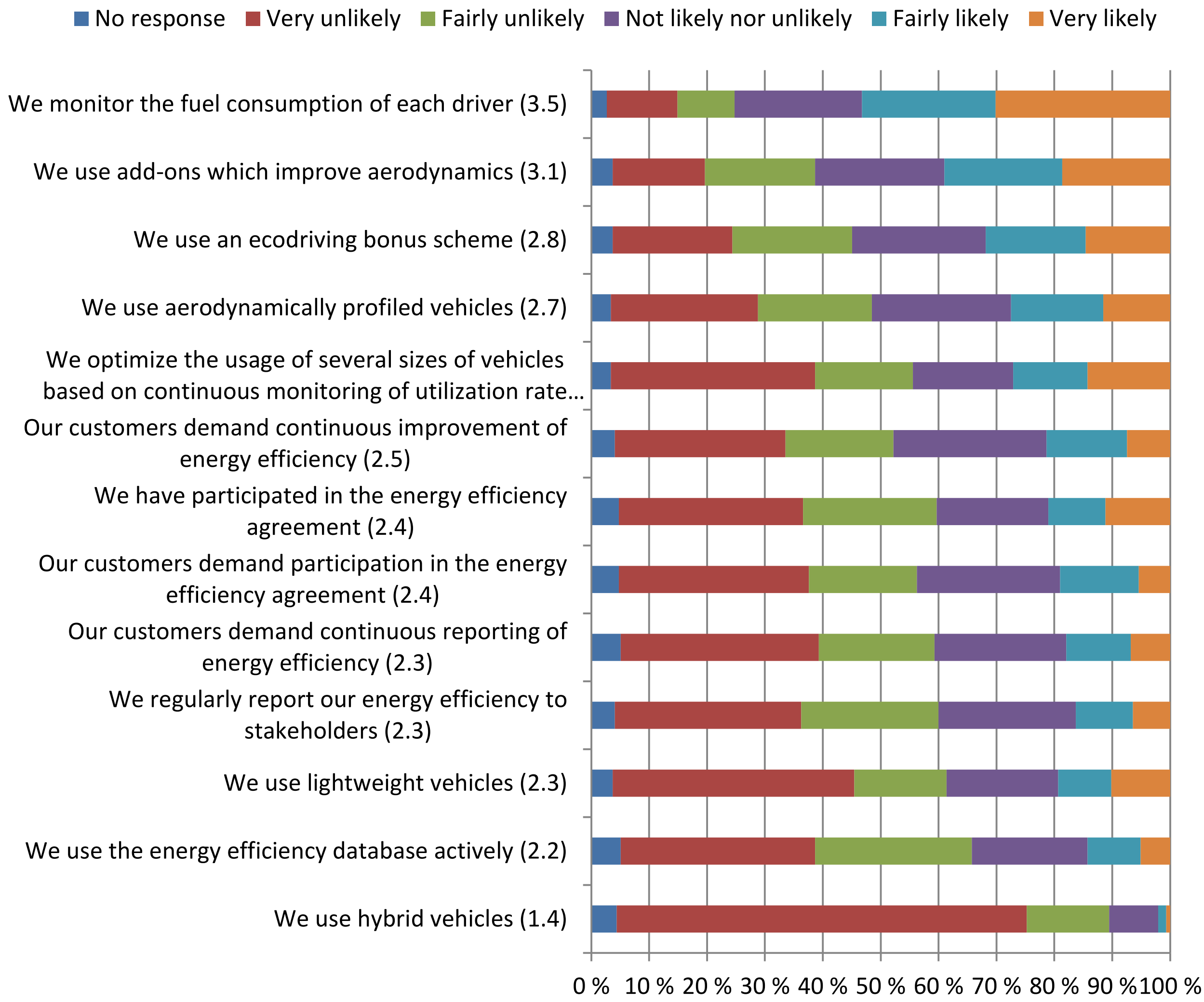

Figure 39. Likelihood of the future statements by 2016.

It seems that driver-level fuel monitoring is going to increase in the future. Currently 30% of respondents utilise it, but more than half consider it likely by 2016. This enables ecodriving bonus schemes, which are seen to be much more common by 2016 than they are now. Also the usage of add-ons to improve aerodynamics is going to increase a little, but the use of aerodynamically profiled vehicles is seen to remain at the current level.

Choosing the vehicle according to the load is currently done by more than 60% of respondents, but in the future the optimization of vehicles of different sizes based on continuous monitoring of utilization rate is seen as likely by only one fourth. This seems unexpected at first, but the future statement has two critical differences with the current energy efficiency action: use of several vehicles and continuous monitoring of utilization rate. Many respondents only have one or two trucks and this is probably not seen to be changing by 2016, so it is unlikely that several vehicles could be optimized. Furthermore, monitoring utilization rate is not currently performed by many companies and this is seen unlikely to change in the future.

About 20% of respondents considered it likely that their customers will demand continuous improvement of energy efficiency, participation in energy efficiency agreement or continuous reporting of energy efficiency. This prevalence is about the same as the percentage that perceived that their customers have already been interested in these issues. It is rather surprising that the hauliers do not expect this interest to grow. The companies of trade and industry seemed to have quite different expectations in the shipper survey, as more than 40% of them considered it likely that they will require continuous improvement and reporting of energy efficiency from their logistics service provider by 2016. They will also use energy efficiency criteria in purchasing logistics services. According to these results, there seems to be opportunities for gaining competitive advantage if a haulier can prove excellence in energy efficiency monitoring, reporting and improvements.

Responses to the future statements cast doubts on the likely success of the energy efficiency agreement. Only about 20% of the respondents considered it likely that they participate in the agreement in 2016 and fewer than 20% will actively use the energy efficiency database. Just one third of the companies which said that they either wanted more information on the agreement or that they had decided to participate, expect that they will actually participate. Just a few percent of companies which had not heard of the agreement expect that they will participate in the agreement by 2016. Also about 10% of companies that currently participate in the agreement are uncertain whether they still participate in the future. The results highlight that the energy efficiency database should be actively developed and the agreement marketed to motivate companies to participate.

Overall, the hauliers expect that no great changes towards better energy efficiency will take place in the next 5 years. Thus, achieving the target set for the energy efficiency agreement will not be easy if this proves to be the case. Even though driver-level fuel monitoring can lead to improved fuel economy, the change will not be enough without better cooperation between the shippers and hauliers. After all, the energy efficiency of road freight operations is largely determined by the strategic decisions of shippers. Additionally, improved vehicle technology is necessary for improvements in energy efficiency, but the hauliers consider, for example, it unlikely that lightweight or hybrid vehicles will be utilized by 2016.

However, all this can change if the fuel prices continue to rise. Rising fuel price was considered as the most important driver for improving energy efficiency by 60% of respondents. Keeping up with the competing companies was considered as the most important driver by 21%, targets set by the management of the company by 7%, fulfilling customer demands by 6% and legislation by 2% of hauliers. The responses to the questions about drivers for improving energy efficiency reveal that road freight transport is very cost driven business with fierce competition. This is most likely the result of the huge amount of very small companies, which have to fight for their financial viability, or agglomerate to larger firms. The issue is not specific to Finland since, for example, 80–90% of British hauliers have fewer than six vehicles and operate on very small (2-3%) profit margins (McKinnon 2009a).

7.8. Conclusions

The haulier survey aimed to answer the fifth research question: *How do the hauliers take the environmental issues into account in their operation and are they going to change their operations because of environmental policy targets?* According to this research, small companies do not have the resources to gather information on energy efficiency actions and they also seem to not notice the growing customer demands for energy efficiency reporting and improvements. Small companies seem to be familiar with various energy efficiency actions, but may lack knowledge of how to conduct a full investment appraisal. This could be tackled by government sponsored energy efficiency audits and development plans. Government energy agency Motiva could educate a group of energy efficiency experts who could perform the audit, which would be paid partially by the government. The audits could be available only for companies participating in the energy efficiency agreement to give companies further incentive to participate.

There is clear evidence that voluntary environmental agreements need to be complemented with rethinking the institutional settings that the agreements fit in, in order to overcome barriers of the technological lock-in (see Könnölä et al. 2006). Therefore, all policy measures which the government uses in promoting energy efficiency should be related to the energy efficiency agreement, because it provides a good framework for these measures. Additionally, the energy efficiency database should be developed to include information on best practices and a tool for companies to estimate the effects of energy efficiency actions with their own fleet. The database should also be made as easy to use as possible and the opportunity for benchmarking should be promoted. One possibility for speeding up the implementation of energy efficient technologies is to offer subsidies for companies which participate in the agreement. If the solutions are searched from a more regulative perspective, the government could require participation in the agreement in all purchases of logistics services that it itself orders. In terms of promoting fuel saving technologies through regulation, the government has many options. The trucks are already equipped with maximum speed limiters in Finland, but these are usually set to 88 km/h although the regulated maximum speed is 80 km/h. Stricter enforcement of the 80 km/h limit would save fuel. Also automated engine shut down to avoid idling and tyre inflation monitoring systems could be made mandatory, at least for all new trucks. Rolling resistance tests and labels could also be made mandatory for new heavy-duty tyres. In terms of improving aerodynamics the adjustable cab roof spoiler could be made mandatory, as it already is widely used. Aerodynamics could also be improved by allowing the use of “boat tail” solutions at the rear end of the trailers for reducing the drag. These solutions are currently not feasible because of the maximum vehicle length restrictions, but restrictions could be changed to regulate the maximum length of the cargo space to allow the use of boat tails.

Information about the energy efficiency agreement should also be communicated to shippers so that they can require participation in their purchasing decisions. This communication can be done through the sectoral energy efficiency agreements, which have been introduced in Finland to oil sector, property sector, industry sector, energy sector, private services sector, municipalities and farms, as well as to the public transport sector and freight transport and logistics sector (Motiva 2012).

There seems to be competitive advantage available for companies that monitor and improve their energy efficiency and report to their customers. Reporting may improve the trust between the companies, and thus lead to a deeper cooperation which enables long-term planning of logistics. This would be beneficial to both parties. Monitoring is the prerequisite for improving energy efficiency, and monitoring just fuel consumption is not enough. The monitoring system should also include data on the determinants for fuel consumption, i.e. on loading, route characteristics and vehicle specifications (see Liimatainen & Nykänen 2011). Each operation should be recorded accurately to be able to analyse the effects of energy efficiency actions and report the CO_2 emissions and energy efficiency to the customer. In the light of this survey, the Finnish hauliers have a lot of work to do in order to achieve this level of information management.

8. Expert panel workshops

This chapter is modified from the following paper:

Liimatainen, H., Kallionpää, E., Pöllänen, M. 2012. Building a national action plan for improving the energy efficiency and reducing the CO_2 emission of road freight transport. Proceedings of the 17th International Symposium on Logistics (ISL2012). July 8-11, Cape Town, South Africa.

8.1. Expert panel

In this study the expert panel was invited to attend a series of workshops bringing together the most important stakeholders of the road freight transport sector. Representatives from 26 organisations were invited to each workshop meeting of the expert panel. These organisations included:

- 3 ministries
- 3 government agencies
- 4 freight transport associations
- 1 research organisation
- 1 consultant
- 4 freight transport companies
- 2 heavy duty vehicle importers
- 8 companies from various branches of industry and trade

15 participants attended the first workshop in February 2011. At least one participant from each stakeholder group, except research organisation, was present. The second workshop in May 2011 was attended by 8 participants and seven of them had also participated the first workshop. The consultant and industry and trade companies were not present in the second workshop. 10 participants attended the third workshop in November 2011 and three of them had not participated the previous workshops. Six experts participated every workshop and contributed greatly to the process.

8.2. Workshop process

The future workshop consists of five phases which usually take place during one or two days (Vidal 2006), but in this study took place in three separate workshops in February, May and November 2011. The five phases are (Vidal 2006):

- preparation (invitations, facilities, timetable)
- critique (critical and open discussion of the current situation)
- fantasy (free visioning of the future and ideas for achieving the future)
- implementation (critical evaluation of ideas and development of strategy)

- follow-up (reporting and dissemination of results)

The workshops of this study followed these phases and the workshops comprised a continuing process to build a national action plan for improving the energy efficiency and reducing the CO_2 emissions of road freight transport. In the first workshop (critique phase) the current situation of the energy efficiency of road freight transport in Finland was critically discussed in order to identify the obstacles of improvement. In the second workshop (fantasy phase) possible measures for overcoming these obstacles were identified. In the third workshop (implementation phase) these measures were evaluated and a strategy was developed. The results of the workshops were reported (follow-up) in a research report in January 2012.

Each workshop lasted four hours and included a presentation about the results of other phases of the research. A presentation about the research results and measures taken in the United Kingdom was also held in every workshop. Most importantly, each workshop contained a discussion session and these discussions formed a continuous process which aimed at producing an action plan for improving the energy efficiency and reducing the CO_2 emissions during the period of 2012-2016. In the first two workshops the discussion consisted of four parts. Firstly the experts considered the themes by themselves. Secondly the topic was discussed in small groups of 4-5 persons with one researcher facilitating and taking notes of the small group discussion. Thirdly the findings of each small group were gathered and discussed openly among all participants. Finally a voting was organised to rate the findings of the discussion. The third workshop was different as the discussion was done openly among all participants and no small group discussions or voting was performed.

8.3. First workshop - identifying the obstacles

The discussions in the first workshop focused on the following themes:

- What are the strengths of the Finnish road freight transport sector considering the energy efficiency?
- What are the most important trends and drivers which will affect the energy efficiency of road freight transport in the next 5-10 years?
- What are the most important obstacles for improving the energy efficiency?

The participants first considered these themes by themselves and then discussed their views in groups of five experts. A member of the research team followed the discussion in each group and wrote the key findings to a flip chart. Each group then presented their findings and these were discussed upon by all participants. Finally there was a voting on the severity of the obstacles identified in the last theme and on the possibilities for removing these obstacles.

In the discussion about the first theme there was a common view that the utilisation of long and heavy vehicles is a strength for the energy efficiency of Finnish road freight transport sector.

However, this strength may also turn to a weakness if the hauliers purchase the largest possible trucks in order to avoid a situation where their truck is too small for any haulage. This may be the case in particular with the small hauliers who prepare for sudden changes of their customers. Such a situation can be avoided if the hauliers collaborate as many of the Finnish hauliers do. These consortiums were also seen as a strength of Finnish road freight sector as they enable effective consolidation and wide geographical coverage. Finland was also seen to be one of the forerunners in ecodriving training and the European directive (2003/59/EC) on the periodic driver training ensures that the drivers continuously update their proficiency. Finland is a small country in terms of the population and this was seen to be helpful in maintaining close cooperation between the government and the key stakeholders of the sector.

In the next 5-10 years the most important trends and drivers of the energy efficiency and CO_2 reduction were seen to include most importantly the expected rise in the price of fuel. This view was further confirmed in the haulier survey in which the rising fuel costs were selected by most hauliers as the primary target for energy efficiency actions (see chapter 7.4.2). The EU regulation and policy objectives were also seen to have an effect on the energy efficiency in the next 5-10 years. These regulations also affect the national policies. EU was also seen to enable more foreign transport companies to enter the Finnish roads and increase the competition in the market. Attendees of the first workshop also saw that the economic development on different sectors of the economy affects the demand for transport and hence the energy efficiency and CO_2 emissions. The technological development was also seen to continue in terms of vehicles, routing and scheduling software and also intelligent transport systems and services, such as continuous monitoring of driver's performance in ecodriving. All these trends and drivers were also mentioned by the Delphi panellists (Chapter 5), which confirms the importance of these issues. The panellists also mentioned many of the following obstacles identified in the workshop.

Several obstacles for improving the energy efficiency of road freight transport were identified in the first workshop. A major obstacle and target for development is the shipper demands which lead to inefficient transport operations. Shippers try to minimise their inventory and apply just in time principles which lead to frequent small shipments which are not the most energy efficient way to transport goods. The experts in the workshop also saw that insufficient communication between the shipper and the haulier makes this problem worse. In many cases the order for transport is given to the haulier on very short notice and thus the vehicles may not be used most efficiently. The large share of very small hauliers in Finland is also a challenge to energy efficiency. The small hauliers may not have the necessary negotiating power with shippers to enable long-term cooperative initiatives for improving the efficiency. This may cause the use of too large vehicles in the operations as already mentioned above. Owner-operators may also lack the time to update their knowledge on the energy efficiency and the resources for investing in new technologies which improve energy efficiency. There is a need for improving the level of knowledge of both hauliers and shippers on measuring and improving the energy efficiency. There are many actions that can be taken to remove the knowledge-related obstacles. However, some obstacles are harder to act on. One such obstacle was identified to be the geographical imbalance of transport flows in Finland, which causes inefficiency. Northern and eastern Finland mostly produce industrial products but require consumer goods. The different types of goods cannot be transported with the same vehicles which causes inefficient use of vehicles.

The identified obstacles were listed on flip charts for voting. Each expert was given five red stickers and five green stickers to put on the charts next to the obstacles. Several stickers could be assigned to same obstacle and not every sticker was required to be used. The experts were asked to indicate a severe and important obstacle with the red sticker. Green sticker indicated an obstacle which should be acted on, i.e. it would be possible to remove the obstacle. Results of the voting are presented in Figure 40.

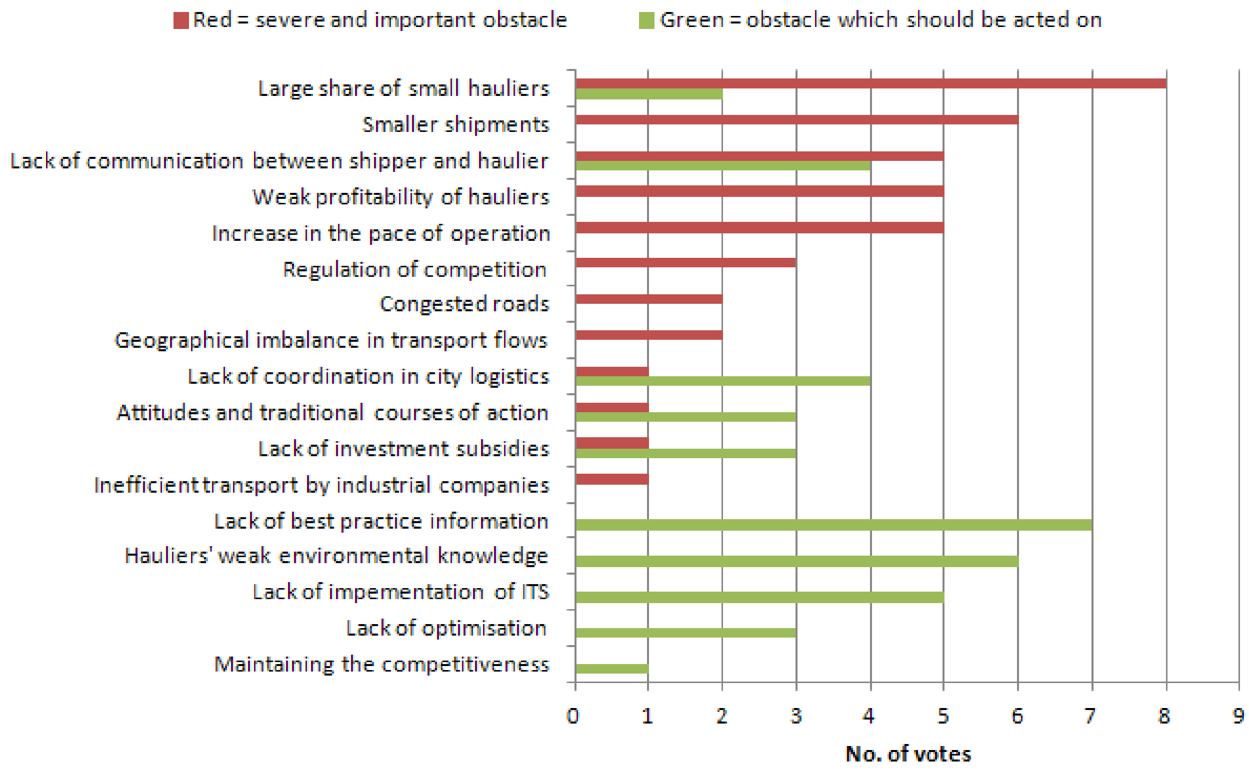

Figure 40. Votes on the obstacles

Some of the obstacles were rather similar or relate to a larger problem area, so the obstacles were grouped into the following seven problem areas.

- Hauliers' lack of environmental knowledge and best practices (1 red, 19 green votes)
    - lack of optimisation
    - hauliers' weak environmental knowledge
    - lack of best practice information
    - attitudes and traditional course of action

- Lack of coordination in city logistics (1 red, 4 green votes)
- Lack of implementation of ITS (0 red, 5 green votes)
- Financial problems (14 red, 6 green votes)
    - large share of small hauliers
    - weak profitability of hauliers
    - lack of investment subsidies
    - maintaining the competitiveness
- Infrastructure and geography (4 red, 0 green votes)
    - geographical imbalance of transport flows
    - congested roads
- Shippers' lack of environmental consideration (12 red, 0 green votes)
    - inefficient transport by industrial companies
    - increase in the pace of operation
    - smaller shipments
- Lack of communication between shipper and haulier (5 red, 4 green votes)

It seems clear according to the votes that shippers' lack of environmental consideration and financial problems of small hauliers are the most severe obstacles for improving the energy efficiency and reducing the carbon dioxide emissions of road freight operations. These obstacles also seem to be difficult to act on. Measures to address the hauliers' lack of environmental knowledge and best practices, on the other hand, seem easy to be found, but these obstacles are not seen very severe. These problem areas identified in the first workshop formed the basis for identifying various measures to overcome these obstacles in the second workshop.

8.4. Second workshop - identifying energy efficiency measures

In the second workshop the experts were given papers showing each eight problem areas identified in the first workshop. The experts were then asked to consider the problem areas by themselves and suggest measures which could be taken to overcome the obstacles. Also the potential effects, possible difficulties, costs, benefits and responsible organizations were asked to be evaluated of each measure. However, the experts did not have enough time to evaluate these details accurately, so they indicated mainly just the responsible organisations. After the individual consideration the measures were discussed in small groups and then openly with all attendees. Finally the measures were listed on flip charts and each expert was given five stickers. The experts were asked to indicate the most important measures with the stickers and divide the stickers to at least three measures.

There were three measures suggested to overcome the hauliers' lack of environmental knowledge and best practices. Collecting and sharing benchmarking data got three votes out of the total of 35 votes. Currently there is no information about the energy efficiency and CO_2 emissions available for hauliers to benchmark their performance. Such information should be gathered and made available. As well as benchmarking information, the hauliers would benefit from education about various energy efficiency measures and their costs and benefits. Such education could be done in various forms and it could be attached to the mandatory periodic driver training and various courses which the trade associations offer to their members. Educational measures also gained three votes in the workshop. In addition to the education, there should also be active communication about the energy efficiency measures to the hauliers. Communication got two votes. These measures were seen to be common efforts with shared responsibility. Government agencies and trade associations should cooperate in the matter. It was also seen that there could be opportunities for new businesses in the education, similarly to the ecodriving training business.

Measures to improve the efficiency of city logistics were seen important in the voting. Most important measure would be the development of collaborative consolidation centres for urban distribution. This measure got four votes. Such consolidation could also enable the use of more environmentally friendly vehicles such as battery powered or hybrid electric small delivery trucks. Usage of these vehicles could also be encouraged by establishing low emission zones in city centres. Use of environmentally friendly vehicles got 2 votes. Whether the urban distribution is performed using current practices or new consolidation centres, the routing should be optimised better than it currently is. This measure got one vote. Municipalities have an important role in the city logistics and they can set an example by consolidating the material flows of their own operation. This measure was also seen important by one vote. Municipalities were seen to be responsible for making initiatives of collaboration to involve shippers and hauliers in the common effort of improving the efficiency of city logistics.

Road freight transport is seen to gradually implement more and more intelligent transport systems and services (ITS). However, this development could and should be accelerated in order to improve the energy efficiency and reduce CO_2 emissions of road freight transport. For example electronic consignments should be promoted. This measure got three votes. New vehicles also have telematic systems as standard equipment which enables accurate monitoring of fuel consumption and payload, for example. However, information management should be developed to fully utilise this data in improving the energy efficiency. This measure got one vote. ITS also enables dynamic route guidance and routing which takes into account congestion or road geometry to minimise fuel consumption. Although promoting such measure was mentioned in the workshop, it did not get any votes. The experts saw that there is a need for new businesses which would develop inexpensive and easy to use services which would accelerate the implementation of ITS in the road freight sector. The trade associations also have a role to play in promoting these measures and communicating best practices to their members.

Financial problems, especially among small hauliers, were seen in the first workshop as severe obstacle for improving energy efficiency. These problems could be addressed by offering investment grants, loans or tax subsidies for hauliers who purchase equipment or services which improve energy efficiency. Financial aid should be targeted to hauliers who participate in the Finnish energy efficiency agreement for freight transport and logistics as this would also promote the agreement and make it easier to evaluate the effects of the financial aid. Financial aid was considered to be important by four votes. Most energy efficiency actions are financially profitable even without any aid, but the hauliers may lack proper knowledge on the costs and benefits of the actions. This is why two votes were given to highlight the importance of information and education for hauliers to make investment appraisals of the various energy efficiency actions. The government is mainly responsible for these measures but research institutes are also needed to determine what energy efficiency actions have the greatest benefits and should therefore be included in the financial aid schemes.

Geographical imbalance of goods flows and congested roads were identified in the first workshop as obstacles for improving the energy efficiency. However, no measures for changing the geographical imbalance were considered viable in the second workshop. Congestion on the other hand was seen to be a minor problem in Finland and only affects the main roads around Helsinki during the rush hours. Reducing the car traffic on these roads was seen important by two votes. This could be done by implementing congestion charges in Helsinki. Another way to avoid congestion is to increase off-peak and night time deliveries in the congested areas, but this measure did not get any votes from the experts.

Shippers' lack of environmental consideration in their logistics was seen in the first workshop as a very severe problem area but also very hard to act on. The same was highlighted in the second workshop. Several measures were suggested, but only one suggestion got votes from the attendees. This measure which got four votes is that energy efficiency criteria should be used when the state or municipalities purchase freight transport services. The government and municipalities should take responsibility on this measure. Other measures suggested in the workshop included awareness campaign for consumers to get them to ask for more efficient freight transport and guidance in the sectoral energy efficiency agreement on purchasing environmentally friendly logistics services. Promoting carbon labelling was also suggested as well as developing online freight exchange services. Regional consolidation centres and agreements of cooperation were suggested as well. However, these measures did not get any votes as these were seen as issues which are close to the core business of the companies of trade and industry and thus cannot be affected from outside. Trade associations and government agencies can promote these measures, but the final decisions are to be made within the companies.

The final problem area identified in the first workshop was the lack of communication between the shipper and the haulier. Lack of communication about environmental issues may well be due to the fact that there is lack of knowledge on both sides. However, this may also be a good thing if the shipper and the haulier begin to work towards more energy efficient logistics together. The experts in the second workshop saw that the large logistics service providers play an important role in raising the awareness about the environmental issues of logistics. Three votes were given for this measure. It was seen positive that global logistics companies have taken the environmental issues seriously and use these issues in their marketing. Other LSPs could adopt similar activities. It was also suggested that new forums of cooperation should be established to bring together shippers and hauliers to discuss environmental issues. This measure did not get any votes, however.

8.5. Third workshop - energy efficiency action plan

Findings from the two workshops and also other parts of the research were used to write a draft of an action plan for improving the energy efficiency and reducing the CO_2 emissions of road freight transport in Finland in 2012-2016. This draft was sent to the attendees of the third workshop one week before the event. The draft was discussed upon in the workshop and each proposal was dealt with an open discussion. Based on the comments from the experts in the third workshop the action plan was finalised and is presented Chapter 9.7.

8.6. Conclusions

The expert panel workshops aimed to answer the sixth research question: *What policy measures can be taken in order to promote a change towards more sustainable practices of shippers and hauliers which leads to achieving the energy efficiency and CO_2 emission targets?* Three major problem areas were identified in the workshops: (1) lack of knowledge and best practices of energy efficiency within logistics service providers, (2) inadequate environmental consideration by industry and trade in purchasing logistics services and (3) lack of coordination of urban logistics. In order to overcome these issues, seven action packages are proposed in Chapter 9.7 and their benefits, challenges and responsibilities are analysed. There is an on-going initiative to promote energy efficiency through sectoral energy efficiency agreements in Finland and many proposed actions aim to improve these agreements. International best practices were also used in the action plan. In the proposed action plan cooperation and division of responsibilities between various stakeholders of the road freight sector are emphasized.

The study showed that the multi-stakeholder workshops are a practical tool for identifying the obstacles and measures for improving the energy efficiency and reducing the CO_2 emissions of road freight transport. The workshops provided an excellent forum for discussion between various stakeholders of the road freight sector. Workshops summoned the key actors and thus enabled networking and sharing of knowledge. Active involvement in the process also enabled a deep commitment to the resulting national energy efficiency action plan.

9. Scenarios and action plan

This chapter is modified from the following papers:

Liimatainen, H., Kallionpää, E., Pöllänen, M. 2012. Building a national action plan for improving the energy efficiency and reducing the CO_2 emission of road freight transport. Proceedings of the 17th International Symposium on Logistics (ISL2012). July 8-11, Cape Town, South Africa.

Liimatainen, H., Kallionpää, E., Pöllänen, M., Stenholm, P., Tapio, P., McKinnon, A. 2013. Decarbonising road freight in the future – Detailed scenarios of the carbon emissions of Finnish road freight transport in 2030 using a Delphi method approach. Technological forecasting and social change. DOI: 10.1016/j.techfore.2013.03.001.

The cluster analysis was performed separately with all 8 indicators forecasted by the experts in the Delphi survey (Chapter 5). Hierarchical cluster analysis with furthest neighbour -method and Euclidean distance measure was performed with SPSS software. Five clusters with more than one expert's forecast were identified for each indicator to serve as a basis for the scenarios. In addition to these five clusters the indicators had up to two very different views by single experts. These very different views were left out of the scenarios. The average of the expert forecasts in each cluster was used as the future value of that cluster in the scenarios. Five scenarios were thus formed based on the cluster analysis by grouping the forecasts of each indicator to develop a consistent set of indicator values, i.e. a future image that could be possible if a certain future development would occur (Table 29). The sixth, baseline, scenario was formed with the median values of all expert forecast for each indicator. The scenarios were named according to a characteristic that best described the most important driver that could lead to the future image. The scenarios described in the following chapters are subjective narratives of the development which might, based on the findings in the previous parts of this research, lead to the consistent set of indicator values presented in Table 29.

Table 29. Images of the future based on the cluster analysis.

		Baseline (median of all expert forecasts)	Technology industry	Mining and bioindustry	Eficient road transport	Eco society	Recession	Omitted single forecasts	
GDP [€]	No. of forecasts	27	3	14	3	4	2	1	
	Value	200	242.7	209.1	193.3	176.3	157.5	28.0	
Value density [€/t]	No. of forecasts	28	6	6	9	3	2	1	1
	Value	480	667.7	444.8	486.1	563.3	331.0	70.0	1000.0
Share of road tonnage [%]	No. of forecasts	28	6	2	7	4	9		
	Value	88%	93%	82%	89%	75%	86%		
Average length of haul [km]	No. of forecasts	28	6	6	6	5	4	1	
	Value	62	60.8	72.9	65.0	49.0	55.3	100.0	
Average load on laden trips [t]	No. of forecasts	28	7	5	4	3	9		
	Value	14.5	11.2	19.2	16.4	13.0	14.5		
Share of empty running [%]	No. of forecasts	28	3	5	10	3	6	1	
	Value	21%	21%	25%	20%	18%	23%	15%	
Fuel consumption [l/100km]	No. of forecasts	28	3	6	6	2	10	1	
	Value	32.1	28.0	34.9	30.3	23.2	32.4	11.1	
Share of biofuels [%]	No. of forecasts	28	4	5	6	3	9	1	
	Value	20%	14%	25%	20%	33%	8%	50%	

Most scenarios are driven by, and accordingly named after, different economic developments which are then seen to cause the differences in the other indicators. The importance of the economic development as a driver of the transport volume, characteristics and related energy use and emissions was seen in Chapter 4 and can thus be used as a basis for building the scenarios.

9.1. Technology industry scenario

The technology industry scenario is driven by a rapid growth of the technology industry in Finland. This can be seen as a continuum of the development from 1995 to 2010 in Finland which was characterised by the growth of the IT-industry lead by Nokia Corporation. In this scenario the GDP grows on average 2.1% annually. The technology industry produces valuable products and this increases the value density greatly. Valuable products are transported in small shipments frequently and this increases the share of road transport and decrease the average load on laden trips. The average length of haul is forecasted to remain approximately at the current level. The control over the freight transport operations will concentrate to large industrial companies or logistics service providers, which have advanced software for efficient vehicle routing and scheduling. This leads to a reduction in empty running. The fuel consumption per kilometre also decreases as smaller trucks are used than previously because of the smaller shipments. The vehicle technology also develops and decreases the fuel consumption. The biofuels are used more widely than currently, but the usage is not as widespread as the EU policy targets aim it to be.

9.2. Mining and bioindustry scenario

The mining industry has been booming in northern Finland during last few years with major mine opening and new discoveries (Talvivaara 2011, Mining Weekly 2011). Bioindustry is also growing in Finland with large forest cluster companies changing their focus from paper and pulp production to biofuels and advanced wood based products (UPM 2011; Stora Enso 2009). This growth is seen to characterise the development in the Mining and bioindustry scenario. The GDP grows slightly faster in this scenario than in the baseline because of the growth in these sectors. These sectors require large quantities of low value soil and biomass to be transported and this leads to the value density to be slightly lower than in the baseline. It is expected that new rail connections will be built to new mines and this leads to the share of road transport to diminish. The new industry develops mainly in the northern parts of Finland, which causes the average length of haul to lengthen. Also the average load increases considerably because of long hauls and heavy goods. The empty running is naturally high in mining and bioindustry sectors so it remains at current level. The average fuel consumption decreases slightly from current level even though the average load increases considerably. The decrease in consumption is due to fast rotation of vehicles because of high utilization which speeds up the adoption of new fuel saving technology in vehicles. The bioindustry provides large quantities of advanced biofuels which increases the share of biofuels to 25% of energy consumption.

9.3. Efficient road transport scenario

The economic development follows the baseline in the efficient road transport scenario and the GDP grows rather slowly, only approximately 1% annually. No great changes happen in the importance of different sectors, so the value density develops similarly to the baseline and the modal split remains similar to the current split. The geographic structure of Finnish industry and population remains at the current state, but logistics and supply chains are redesigned and centralized which leads to the average length of haul to increase slightly. The redesigning of logistics is mainly due to a considerable rise in fuel prices, which forces the companies to cooperate. The effects of cooperation are shown clearly in the increased consolidation of loads which increases the average load and decreases the empty running. Similarly to the mining and bioindustry scenario, the average fuel consumption decreases slightly from current level even though the average load increases, because of fast rotation of vehicles. Increased cooperation between companies also enables fast dissemination of best practices which helps companies to reduce fuel consumption. Biofuels also become more viable financially when fuel price increases and the share of biofuels is thus quite high.

9.4. Eco society scenario

Eco society scenario describes a future in which the price of fossil fuel has increased dramatically and climate change has had severe effects on the society. These changes have affected the public opinion and government policies towards strict measures to mitigate climate change. As a result the structure of the economy has changed and the economy has grown only a little from current level. The value density, however, has increased a lot because heavy industry has moved away from Finland due to the high costs of energy and carbon allowances. Heavy industry has been replaced by high technology environmental industry, such as water treatment and alternative energy related industry. Much of freight transport has moved from road to rail because of high fuel price and large investments to new passenger rail tracks which have freed capacity for freight trains. Road transport is used only to feed the rail network on long hauls, so the average length of haul has decreased considerably. The average load is close to the current level, but loads are moved with smaller vehicles which are utilised more efficiently, so empty running and average fuel consumption have decreased. The average fuel consumption is at a very low level, because investments in energy efficient vehicle technology have become more viable financially. Hybrid electric vehicles are widely used as road transport is mainly done on urban roads on which their benefits are the greatest. Also the use of biofuels is widespread.

9.5. Recession scenario

In the recession scenario the current financial crisis prolongs as Europe loses its financial competitiveness against the developing economies in Africa and Asia. As a result the Finnish GDP remains at the current level and the value density even decreases slightly. High technology industry has moved away from Finland and Finland mainly produces goods only to European markets because of the barriers to international trade. The cost of energy is high and rail is increasingly used for long hauls, resulting in decreasing average length of haul in road transport. The average load is slightly heavier than currently and there is less empty running because the hauliers have to cooperate and consolidate loads to deal with high fuel prices. High prices also make it necessary to invest in fuel efficient vehicles so the average fuel consumption is quite low. New facilities for producing biofuels have not been made because of the trade barriers and lack of European raw materials, so the use of biofuels is only slightly higher than currently.

9.6. CO_2 emissions in 2030 in the scenarios

Official targets for the CO_2 emissions of road freight transport in 2030 have not been set in Finland. However, the new White Paper on European transport sets a target of reducing CO_2 emissions by 20% from the 2008 level by 2030 and 60% from 1990 level by 2050 (COM/2011/0144). If this is taken as the target for Finland, the CO_2 emissions of road freight transport should be approximately 1.9 million tons in 2030 and 1.0 million tons in 2050. However, this target for 2030 requires dramatic changes in 2030-2050, so it would be best if the emissions could be reduced steadily throughout the period from 2011 to 2050. Steady decline would mean that the emissions target for the year 2030 is approximately 1.6 million tons. Table 30 shows the level of key ratios and aggregates in the six scenarios described above and it can be seen that all the scenarios forecast the CO_2 emissions of fewer than 1.7 million tons in 2030.

Table 30. Key indicator, aggregate and indicator values in 1995, 2010 and forecast to 2016 and 2030 in different scenarios.

	1995	2010	Delphi baseline 2016	Baseline	Technology industry	Efficient road transport	Mining and bioindustry	Eco society	Recession	Target
				Delphi 2030						
GDP [billion €]	105	159	**170**	**200**	**243**	**193**	**209**	**176**	**158**	
Value density [€/t]	232	360	**430**	**480**	**668**	**486**	**445**	**563**	**331**	
Total goods moved [million t]	450	441	**395**	**417**	**363**	**398**	**470**	**313**	**476**	
Road's share of goods moved [% of total]	90%	90%	**90%**	**88%**	**93%**	**89%**	**82%**	**75%**	**86%**	
Goods moved by road [milllion t]	405	397	**355**	**367**	**338**	**354**	**386**	**235**	**409**	
Average length of haul [km]	48.3	59.1	**64.0**	**62.0**	**60.8**	**65.0**	**72.9**	**49.0**	**55.3**	
Total haulage [billion tkm]	22.3	26.0	**25.2**	**25.2**	**22.8**	**25.5**	**31.2**	**12.8**	**25.1**	
Average load on laden trips [t]	14.9	13.9	**13.7**	**14.5**	**11.2**	**16.4**	**19.2**	**13.0**	**14.5**	
Mileage on laden trips [billion km]	1.31	1.69	**1.67**	**1.57**	**1.84**	**1.40**	**1.46**	**0.88**	**1.56**	
Empty running [% of total mileage]	32%	27%	**25%**	**21%**	**21%**	**20%**	**25%**	**18%**	**23%**	
Total mileage [billion km]	1.93	2.32	**2.22**	**1.97**	**2.31**	**1.74**	**1.95**	**1.07**	**2.02**	
Average fuel consumption [l/100km]	38.4	37.2	**35.4**	**32.1**	**28.0**	**30.3**	**34.9**	**23.2**	**32.4**	
Total energy consumption [GWh]	7510	8724	**7931**	**6380**	**6537**	**5338**	**6884**	**2511**	**6619**	
Fuel CO_2 content [kg/l]	2.66	2.66	**2.61**	**2.48**	**2.54**	**2.48**	**2.44**	**2.37**	**2.59**	
Total CO_2 emissions [million t]	1.98	2.30	**2.05**	**1.57**	**1.64**	**1.31**	**1.66**	**0.59**	**1.70**	**1.6**
CO_2 intensity [g/€]	18.9	14.4	**12.1**	**6.8**	**6.8**	**6.8**	**8.0**	**3.3**	**10.8**	
Transport intensity [tkm/€]	0.21	0.16	**0.15**	**0.12**	**0.09**	**0.13**	**0.15**	**0.07**	**0.16**	
Energy efficiency [tkm/kWh]	2.97	2.98	**3.18**	**3.96**	**3.49**	**4.78**	**4.53**	**5.08**	**3.79**	

The CO_2 emission target of 1.6 million tons in 2030 seems to be achievable based on the scenarios. It is important to realize how very different indicator values in the scenarios can lead to quite similar CO_2 emissions. The emissions are very low in the Eco society and Efficient road transport scenarios, but all other scenarios forecast similar emissions, even though the GDP and total haulage are very different in the scenarios. It is also worth noting that the biofuels have only a minor contribution to achieving the emission target. The effect of the biofuels on the emissions is 10% at most in the Eco society scenario. For example in the baseline scenario the CO_2 emissions would be only 0.1 million tons greater if the biofuels would not be taken into account. The scenarios also highlight the fact that transport policy has a wide variety of measures to affect the efficiency and emissions of road freight operations. It is necessary for policymakers to have a holistic understanding on the various aspects that affect the efficiency and emissions. Scenarios such as these help them to achieve this understanding.

A closer look in the Baseline scenario is presented in Figure 41, in order to further understand the effects of the change of each indicator to the total CO_2 emission. Figure 41 is based on the concept of "stabilization wedges" presented by Pacala and Socolow (2004). It represents how much the change in each of the eight indicators has contributed to the total change in the CO_2 emission from 2009 to 2030. This is analysed by calculating how much higher or lower the emissions would be if only one indicator changed to its 2030 value while others remain in their 2009 value. This analysis is done to all indicators one after another.

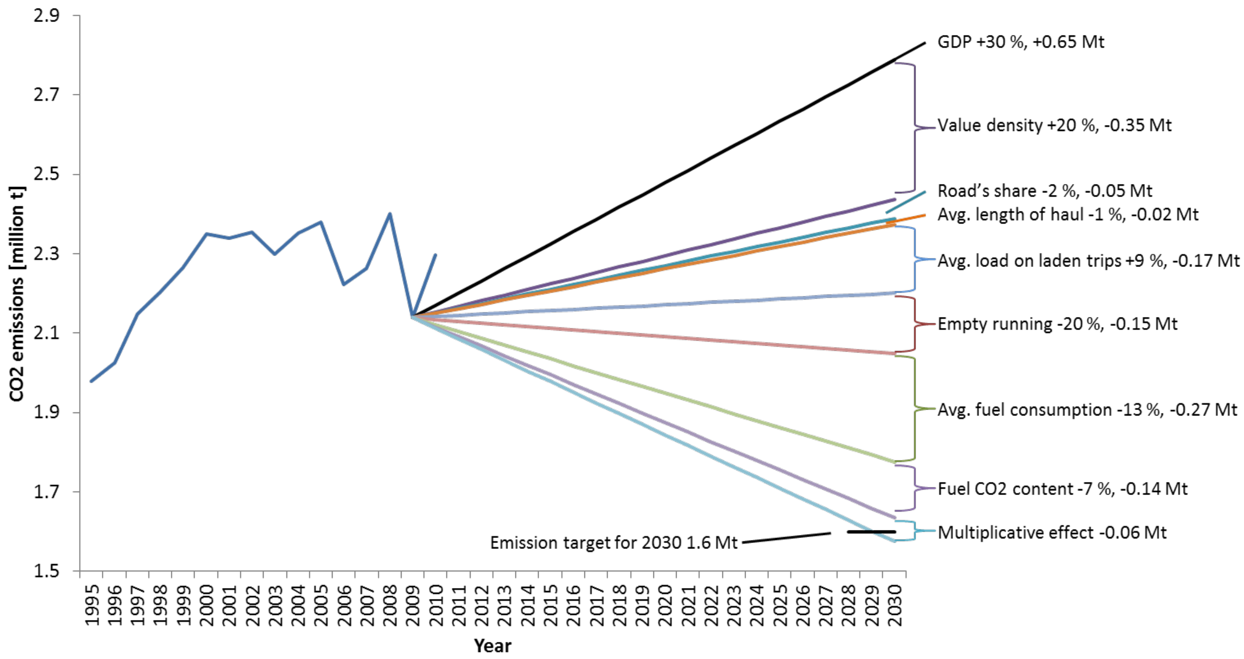

Figure 41. The effect of the changes of each indicator to the total CO_2 emissions in the Baseline scenario.

As can be seen from Figure 41, only the change of GDP increases the CO_2 emissions. If the GDP would increase by 30% by 2030 as forecasted by the experts but other indicators would remain at the 2009 level, the emissions in 2030 would be 0.65 million tons greater than in 2009, i.e. 2.75 million tons. All the other indicators are forecasted to change in a way that decreases the CO_2 emissions. This decrease varies from the 0.02 million ton decrease because of the minor shortening of the average length of haul to the 0.35 million ton decrease due to the 20% increase in the value density. The changes of the indicators also have feedback loops, i.e. a change in one indicator affects also other indicators and this causes a multiplicative effect which also decreases the emissions by 0.06 million tons. As a result of the changes the CO_2 emissions decrease by 0.56

million tons from 2009 to 1.57 million tons in 2030 and thus the intermediate target of 1.6 million tons for 2030 towards the 2050 target of 1.0 million tons is achieved.

9.7. The energy efficiency action plan

The CO_2 emission reductions forecasted in the scenarios presented above can only be achieved if the shippers and hauliers actively implement efficiency actions. The policy makers have various possibilities for promoting this implementation. As described in Chapter 8, the workshop process resulted in an energy efficiency action plan. The action plan is organised to address three problem areas identified in the workshops with seven action packages which include several actions which can be implemented fairly rapidly if there is sufficient political will, approval of freight transport associations and company commitment.

9.7.1. Improving the energy efficiency agreement

Action package 1: Marketing of energy efficiency agreement for freight transport and logistics and related communication and education activities

A marketing plan should be developed for the energy efficiency agreement for freight transport and logistics. Necessary resources should also be reserved for marketing to ensure that the agreement is promoted in all important events of the transport sector. Such events are for example Logistics - Transport Tradeshow which is organised every three years as well as the annual Logistics Seminar. In addition to the events, marketing should be done via theme issues and regular articles in trade press. Marketing efforts should highlight the best practices and communicate information on the costs and benefits of energy efficiency actions. Further publicity would be attracted in the marketing events by granting a “Freight energy efficiency innovation prize” to a haulier who has been highly successful in implementing energy efficiency actions.

The national energy efficiency monitoring system, PIHI, provides a good platform for developing useful tools for the companies who participate in the energy efficiency agreement and thus use the PIHI-system. One tool which should be developed is an application which allows the hauliers to estimate the costs and effects of energy efficiency actions with their existing fleet. The PIHI-system includes information of the hauliers’ vehicles and it should be possible for the haulier to choose the energy efficiency actions they have applied in a vehicle from a defined list of actions. The list should have default fuel saving values and cost estimates defined in research, but the haulier should also be allowed to change the default values. The haulier could then choose new actions for the fleet and get an estimate of the fuel savings and investment costs of these actions. PIHI-system should also be developed to contain practical guides and best practice case studies similarly to the British Freight Best Practice programme (FBP). FBP was very successful in providing useful information to hauliers and helped them to save fuel (AECOM 2010; Databuild 2007).

Education of energy efficiency should be developed into a one-day course which could be included in the periodic driver training. The course should include not only ecodriving, but also other aspects of saving fuel. Advice on measuring the transport performance and fuel consumption as well as calculating the carbon footprint of transport operations should also be an important part of the course.

Action package 2: Producing and communicating benchmarking information

Information on the energy efficiency and carbon dioxide emissions of road freight transport should be produced and communicated in a more systematic manner than it currently is. New method for producing detailed information was developed in Chapter 4 and similar analysis should be done annually in the future. This information should also be made available for the hauliers via PIHI-system so that hauliers can benchmark their performance against sectoral averages. Branch-level information should also be communicated to the shippers who participate in the sectoral energy efficiency agreements so that they can evaluate the performance of their hauliers. Sectoral Transport Key Performance Indicator studies should also be done in Finland similarly to the ones done in Britain (McKinnon 2009b). These studies would give more detailed sectoral benchmarking information than the analysis based on the Good Transport by Road Statistics (GTRS). Also the haulier survey done during this research should be repeated every three year to find out the long-term changes in the hauliers' attitudes, level of energy efficiency and implementation of energy efficiency actions.

The data collection processes of the GTRS were changed in 2011 (Statistics Finland 2011). Statistics Finland should ensure that comparable time series will be available from 1995 onwards also after the changes. A question about fuel consumption should also be included in the GTRS questionnaire. The hauliers could indicate the actual fuel consumption of each trip that they report or they could give an estimate on the total fuel consumption during the survey dates or the average fuel consumption of the truck. This would provide yet another source of information on the fuel consumption and enable more accurate analysis of energy efficiency than the fuel consumption estimates used in this research.

Action package 3: Investment grant for hauliers

Many energy efficiency actions require investments that the small hauliers cannot make. An investment grant scheme should be developed to help hauliers make these investments. Investment grants should only be available for hauliers who participate in the energy efficiency agreement. These hauliers could get free energy efficiency audit and then apply for grants to invest in new vehicles or improvements of the existing vehicles and also to implement ITS.

Research is necessary in order to determine which actions are eligible for the grant. Manufacturers of vehicles, parts and add-ons should give their product to be tested by an independent research institution which verifies the effects of the energy efficiency action. Investment grants may only be given to verified actions and only verified actions could be advertised in the PIHI-system.

Expected results

The measures suggested in these three action packages primarily affect the average fuel consumption of trucks, but also the use of biofuels, the level of empty running and the average load on laden trips. In the baseline scenario the average fuel consumption is estimated to decrease by 13% from 2009 to 2030 and result in 0.27 Mt decrease in CO_2 emissions. Based on the current level of usage of energy efficiency actions reported in Chapter 7, there is potential for achieving the 13% decrease in fuel consumption through wider implementation of the energy efficiency actions. Hauliers can also contribute to the estimated 20% reduction in empty running leading to 0.15 Mt decrease in CO_2 emissions. Reducing the empty running requires wider collaboration between hauliers either through direct networking or indirectly through online load exchange services. However, the shippers should also create opportunities for reducing empty running.

9.7.2. Energy efficiency in purchasing transport services

Action package 4: Including energy efficiency criteria in the transport service purchases by state and municipalities

State and municipalities should require certain minimum level of energy efficiency from the hauliers when purchasing transport services. For example, the haulier must participate in the energy efficiency agreement and must be able to verify it by showing the energy efficiency certificate which can be printed from the PIHI-system. State and municipalities should also ask what energy efficiency actions the hauliers have implemented and prefer active hauliers. Monitoring the level of energy efficiency of the operations is also important. Government agencies should give guidance on how these issues should be done. Municipalities have their own energy efficiency agreements and the energy efficiency of purchased transport services should be mentioned in this agreement.

There is a new law in process on the purchasing of environmentally friendly vehicles in public procurement (MINTC 2011). When this law comes into effect there will be education and communication campaigns for municipalities. Also information on how to take the environmental aspects into consideration when purchasing transport services should be included in these campaigns.

Action package 5: Including freight energy efficiency information into the sectoral energy efficiency agreements

In addition to the energy efficiency agreements for transport and municipalities, there are also agreements for industry, energy sector, private service sector, property and building sector, oil sector and farms (Motiva 2012). Guidance on how to take the energy efficiency into consideration when purchasing transport services should be included in the energy efficiency agreements of all these sectors. Similarly to the public procurement the shippers should require that the haulier is participating in the energy efficiency agreement and verifies this with the energy efficiency certificate. Shippers should also require continuous reporting considering the energy efficiency of the transport operations they purchase. PIHI-system could be developed to enable the shippers to see the sectoral benchmarking information so that they could evaluate the energy efficiency of their logistics service provider.

Action package 6: Improving the communication between shippers and hauliers

Communication and cooperation between the shippers and hauliers is vital for improving energy efficiency and reducing CO_2 emissions. Company-level communication with a common goal of improving the efficiency and reducing the costs of road freight operations is the most important form of communication. The largest logistics service providers have a key role in improving the communication, because they can influence the shippers and their sub-contract hauliers. It is difficult to affect the company-level communication through policy measures. However, policy measures can encourage companies to this kind of communication by facilitating with the trade associations forums for communication. The government energy agency Motiva should also be active in promoting communication in trade fairs and conferences. There is an example of successful cooperation and communication forum in Sweden where the Network for Transport and the Environment (NTM 2012) brings together the shippers, logistics service providers, researchers and government agencies. NTM has done excellent work in developing calculation methods of the environmental effects of transport services. Such a forum could be developed in Finland as well.

Expected results

The shippers make important strategic decisions which determine the energy efficiency and CO_2 emissions of their logistics. Shippers affect directly the modal split, average length of haul and average load on laden trips. In the baseline scenario these indicators were estimated to result in 0.24 Mt decrease in CO_2 emissions, with majority of the decrease coming from 9% increase in the average load. Such increase should be possible to achieve through improved logistical planning. Shippers can also affect empty running, average fuel consumption and the use of biofuels indirectly through the requirements they set for the hauliers. It was seen in chapter 3 that empty running is partly caused by shippers' requirements for strict delivery times, thus relaxing these requirements can help reducing the empty running and contribute to the 0.15 Mt reduction in CO_2 emissions estimated in the baseline scenario.

9.7.3. City logistics

Action package 7: Improving the city logistics

The largest cities should consolidate their own freight movements and thus show an example to other actors. Cities may control their logistics on their own or they may outsource it to a logistics service provider, as e.g. Stockholm has done with good results (Schenker 2006). The cities can also promote consolidation of companies' freight movements in urban areas by establishing a consolidation forum. The key members of such forum are the large logistics service providers, retailers, hotels and restaurants. Cities can also perform survey to determine the freight transport demand and opportunities for consolidation. Based on this survey the city can encourage the companies to cooperate and consolidate their freight. Cities can also encourage hauliers to use environmentally friendlier vehicles by using low emission zones or by decreasing parking fees or congestion charges for low emission vehicles. Future city logistics can be planned in advance by requiring a delivery and servicing plan (DSP) for new buildings as has been done in London. London is also a good example of how the construction logistics can be organised with construction logistics plans (CLP) and a consolidation centre (TfL 2011).

Expected results

Currently 20% of CO_2 emissions of road freight transport are emitted on urban roads. The average loading of a truck on urban roads is 8.6 tons compared to the 15.5 tons on rural roads, suggesting there are opportunities for increasing the loads through consolidation. Consolidation increasing the average load on urban roads to 10 tons could result in reducing the CO_2 emissions by an estimated 0.05 Mt.

10. Discussion and conclusions

10.1. Main findings

The objectives of this research were outlined in Chapter 1 to be to

1. forecast the future of road freight energy efficiency and CO_2 emissions in order to find out whether the policy targets can be achieved, and
2. give the policy makers guidance on effective measures for promoting the road freight energy efficiency and CO_2 reduction.

In the research it was found out that the policy targets for CO_2 emissions of road freight transport set for year 2030 can be achieved and achieved through very different developments as highlighted by the scenarios. However, achieving these targets requires close collaboration between policy makers, hauliers and shippers to realise the potential of the various measures outlined throughout this thesis for promoting the road freight energy efficiency and CO_2 reduction.

The objectives of this research were fulfilled by answering the six research questions set in Chapter 1.

RQ1: What indicators can be used to analyse the relationship between economic development, road freight transport and its energy use and CO_2 emissions?

A decarbonisation framework was presented in Chapter 3 outlining the eight indicators which disaggregate the relationship between economic development, road freight transport and its CO_2 emissions:

- Gross domestic product (€)
- Value density (€/t)
- Modal split (% of tons transported by road)
- Average length of laden trips (km)
- Average load on laden trips (t)
- Empty running (% of total mileage run empty)
- Average fuel consumption (l/100km)
- Fuel CO_2 content (kg/l)

Also three key indicators for analysing the decoupling of economic growth, road haulage and energy use were presented:

- CO_2 intensity (g/€)
- Transport intensity (tkm/€)

- Energy efficiency (tkm/kWh)

These indicators were used throughout the thesis and related information was gathered and analysed using a variety of research methods.

RQ2: How have these indicators developed in the past and what kind of a future can be expected in the short-term if the past trends continue?

The results show that the energy efficiency of Finnish road freight transport had an improving trend from 1995 to 2002, but has declined since. The major drivers have been the trends in empty running as well as in fleet composition, indicated by the Euro factor, i.e. the level of fuel consumption of the truck fleet compared to the pre-Euro trucks. Empty running hit its lowest level in Finland in 2003 and has since fluctuated considerably. Euro factor decreased quickly during the 1990s but the pace of that decrease has slowed down since, most likely due to emphasizing strict Euro-standards for particulate matter and NO_x emissions in power train design.

The energy efficiency target for the year 2016 set by the Finnish government was defined as a single figure of 3.41 tkm/kWh for the first time in this research. The energy efficiency target will not be achieved if the current trends continue as extrapolated. The target could be achieved with a combination of small changes in the determinants of energy efficiency, although the target is now even further away than it was in 2008, when it was set. The energy efficiency decreased from 3.03 tkm/kWh in 2008 to 2.98 tkm/kWh in 2010. In terms of CO_2 emissions the target for 2016 is 2.13 Mt. Interestingly, in 2009 the emissions were 2.14 Mt due to the economic crisis, but in 2010 the emissions were 2.30 Mt so a reduction of 7% is needed to achieve the target.

The research confirmed that the sectoral economic development has a great impact on the energy efficiency and CO_2 emissions of road freight transport. Bulk goods sectors (forest, construction, energy and chemical) are transport intensive and energy efficient, because they carry heavy loads mostly on rural roads. A shift in balance towards these sectors would improve the energy efficiency of road freight operations but also rapidly increase the overall CO_2 emissions. A shift towards sectors transporting general cargo (technology cluster and trade) would result in worsening energy efficiency and more slowly increasing or even decreasing CO_2 emissions. The economic development in Finland from 1995 to 2002 was characterised by growth in all sectors, which led to growing CO_2 emissions and, at the same time, improving energy efficiency. Economic development from 2002 to 2010, on the other hand, saw diminishing importance of forest cluster and growing importance of technology cluster and trade. This has led to diminishing CO_2 emissions but also diminishing energy efficiency.

If the past trends continue, the energy efficiency and CO_2 emission targets for 2016 will not be achieved. The future development was forecasted with three different trend extrapolation forecasts:

- national forecast
- sectoral forecast using extrapolated GDP forecast
- sectoral forecast using ETLA's GDP forecast.

The level of CO_2 emissions in 2016 is 2.18 Mt in national forecast and 2.39 Mt and 2.42 Mt in the others, respectively. However, the difference between national and sectoral forecasts is mostly due to the smaller GDP in the national forecast. The CO_2 intensity is the same, 12.9 g/€, in each three forecast. The trend forecasts highlight that changes in the logistics are needed in order to achieve the targets. These changes can be made mostly by shippers and hauliers and encouraged by transport policy.

RQ3: What factors affect the long-term future development of the indicators and will the long-term emission targets be achieved?

Five megatrends affecting the long-term development of the energy efficiency and CO_2 emissions were identified from the factors identified and evaluated by the Delphi panellists:

- structural change of the economy
- changes of regional structure
- changes of consumer habits
- concerns of energy and environment
- efficiency of road freight transport.

Each indicator is affected by many factors within the megatrends and the effects may be contradictory.

A long-term CO_2 emission target of 1.6 Mt in 2030 was set in this research in order to achieve the 60% reduction target for 2050 set in EU transport policy. According to the scenarios built based on the expert forecasts of the eight indicators, this emission target can be achieved. Furthermore, it can be achieved through very diverse sectoral economic development. The Delphi panellists expect a clear change towards decarbonisation of road freight transport.

RQ4: How do the shippers take the environmental issues into account in their operation and are they going to change their operations because of environmental policy targets?

Carbon auditing on a supply chain or company level is expected to have a great potential for identifying opportunities for carbon reductions. Information from logistics service providers is needed to perform supply chain carbon audits but it was found out in the shipper survey that currently environmental reporting to the shippers by their logistics service providers (LSPs) is nearly non-existing. Almost a half of the shippers want to improve the environmental reporting of their LSPs. Reporting of the CO_2 emissions, fuel consumption per haulage and vehicle utilization rate are mostly wanted, but all of these are currently difficult for the LSPs to produce. Many shippers said they prefer an LSP which can provide good environmental reporting. However, shippers are not willing to pay any extra for environmental reporting and this fact may effectively undermine improvement efforts of the LSPs.

There seems to be competitive advantage available for hauliers which monitor and improve their energy efficiency and report to their customers. Reporting may improve the trust between the companies, and thus lead to a deeper cooperation which enables long-term planning of logistics. This would be beneficial to both shippers and hauliers. Monitoring is the prerequisite for improving energy efficiency, and monitoring just fuel consumption is not enough. The monitoring system should also include data on the determinants for fuel consumption, i.e. on loading, route characteristics and vehicle specifications. Each operation should be recorded accurately to be able to analyse the effects of energy efficiency actions and report the CO_2 emissions and energy efficiency to the shippers.

RQ5: How do the hauliers take the environmental issues into account in their operation and are they going to change their operations because of environmental policy targets?

According to the survey results, the hauliers seem to not notice the shippers' growing demand for environmental reporting. Currently 5-15% of hauliers report their fuel consumption to the shippers and less than 20% considered it likely that they will regularly report their energy efficiency to the shippers in 2016. There also seems to be a lack of knowledge among hauliers on how to monitor the energy efficiency. 13% of hauliers do not even monitor their fuel consumption actively and only 11% of hauliers said they monitor tonne-kilometres. 60% of companies have set themselves fuel saving targets and a clear difference in the company size of active and non-active hauliers was found.

The hauliers are familiar with possible energy efficiency actions, but have mostly implemented only measures which are inexpensive and easy to implement. Idling avoidance, choosing the right truck for each operation, reducing cruising speed, monitoring tire pressure and ecodriving training are commonly in use. The hauliers are estimated to currently use 21% less fuel than they would if they had not implemented the energy efficiency actions. If actions are implemented similarly throughout the Finnish truck fleet this would mean a saving of about 0.6 Mt of CO_2 annually, but this is a very rough estimate.

The hauliers do not expect great changes in their operations and energy efficiency practices by 2016. Only the driver-specific monitoring of fuel consumption is seen likely to increase and also the use of aerodynamic fittings is expected to become more common. The Finnish energy efficiency agreement, on the other hand, seems to be unattractive both now and in 2016.

RQ6: What policy measures can be taken in order to promote a change towards more sustainable practices of shippers and hauliers which leads to achieving the energy efficiency and CO_2 emission targets?

Three major problem areas were identified in the workshops of expert panel: (1) lack of knowledge and best practices of energy efficiency within logistics service providers, (2) inadequate environmental consideration by industry and trade in purchasing logistics services and (3) lack of coordination of urban logistics. In order to overcome these issues, seven action packages are proposed and their benefits, challenges and responsibilities were analysed. These action packages included:

- Marketing of energy efficiency agreement for freight transport and logistics and related communication and education activities
- Producing and communicating benchmarking information
- Investment grant for hauliers
- Including energy efficiency criteria in the transport service purchases by state and municipalities
- Including energy efficiency information into the sectoral energy efficiency agreements
- Improving the communication between shippers and hauliers
- Improving the city logistics

There is an on-going initiative to promote energy efficiency through sectoral energy efficiency agreements in Finland and many proposed actions aim to improve these agreements. International best practices were also used in the action plan. In the proposed action plan cooperation and division of responsibilities between various stakeholders of the road freight sector are emphasized. It is estimated that these action packages can achieve the changes in modal split, average length of haul, average load on laden trips, average fuel consumption and fuel CO_2 content needed to achieve the CO_2 emission reductions outlined in the baseline scenario. However, the action packages do not include actions affecting the GDP and value density changes outlined in the baseline scenario, as these are considered to be outside the scope of transport policy.

10.2. Validity and reliability, limitations

The research relied heavily on the goods transport by road statistics, which are known to have a margin of error of 5-7% on national level. This data was used in this research on sectoral level and some sectors only had a few dozen reported trips in the data and thus cannot be considered reliable. This issue was taken into account in this study by analysing a time series of 17 years to minimise the effect of annual variations. However, there are some sectoral figures for a single year presented in the research and these figures should be interpreted with caution.

The fuel consumption analysis in this research was not based on actual reported fuel consumptions, but on fuel consumption functions built using average fuel consumptions found in literature. The fuel consumption functions do not capture the variations occurring in the actual operations and e.g. the effects of driver behaviour and road geometry are not taken into account, although urban and rural road conditions are considered. The fuel consumption reported by the hauliers in the survey was used to identify some sectoral variation in fuel consumption, but significant uncertainties remain.

The shipper and haulier surveys both had quite low response rates. It is possible that the companies who responded to the surveys are more interested in the environmental issues than the companies on average. An indication of this is the fact that the hauliers who responded were on average larger companies than the average size in Finland and in the survey the larger companies were found out to be more active in monitoring their fuel consumption than the small companies.

Future forecasts are uncertain by nature, because there are no methods for acquiring certain knowledge about the future. Many different futures are possible and this uncertainty is in this research taken into account by building several future scenarios and by using forecast of panellists with varying expertise. This variety of expertise of panellists also improves the quality of the results acquired by the expert methods, i.e. Delphi survey and expert panel workshops.

10.3. Theoretical contribution

The reviewed literature showed that the previous research on the future of road freight transport energy efficiency and CO_2 emissions has focused mainly on national and transport policy level analysis (Kamakate & Schipper 2009, Kveiborg & Fosgerau 2007, Piecyk & McKinnon 2010, Sorrell et al. 2009, Perez-Martinez 2009, Eom et al. 2012) with less focus on the environmental decisions made by shippers and hauliers and in the shipper-haulier interaction and the influence the policy measures have in these decisions. Richardson (2005) highlighted that the policy measures and market forces are the most important drivers of sustainability in road freight transport. This research showed that legislation was the least important driver for energy efficiency improvements of hauliers. This illustrates that the motivation for improving energy efficiency does not come from national transport policy, it comes primarily from the rising fuel costs and secondly from the competitive situation with other hauliers. The competitive situation with other hauliers is affected by shippers. The research showed that the shippers prefer hauliers who can provide environmental reporting, as long as it does not induce extra costs. However, such preference seemed to gone unnoticed by hauliers, but the shippers saw it likely that they will require environmental reporting and their logistics planning will be done with hauliers in the future. Such development may be supported by policy measures.

The research presented a new method for analysing the relations between economic activity, transport demand, energy efficiency and carbon dioxide emissions with a high level of detail in different economic sectors. The method is based on the decarbonisation framework used in previous analysis (McKinnon & Woodburn 1996, REDEFINE 1999, Piecyk & McKinnon 2010, Piecyk 2010a). Previous research has not been able to analyse the empty running on sectoral level using road freight statistics (Sorrell et al. 2012), but the new method enabled this. The method is based on a unique way to determine the fuel consumption for each vehicle and trip in the Finnish Goods Transport by Road -statistics. In this way, the total energy consumption can be calculated and decoded similarly to other indicators in the statistics, thus making it possible to analyze the impact of different factors affecting the energy efficiency. This was done by using the statistics that are available in many countries and are gathered in a harmonised manner in the EU member states (Council Regulation 1172/98). Hence, the method is applicable in other countries and enables in-depth comparison between countries. Although it should be noted that there are national differences in collecting the statistics, and thus the method may need to be adjusted (McKinnon 2010b). Energy consumption data might be available directly from the statistics or there might not be weight based vehicle utilisation data available.

Various energy efficiency measures which can be taken by road freight hauliers have been widely studied (FTA 2012, RICARDO 2009, DfT 2010a, RASTU 2009). However, previous research on the actual level of utilisation of these measures is very limited (AECOM 2010, Tacken et al. 2011). This research analysed the utilisation of 16 energy efficiency measures among the Finnish road freight hauliers and estimated the fuel savings gained by these measures. Similar surveys could be done in other countries to enable international comparison of the level of energy efficiency of hauliers.

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 interesting, as it made it possible to have factors not available as statistical data analysed with the help of expert views. This study utilized the disaggregative policy Delphi approach, which has been previously used for many purposes (Tapio 2003, Tapio et al. 2011), to forecast the future of road freight energy efficiency and CO_2 emissions. The Delphi survey was enhanced with a method for making the qualitative data from the first round of the Delphi study quantitative in the second round. This enabled finding out the importance and the effects of the statements given in the first round.

The study showed that the multi-stakeholder expert panel workshops are a practical tool for identifying the obstacles and measures for improving the energy efficiency and reducing the CO_2 emissions of road freight transport. The workshops provided an excellent forum for discussion between various stakeholders of the road freight sector. Workshops summoned the key actors and thus enabled networking and sharing of knowledge. Active involvement in the process also enabled a deep commitment to the resulting national energy efficiency action plan.

10.4. Practical contribution

The research highlights the importance of making decisions that promote energy efficiency on every level of logistics management. Planning the supply chains efficiently, optimizing the vehicle utilization, minimizing the empty running, choosing the vehicle of the right size and type for each operation and motivating the drivers to drive economically have a much greater potential to increase the energy efficiency than the technological measures which enhance the fuel economy of trucks, at least in the short term.

The research showed that the future of road freight energy efficiency and CO_2 emissions is greatly affected by the economic development in each sector. In the short run policymakers have only limited means to affect the economic drivers (such as private investments, labour and energy costs, access to raw materials, level of technology and know-how), which in the end determine the sectoral economic development and also the need for, and to some extent the efficiency of, freight operations. However, the policymakers can affect for instance the modal split (e.g. investments in rail or port infrastructure), average length and load on laden trips and empty running (e.g. fuel taxation, land use planning, urban or regional co-operative distribution centres and regulation of distribution times), and average fuel consumption (e.g. dissemination of best practices, introducing subsidies for energy efficient vehicle technologies and improving the traffic flow).

This research showed how very different economic developments can result in rather similar total CO_2 emissions from road freight transport. It was also shown that the development of GDP and value density influence the CO_2 emissions greatly. On the other hand, based on the shipper survey and the expert forecasts of the future, the modal split and use of biofuels, which are strongly emphasized in European transport policy, only have a minor effect on the total CO_2 emissions.

The research helps the Finnish Ministry of Transport and Communications in planning the future transport policy as it gives the understanding about how the changes of one indicator affect the total CO_2 emissions. The study also highlighted several trends which affect the future development of the emissions and this enables the policy makers to find measures to affect these trends. The representative of the ministry summarised the research in the last workshop as "a research with exceptional practical relevance". Also the representative of the government energy agency Motiva commented the proposed action plan by saying: "This is exactly what should be done". These comments confirm that the practical aim of the research, i.e. *to support the initiatives of the Finnish government for improving the energy efficiency and reducing the CO_2 emissions of freight transport*, was fulfilled.

10.5. Recommendations for future research

Though the method was tested using Finnish statistics, it can be applied to other countries which gather goods transport data using continuous company surveys. Statistics on the carriage of goods by road are reasonably similar within EU member states (following the Council Regulation 1172/98) and at least a European comparison of energy efficiency by using this method could be possible. It would also be highly interesting as it might give more insight of the differences between countries and possibly some indications of good or best practices in energy efficiency of road freight transport. However, such comparison would require access to primary data of national continuous goods transport surveys as the currently available Eurostat data is not sufficient for this purpose. Comparisons between countries would give more understanding on the dynamics of the economy, freight transport, energy consumption and CO_2 emissions. With the method a sector can gain knowledge of its transports and compare the energy efficiency and CO_2 emissions of the transport operations with other operations, and prioritise the actions for improvements.

The fuel consumption estimates produced in this research are based on several assumptions and simplifications. To gather more accurate fuel consumption data, a question of fuel consumption for each trip could be added to GTRS-survey, although already the current load on the respondents has been evaluated to be high and there might be difficulties in determining and reporting the actual fuel consumption of each journey. Another possibility to gather more accurate data in Finland is the PIHI system, though it requires higher amount of reporting companies to produce more reliable data. Furthermore, PIHI does not withhold much data on tonne-kilometres, because most hauliers have difficulties in reporting this data. This means that further research on accurate and reliable ways to measure and report also tonne-kilometres is needed.

Also, if each haulier begins to develop environmental reporting that fits their own business best, there will be various environmental reports, none of which would have any relevant information to shippers because they have all been done differently. Therefore there is a great need for collaborative effort by hauliers, shippers and researchers to develop measuring methods and reporting standards to be commonly used for environmental reporting of logistics services to ensure transparent and comparable results.

This research forecasted the future of CO_2 emissions if certain changes happen in the indicator values. It would be very interesting to perform a backcasting study in which the European CO_2 reduction targets for 2030 and 2050 would be taken as the starting point and then possible and feasible indicator values would be analyzed. Such analysis would give further understanding about the policy measures which could be used to achieve such values of individual indicators. In all, two important aspects of scenario planning could be integrated – opening the decision-makers' eyes to a wider set of alternatives than is usual in mathematical modelling exercises, while maintaining the rigorous description of causal relationships between factors affecting the issue.

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