
# Essays on operational freight transport efficiency and sustainability

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SCHOOL OF BUSINESS, ECONOMICS AND LAW

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Doctoral Thesis in Business Administration
November 2013

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ISBN 978-91-628-8808-4
http://hdl.handle.net/2077/34191

Printed by Reprocentralen, Campusservice Lorensberg, University of Gothenburg

# Acknowledgements

I would like to extend my deepest gratitude to my supervisors Johan Woxenius and Anna Nagurney for their mentoring and constructive feedback as well as for allowing me to answer the RQs in a manner I felt comfortable with. I am heartily grateful to my colleagues and friends Ala, Fredrik, Viktor, Helen, Sasha, Vendela, Catrin, Ove, Neil, Allan, Benedikte, Östen, Magnus, Zoi, Mike, Anders, Jonas, Taylan, Ali, Edith, Karin, Marcus, Inge, Anna, Rickard, Martin, Christina, Lars, Carl, Catrin, Anna and Johan for fruitful feedback and open discussions. This paper would not have been possible without the support of Norden Energy & Transport, Marie Curie IAPP, Vinnova, Northern Lead, the Logistics and Transport Society LTS, Volvo Logistics, DB Schenker, Stora Enso, Västra Götaland Region, and City of Göteborg Traffic & Transport Authority. Finally, I offer my regards to everyone who supported me in any respect during the completion of the project, especially my family and wife, Ala. Thanks to all for making this process such a great experience, and my apologies for those not mentioned here. Of course no one mentioned above bears the slightest responsibility for the content of this dissertation. That responsibility is solely mine.

Göteborg, On a beautiful November day 2013

## Abstract

Freight transport efficiency, as one proposed abatement strategy for transport related emissions, is a concept that has received much research attention during the last decade, often from the transport buyers' perspective. In contrast, the aim of this thesis is to explore the subset concept of operational freight transport efficiency and how it affects transport related emissions from the perspective of the transport operator. The focus is on the transport operators and their interfaces with other actors such as transport providers/forwarders, transport buyers, and the society. I open with a dissection of the term "operational freight transport efficiency." I make these primarily semantic efforts to open up and introduce a few aspects that are commonly overlooked. The concept is argued to be "fuzzy", in the sense that it means different things depending on who you ask, and a "wicked problem", in the sense that the problem has no clear solutions with significant and present trade-offs. The methodology, or vessel, used in this thesis to launch a "critical spirit" is "phronetic social science". After phronetically testing the efficiency measures, some recommendations are presented. A suggestion on operational decarbonisation is provided and the attitudes and trade-offs among the actors are explored. The thesis identifies a gap with respect to the absence of a common semantic definition of the concept of operational freight transport efficiency measures. The thesis proposes that the gap be filled with the following derived definition of operational freight transport efficiency: "A set of utilisation measures of time, space, vehicle, fuel and driver in the movement of goods". From the operators point of view, as well as from an aggregated level, also missing are the trade-offs between environmental and economic considerations. Most operational freight transport efficiency improvement measures are likely to reduce emissions, however; it is probable that mere cost-reduction measures will not lead to reduced emissions in the long term. The traverse across these topics represented by the present thesis is offered as a theoretical contribution to the discussion about defining what is meant by sustainable logistics. In other words, what the word sustainable means in a logistics context.



**Keywords:** operational freight transport efficiency, operator, sustainability, logistics, phronetic



**Author: Niklas Arvidsson**


**Language: English**
**Pages: 150**
**Thesis 2013**



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*"Would you tell me, please, which way I ought to go from here?"*
*"That depends a good deal on where you want to get to," said the Cat.*
*"I don't much care where" said Alice.*
*"Then it doesn't matter which way you go," said the Cat.*
*Alice's Adventures Lewis Carroll*

# 1 Introduction

This is not a thesis for operational freight transport efficiency, neither is it a thesis against it. It will not include discussions of binary terms like *for* or *against*, *right* or *left*, *correct* or *false*, *good* or *evil*. This thesis is one of different perspectives, shades, and trade-offs.

The transport sector is and has been an important part of the economies of cities and nations for centuries. Transportation is important for economic growth, but it is also the cause of 13-15 per cent of total global greenhouse gas emissions (Fuglestvedt et al., 2008; IPCC, 2007) although this figure also includes passenger transportation. OECD (2003) estimates freight to contribute approximately 30 per cent of transport related energy consumption, which in turn accounts for roughly 20 per cent of all energy consumption in the Western world. Energy consumption has a strong correlation with the level of development. The benefits derived from this correlation in terms of an increase in mobility and exportation of comparative advantages have so far compensated for the increase of energy used (Rodrigue et al., 2009). From the world's power production, 86 per cent is based on fossil fuels. Freight transport was responsible for 8 per cent of total emissions in 2004 (IPCC, 2007). Within an EU-27 context, and taking into account international shipping, more than 70 per cent of emissions can be related to road transport (European Commission, 2012, p 123). For that reason, it seems appropriate to focus on road traffic as the main source of traffic related GHG emissions for the next few decades.

Emissions are not the only challenge, however, as others include; large investments, congestion, safety, and negative spillovers to non-users through air pollution, noise, aesthetics, water quality, and competition for open space, especially in the urban environment. These are all examples of negative externalities (GAO, 2011). These challenges have provoked numerous policy responses to reduce the negative effects. Researchers have studied the concept of externalities for nearly a century, referring to techniques such as "polluter pays" and "internalise external costs" as ways to pass on the costs to customers. A relatively new term has surfaced as a response: green/sustainable logistics/distribution/transportation. Belz and Peattie (2009), for instance, stress the importance of sustainable distribution as a means of integrating or "tackling" sustainability issues in the macroeconomic allocation of objects without compromising the efficiency of the conventional distribution functions, but also delivering a substantial reduction of environmental and social impacts at a global level. One way to achieve this is through transport efficiency. So far, the different actors of the system—transport operators, transport providers and transport buyers—have agreed on transport efficiency as economically and environmentally desirable. This thesis will use phronesis and critical theory to explore the concept of operational freight transport efficiency, clarify and consider the problems and risks we face and outline how some processes may be carried out in a different way using an interpretive narrative of the consequences of some of the issues that need to be addressed. This helps achieve the scope and fulfil the scholarly role of facilitating adaptation by conversing transport operators' and societal needs related to these issues, in accordance with Corley and Gioia (2011), for instance. Examples of *transport efficiency measures* are: eco-driving, keeping the right tire pressure, the use of aerodynamic lorries, intelligent transport systems (ITS), improving the load factor, minimizing empty backhauls and a modal shift (McKinnon and Piecyk, 2012). *Operational* refers to what can be achieved in daily operations with available resources. Some of the papers in this thesis have an urban focus, since benefits and drawbacks become particularly apparent in the urban environment as more people migrate into cities. UN research on population shows that more than half of the world's population lives in urban areas. By 2050, 70 per cent of the world´s population will live in urban areas, whereas this is already the case in richer countries, in which over 70 per cent lives in cities. The guidelines from the most recent European White paper (European Commission, 2011, p 9) on transportation sets an operationally ambitious target for city logistics by 2030:

> "Halve the use of 'conventionally-fuelled' cars in urban transport by 2030; phase them out in cities by 2050; achieve essentially $CO_2$-free city logistics in major urban centres by 2030."

The following section informs the reader about the background of the transport efficiency discussion and shows how transport efficiency measures play a part.

## 1.1 Framing the problem

Market failures are present when markets' use of goods and services are not efficient, where there are examples of information asymmetries, non-competition, principal-agent issues or externalities. Examples of market failures are quite frequent in the transport sector (Iannone, 2012).

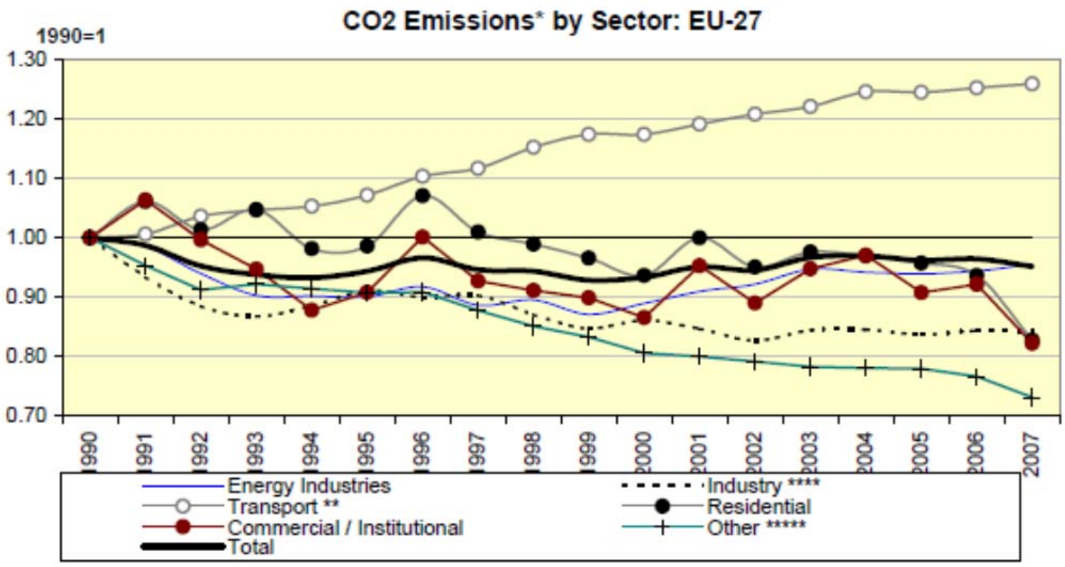


**Figure 1 Carbon dioxide emissions by sector EU-27.**

Figure 1 from the European Commission (2010) is a pictorial presentation of what could be a market failure in transportation. Despite the advances in engine efficiency over the past century and the recent focus on transport efficiency, transport is the only sector that increases its emissions (shares of total $CO_2$ emissions). In other words, transport related emissions grow faster than total emissions. Furthermore, world transport emissions of $CO_2$ are expected to more than double by 2050 (OECD, 2009; Proost and van Dender, 2010), even though the goal is to half the emissions by 2050. It is important to give a more nuanced picture here, as well. The diagram above does not offer the whole truth. It is a result of delimitations of where the emissions appear, at least for the industry sector. Much of the industry sector has been moved elsewhere and so has the obligations to report these emissions.

The improvements in fuel efficiency have not been enough to offset the increase in transport emissions. This has led the European Commission to emphasise the importance of decoupling freight traffic growth from economic growth (CEC, 2001a, 2001b); transport efficiency is considered one tool to break the link between "environmental bads" and "economic goods." However, very little evidence on a decreasing trend or decoupling effect has been shown in absolute terms. The transport sector has experienced unprecedented growth in emissions over the past three decades. The growth of emissions can be observed in both passenger and freight transport. In Europe the growth in freight transport has been faster than economic growth for some years. Between 1995 and 2006, the average annual growth for EU (27) economy was 2.4 per cent and intra-EU freight transport grew 2.8 per cent, exceeding economic growth (European Commission, 2009). Figure 2, from a newer report (European Commission, 2012), shows somewhat different numbers. The authors of the 2009 and 2012 reports do not quite state how this is measured. Nevertheless, projections indicate further growth in freight transport. The growth is unbalanced in terms of the figures being skewed in favour of air and shipping. Air and shipping have both grown rapidly over the past decade and, according to Geerlings (2008), low-cost flights now account for 25 per cent of all scheduled intra-EU air traffic. The unbalanced growth is a trend of much concern, since the growth is primarily occurring in the faster and more energy-intensive modalities, which conflicts with the aim of a more sustainable transport system in Europe.

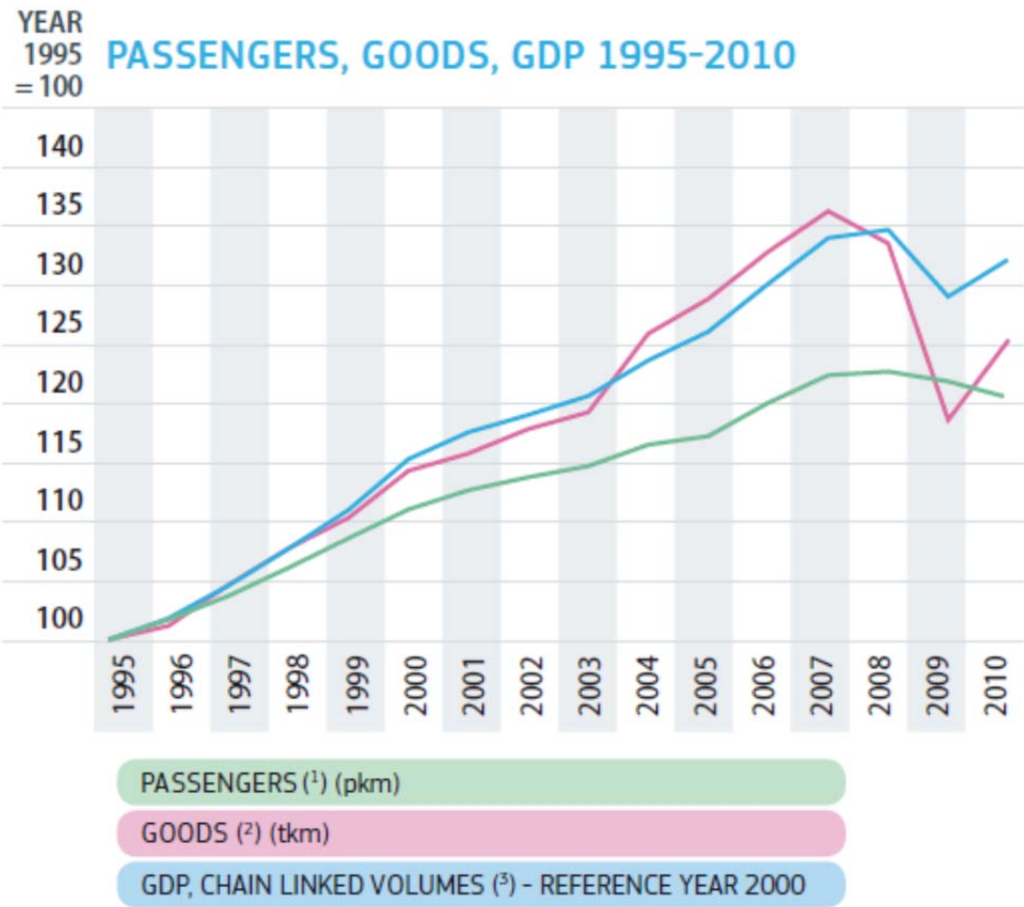


Figure 2 Transport growth in EU-27 (European Commission, 2012).

A number of reports (e.g. Interlaboratory Working Group, 2000; Ecofys, 2001; Intergovernmental Panel on Climate Change, 2001; Greenpeace International and European Renewable Energy Council, 2010) state that many energy efficiency improvements are not realised; it could be argued that transport efficiency is closely related to energy efficiency of which both could be seen as a union of two sets. A problem facing the transport industry is that it is a major contributor to various pollutants, and research shows that measures counteracting this development such as transport efficiency measures are not being realised or that they have not had the desired effect. However, an example of the beginning of such a realisation is shown in Figure 2 as a decoupling of transport from GDP, as proposed by the European Commission (2001). Unfortunately, this could also be explained by the recession in 2008.

Transport efficiency and energy efficiency have long been decarbonising measures advocated by governments, NGOs, and consultancy firms worldwide. The Breakthrough Institute (2011) argues that consulting firms, such as McKinsey and Company (2009) and Rocky Mountain Institute (Lovins, 1990, 2005), promote cost-reducing efficiency measures as a way to single-handedly reduce U.S. consumption of energy by 25 per cent by 2020. Cost reduction means that the net pay-back is positive. Also the International Energy Agency (IEA, 2009) and Intergovernmental Panel on Climate Change (IPCC, 2007) arrived at similar conclusions, such as how energy efficiency will drive the greatest reductions in emissions needed to stabilise the global climate (UKERC, 2007). In this sense, to quote Weizsäcker et al. (1998, p. 38), efficiency is “better than free: not a free lunch, but a lunch you’re paid to eat.” This “Kappa” will critically elaborate on this type of reasoning in a freight context.

From a logistics research point of view, much research has been conducted on the use of different transport efficiency measures. However, less research has been conducted on the problems and possibilities with reductions in transport-related emissions of using these measures for the actors in the logistics system, especially for the operators—the actor group performing the transport act. Furthermore, few researchers in logistics have tried to place freight transport efficiency measures into a greater context and to examine the evidence that these improvements have led to reductions in transport-related emissions, along with studying the logistical implications for the actors in the system. It is valuable to study this development from the transport operator's perspective, since a small change would have great impact because of the sheer number of small transport operators in operation. According to Murphy et al. (1996), small companies are an important group to incorporate, since they usually attach much less importance to management of environmental issues than larger firms. Few things can be studied in isolation, so the interface between the other actors and society must also be an integral part of the analysis.

## 1.2 Purpose

The purpose of this thesis is to frame the concept of *operational freight transport efficiency* mainly for urban areas and to explore how it affects transport-related emissions. The focus is on the transport operators and their interfaces with other actors, such as transport providers/forwarders, transport buyers, and society.

## 1.3 Research questions

To fulfil the purpose of the thesis, three sub-questions are created. The background to the formulations of these questions is explained in the methodology chapter.

RQ1: What should be included in the concept of operational freight transport efficiency for the transport operator in urban areas?

RQ2: From the perspective of a transport operator, what are the likely economic and environmental effects of operational freight transport efficiency measures in terms of opportunities, barriers, and implications in urban areas?

RQ3: What is the status of transport/energy efficiency indicators for freight operations in the Nordic countries?

## 1.4 Delimitations

Freight transport is studied. The focus is mainly on lorry transport. No particular delimitation in terms of the types of goods is made, but the emphasis is on shorter distribution and the collection of smaller quantities of goods in urban areas, which would partly exclude bulk, construction, energy distribution and waste.

The focus is mainly on the environmental and economic dimensions. One exception to this delimitation is present in one of the papers, where social sustainability is studied in relation to the other two dimensions. The social dimension ought to be explored in future research and an elaboration on consequences of this delimitation is made. In this respect and through the remainder of the thesis, both “economic” and “environmental” refer to an equal consideration of the two to meet the present need, as well as future needs.

The thesis considers operational measures and solutions with respect to transport efficiency. The industry is eager to know how it might contribute to a more sustainable transportation system and increase its competitiveness at the same time. Measures for future alternative fuels and vehicle technology improvements are important, but are not considered to have operational characteristics; thus, these are not a major part of the thesis. Also, the localisation of warehouses and centralisation or decentralisation are considered strategic issues and are not part of the thesis. However, some measures could be seen as more strategic in character, but they affect the operator operationally to the point that a delimitation seems unnecessary, such as regulations from local municipalities in urban areas. Many of the efficiency measures analysed in this thesis possess characteristics that affect or are affiliated with other levels, tactic and strategic.

## 1.5 Bridging theory and methodology with research questions and papers

This section will clarify how the connections between the different sections of this thesis are related. As stated, the unit of analysis is operational freight transport efficiency and the perspective is of the operators. The concept of operational freight transport efficiency is sometimes abbreviated to transport efficiency.

To produce operational recommendations from the papers, a thorough study of the concept of transport efficiency is made. I aim to mathematically and semantically dissect the concept under study with the ambition to shed some light on some aspects that are less often discussed. The concept of (freight transport) efficiency is illuminated in a range of different disciplines in a funnel fashion (see Figure 7 Research process on page 31), and this is presented in the theory section. The concept of operational freight transport efficiency is also defined in the “Results” section.

The papers treat different aspects of opportunities and barriers in relation to implementing operational freight transport efficiency measures. What can be expected by the operators? Would they take the first step? The barriers are mostly economic, but some of the possibilities offer new business opportunities to the operators. The common understanding in the logistics industry is the notion of transport efficiency as an economic and environmental solution with few drawbacks. This is an a priori and axiomatic-like notion that will also be scrutinized. As with most works of this nature, with the same amount of time and effort put into it, the development has not been linear, contrary to what is depicted below, but instead it has been formed by an iterative, mildly intuitive, eclectically adaptive and reflexive process.

The tool used to study the unit of analysis, transport efficiency, is critical theory; as explained in the theory section, this is used, as Alvesson (2003) puts it, as a means "to consistently support a dialectic way of interpreting society, and argues that […] phenomena must be understood in a historical context" (p. 154). He continues, saying "critical theory is not an exercise in fault-finding, but in problematizing those ideas, [...] structures, and practices that strongly prevent communicative action and constrain human possibilities" (ibid, p. 166). The author tries to acquire and maintain a critical spirit or as Facione (2010, p. 9) puts it, "use the metaphorical phrase ***critical spirit*** in a positive sense". By it they mean "a probing inquisitiveness, a keenness of mind, a zealous dedication to reason, and a hunger or eagerness for reliable information."

Critical theory provides us with tools to analyse and problematize. This thesis will elaborate on some ways to do this in logistics. It is also a way to be modest about research, to admit that what we might think we know today, we might challenge tomorrow. The methodology or vessel used to launch this critical spirit is inspired by Flyvbjerg's (2001) phronetic social science. Phronetic research is "dialogical," as Flyvbjerg puts it (p. 139), in the sense that it includes a multitude of voices, with no one voice claiming final authority. It emphasizes values, prudence and what is better or worse for humans as the starting point for action. The goal is to produce input to the on-going dialogue and praxis in society rather than producing verified knowledge. The task of phronetic social science is to clarify and deliberate about the problems and risks we face and to outline how things may be done differently. The result of phronetic research is a pragmatic interpretation of the studied practices, a practical-moral and context-dependent action oriented knowledge. Critical theory is sometimes criticized for having a gap between the theory and practice of critique. Lyytinen (1992) argues that much of the research is fragmentary and theory-heavy. Perhaps the common sense approach in phronesis could help make this link between theory and practice, or as Schram and Caterino (2006) put it, the special thing about Flyvbjerg's challenge to social science is the way it bridges theory and practice in a way that unites empirical and philosophical subdivisions in the discipline (p 1).

An important part of this thesis is the Kappa, a frame of the thesis. It shows how the papers are related and the theory used, and it presents a possible first step toward contributing to a dialectic conversation in the area of "sustainable logistics." Therefore, the thesis is a hybrid between a collection of papers and a monograph.

## 1.6 Outline

The aim of this section is to give the reader a quick overview of the different sections of the thesis. The *Introduction* supplies the reader with a background, problem, purpose and delimitations within the research area. The *Theory section* elaborates on the theory used in the papers and attempts to produce a seed of a theoretical definition of operational freight transport efficiency from a literature review while also presenting different views on efficiency. A series of implications from theory are also presented. The concept is argued to be “fuzzy” and “wicked” and a semantic gap is identified. A definition is formed and implications of the concept under study are discussed. In the *Methodology section,* I try to respond to a multidisciplinary call [in the “Kappa”] as well as to a variety of research methods [in the papers] and also describes phronesis. The case under study is operational freight transport efficiency. In the end of the methodology chapter research quality is discussed. The *Results* section provides an analysis and discussion of the concept of operational freight transport efficiency and a definition of operational freight transport efficiency as an answer to RQ1. Also, this section summarizes opportunities, barriers and possible implications of implementing these measures from RQ2 as well as answering RQ3. This part also elaborates on the link between efficiency and productivity on a company level. The *Concluding discussion and future research* expands the implications of the empirical and theoretical findings together with the theory chapter and papers.

*If you want the truth to stand clear before you, never be for or against. The struggle between "for" and "against" is the mind's worst disease. Sent-ts'an, (c. 700 C.E)*

*The progressive state is in reality the cheerful and the hearty state to all the different orders of the society. The stationary is dull; the declining, melancholy (Wealth of Nations, p 72)*

# 2 Theory

Although an admirable goal, sustainability is difficult to define and operationalise. The current literature on the subject demonstrates a range of different interpretations and research angles. An often-cited definition of sustainability is the United Nations General Assembly Resolution 42/187 (1987) that *sustainable development* meets the "needs of the present" while at the same time does not "compromis[e] the ability of future generations to meet their own needs." The definition has later been divided into three parts and is colloquially called the *triple bottom line* introduced by Elkington (1998), where the needs are not only mere survival but stem from economic, social, and environmental considerations that are equally as important for decision making in organisations.

This chapter contains a short summary of ways to view transportation and different notions of operationalisation. After a presentation of the differences and similarities between energy efficiency and transport efficiency as well as an introduction to target setting, a range of different perspectives on efficiency follows. This is divided into transport geography, business administration, operational management, logistics, and economics perspective on efficiency. This section will start with a short summary of perspectives on transportation, as a flow or a chain.

## 2.1 Transportation as a flow

Wandel et al. (1992, p. 98) presents an interesting model of the difference between transport and traffic. Figure 1, *the three layer model*, depicts the infrastructure, transport flow, and material flow. In a freight transportation market, the interplay between the actors can be considered supply and demand actions, in which the transport operators or forwarders supply and the transport buyers consume. As mentioned, the focus of this thesis is on operators who supply a lorry service. The uppermost layer consists of products that are moved to different nodes, such as production and storage. In the next layer, load units such as pallets, vehicles or containers are moved between nodes; this is, for example, where consolidation and modal shifts take place. The last layer shows the infrastructure and how it allows for the other layers to operate. There are many versions of this model, such as those of Sheffi (1986), Lumsden (1998), and Stefansson (2006).

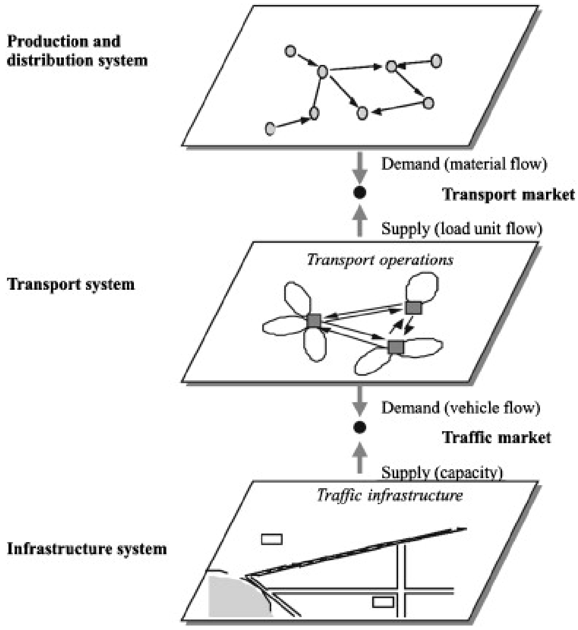


Figure 3 Wandel's three-layer model.

## 2.2 Transportation as a chain

Supply chain management, logistics and transportation/distribution[1] have a wide variety of definitions. A differentiation is presented by Ramstedt and Woxenius (2006), who suggest that the concepts have evolved over the years and are sometimes used in disparate and even confusing contexts. This is why the authors stress the significance of producing operational definitions, and they define the concepts that follow. *Supply chains* focus on a product and range over the chain of actors, activities, and resources that facilitate its availability at the place of consumption. *Logistics chains* focus on items and range from creation of an item number until it is consumed or becomes part of another item. *Transport chains* focus on consignment and range from movement, physical handling, and activities that are directly related to transport such as dispatch, reception, transport planning, and control. They also highlight the difficulties in defining the exact roles of the actors because of the diversity in demand, mode choice, levels of vertical and horizontal integration, division of labour and differences in the use of language, country, and historical variations. An actor can play several roles and the same role can be played by several actors. By using terminology from the transportation domain, the authors identify and distinguish between actors in the freight transport chain in Table 1 below. The main focus for the bulk of previous SCM research has been on costs and service aspects of integrated supply chains with little attention given to energy, ecology, and other sustainability aspects of transportation and distribution, as pointed

[1] Supply chain management, logistics and distribution (SCM) as defined by the Council of Supply Chain Management Professionals (http://cscmp.org/digital/glossary/document.pdf):

Supply chain management "encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities."

Logistics: "The process of planning, implementing, and controlling procedures for the efficient and effective transportation and storage of goods including services, and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements."

Distribution: "The activities associated with moving materials from source to destination."

out by several authors (e.g. Stock et al., 2010; Carter and Rogers, 2008; Viadiu et al., 2006; Pan, 2003 Stock, 1978).

**Table 1 Categories of transport chain actors Source: Ramstedt and Woxenius, 2006.**

| Abstract terms | Generic actor names | Roles | Practically used actor names |
|---|---|---|---|
| Source | Consignor | Send goods | (Product) Supplier |
| Sink | Consignee | Receive goods | (Product) Customer |
| Management | Transport co-ordinator | Co-ordinate transport services | Forwarder, Third party logistics provider, Agent |
| Link operator | Transport operator | Move goods | Road haulier, Rail operator, Shipping line, Airline |
| Node operator | Terminal operator | Tranship, consolidate or deconsolidate goods | Port, Airport, Intermodal terminal operator, Consolidation terminal operator |

To conclude, what metaphor is the best, the most accurate and has the least influence on our perception? Ramsey and Caldwell (2004) claim that all have a place, but also use the famous quotation: that if all you have is a hammer, it is tempting to treat everything as if it were a nail.

## 2.3 Operational

*Operationalisation* is a process of defining concepts into measurable factors or variables to describe what constitutes them. For many fields of science, operationalisation is important. An example is to operationalise hunger in terms of “time since last feeding,” as Tolman does according to Feest (2005). Operationalisation is closely related to an operational definition, which Demining (2000) defines as, “a procedure agreed upon for translation of a concept into measurement of some kind” (p. 105). The term is also commonly referred to as a tool for making “fuzzy concepts” more distinguishable and/or measurable. “In general, we mean by a concept nothing more than a set of operations; the concept is synonymous with the corresponding sets of operations” (Bridgman 1927, p. 5). He warns us to be careful not to slip into conceptual confusion in using the same word to refer to the subjects of different operations, as we might get into the sloppy habit of using one word for different situations. In this sense, it could be argued that operationalising “semantic magnets”, like democracy, freedom, justice, quality, and efficiency serves the purpose of establishing what it is and what it is not. As Mohanty (2010) points out, terms with significant political and rhetorical power, such as those already mentioned, are usually given an interpretation to serve the interest of different groups, but their content and significance is also modified to suit the purpose of different users.

Even though the Swedish word “*operativ*” is not entirely translatable to operationalisation or operational, this could serve as one interesting aspect of its focus and potential impact within transportation. According to Aronsson and Huge Brodin (2006) and to Vägverket (2004), the fundamentals of the transport work from a company are decided on strategic and tactical levels. It is decided on these levels where the production and warehouse facilities should be located, as well as lead times and service levels for customers, and moreover, whether production should be performed in-house or be outsourced. According to Vägverket (2004, p. 21), 70-80 per cent of the freight costs and transport work is decided on a strategic and tactical level, which leaves only 20-30 per cent that can be influenced at an operational level. Drewes Nielsen et al. (2003) claim that this order may vary. Sometimes the more operational measures have strategic qualities; for instance, companies that are heavily dependent on just-in-time (JIT) scheduling of product flows seem to be in the uppermost layer within the hierarchy. Along the same lines, Aronsson and Huge Brodin (2006) found that different measures may have characteristics from different levels. For example, consolidation (increased load or fill rate) can be viewed as both a tactic and strategic decision. The authors also mention that "strategic and tactical decisions influence the operational outcome" (ibid, p. 396), and researchers agree that the strategic decisions have larger impacts than the operational decisions (ibid, p. 397). Worth noticing is that Aronsson and Huge Brodin studied transport efficiency from a transport buyer perspective, not the operator's perspective. McKinnon (2010c) presents an augmented version of the different levels of logistical decision-making: strategic, commercial, operational, and functional, where the operational level is defined as scheduling of production and distribution operations.

According to Hokey and Seong (2006), the *operational efficiency* of third party logistics providers—defined as equipment utilisation or labour productivity—dictates the competitiveness and even survival of the company. To facilitate an increase in productivity and price control in the highly competitive industry of third party logistics, the authors propose the use of data envelopment analysis (DEA[2]) to measure operational efficiency. One way to improve operational efficiency is to imitate best practice firms through benchmarking. They also argue that operational efficiency measured by input and output ratios may reflect the true overall productivity better than traditional financial measures. Operational efficiency is defined by Jeong and Phillips, (2001) as "*equipment utilisation.*"

Freight Best Practice is an organisation funded by the Department for Transport (DfT) in the U.K. and managed by AECOM to promote operational efficiency within freight operations (Freight Best Practice, 2009b). The organisation defines operational efficiency as a series of measures: back-loading (avoid empty running and minimise the empty journey legs) and allocating operational costs (savings are divided between operator and transport buyer). They also define fuel management as a tool for monitoring improvements in operations, in which driver training, office systems, and vehicle management systems are an important part. Another report by Freight Best Practice (2009a; 2011) suggests a greater number of key indicators for operational efficiency, and divides them into the following groups: costs, operational, service, compliance, maintenance, and environmental.

Ramstedt and Woxenius (2006) define the *operational level* from a buyer perspective as the activities that are not fixed. Examples of fixed activities are locations of warehouse and production facilities, main supplier, and customers. The general agreements between the actors are considered fixed. Also studying the process from a buyer perspective, Forslund and Jonsson (2009) state that supply chain management largely concerns downstream and upstream process integration, where two companies perform together and agree on activities in the chain. They identify a series of factors that are important for this integration. The lack of well-functioning supplier relationships is many times due to a lack of trust, to different goals and priorities, to a lack of parallel communication structure, and, to lesser degree, a factor called *operational tools*. Factors including manual performance data gathering, registering and report generation, and non-standardised performance metrics were found not to significantly affect process integration. According to the authors, a possible explanation of this result could be the low existence of standardised metrics.

[2] The tool is a nonparametric linear programming methodology that uses multiple inputs and outputs to measure the efficiency of multiple decision-making units (DMUs).

## 2.4 Energy efficiency or transport efficiency?

The frequently used term *efficiency* commonly relates to a ratio between resources and products, costs and benefits, or inputs and outputs of a defined process. A ratio of output to energy input contributes to a process involving two forms of energy; the output is often work and the input can be labour, material, heat, electricity, or other forms of energy (Tanaka, 2008). Energy efficiency is defined by the EU Directive (2006) as ‘‘a ratio between an output of performance, service, goods or energy, and an input of energy,’’ (Liimatainen and Pöllänen, 2010). Amory Lovins (2004) define energy efficiency as: “Broadly, any ratio of function, service, or value provided to the energy converted to provide it”. To operationalise this for transportation, the research literature proposes a range of different measures; see Liimatainen and Pöllänen (2010) for a selection of examples. They suggest the use of tonkilometers/kWh, total haulage, and energy consumption. Efficiency can also be seen as the inverse of intensity, which is the ratio of energy input to output, kWh/tkm or MJ/tkm. A similar term is “effectiveness,” which disregards input and is more qualitative in character. While efficiency can be defined as doing things in the most economical way or a good input to output ratio, effectiveness is doing the right things and setting the right targets or measures to achieve an overall effect or goal. However, efficiency and effectiveness also leaves open questions. What is “good” and the “right thing”, according to whom? The following section presents some of these open questions for a transportation context.

As mentioned in the introduction, many transport researchers have pointed out the seemingly untapped potential for improvements in energy efficiency to radically decrease total energy use. Despite the efficiency improvements that have already been made, total primary energy use continues to rise in a roughly linear manner (BP, 2011). Accordingly, many other researchers question whether technical efficiency improvements in transportation alone can do more than a marginal reduction of greenhouse gases (Moriarty and Honnery, 2012; Schwanen et al., 2011; Banister, 2011; Whitmarsh, in press; Nykvist and Whitmarsh, 2008).

Drawing on Moriarty and Honnery (2012) example, a lorry is here used to shortly explore the complexity of defining transport efficiency for freight transportation. Viewed as a pure thermodynamic entity, the efficiency of a lorry and its engine can easily be measured. But with added behavioural and operational aspects, like eco-driving, loading, and route planning, questions of human and organisational interaction arise. In this sense, rather than output power from the engine, the distance that the lorry can travel and the utilisation of the vehicle becomes important with respect to fuel, time and other capacity input. Vehicle efficiency can in this way be viewed as the distance that the lorry can move per a specific unit of fuel, as in kilometres per liter, which have made possible comparisons of lorry models with one another. To fully accommodate for the operational aspects in transportation other measures are nevertheless necessary. Today logistics companies charge for tonne kilometres or if the goods are light and voluminous, in volume kilometres. As mentioned, Liimatainen and Pöllänen (2010) suggest the use of tonne kilometers/kWh or tonne kilometers/MJ, total haulage and energy consumption, which could be useful when comparing the use of different transport modes, like electric powered vehicles with diesel fuel in the distribution systems. This shows the importance of where the line is drawn in the analysis, whether a wheel, a tank-to-wheel, a well-to-wheel, or a cradle-to-cradle analysis is used. The pure operational aspects in terms of cost of “fuel” and service of electric vehicles would simply be too advantageous, while operational range and purchase costs would pose a disadvantage. Furthermore, according to Zehner (2012), the production process of an electric car and its battery is far more carbon intensive than the manufacturing of a combustion engine car. Also, transport efficiency for the society and driver might be slightly different than from an organisational perspective. Non-motorised modes like using freight cycles or to even walk with a freight cart the last kilometre in urban areas would require ample opportunity for employment from a societal perspective, but also provides exercise for the driver. In such a case the energy input from the driver's perspective might be partly viewed as a benefit rather than a cost, an output rather than an input. A study by the Postal office in Sweden and Denmark has shown that the drivers of non-motorised vehicles are more healthy and satisfied than their motorized counterparts (Ainson and Polyantseva, 2013). These modes also provide disadvantages like exposure to emissions for the drivers, slower speed, lower capacity, and security problems. Moriarty and Honnery (2012) state that in order for the concept of energy efficiency to have a meaning within systems designed to meet human and organisational needs, such as the freight transportation system, it must be defined as a ratio of the input energy to an output useful in some ways to humans and organisations. In conclusion, transport efficiency is not all about technical improvements, but also about behavioural and operational aspects; this is an observation that is starting to materialise among the operators for example via an increased focus on eco-driving.

## 2.5 Goal-setting perspectives

Goal-setting or target-setting for the reduction of carbon emissions has a range of various applications in transport and logistics operations. The motivations for the companies are usually cost reductions or for CSR reasons (McKinnon and Piecyk, 2012). McKinnon and Piecyk (2012) propose a carbon-reducing framework and describe different ways of implementing the targets: top-down and bottom-up targets. Most targets are intensity targets rather than absolute reduction of emissions, where most managers (all except one) interviewed by McKinnon and Piecyk (2012) feared that an absolute value would hamper the growth of their business. Also, the bonuses and KPIs are often related to financial targets rather than environmental improvements. This is why most targets use a relative measurement, a reduction of emissions in relation to a certain "normaliser".

Critics of these "relative tool driven" methods, like Rossi et al. (2006), argue that they shift the debate to the tool, the assumptions that are made, the data used, and the boundaries drawn, to name a few, rather than to the goals that are set and to how they will be achieved. The value of the tool is that it "informs ignorance", in that it provides (relative) data where none was previously available. To guide behaviours to specific ends, where the tools are in service of these ends, and to transparently evaluate progress toward these goals, Rossi et al. (2006) give examples of "goal driven" methods, like the Swedish 15 national environmental objectives that were created in 1999. Consequently, they defined intermediate benchmarks that were to be achieved within a single generation[3].

The next sections will try to give the reader a feeling for how other fields of research view efficiency and productivity. It begins with the Transport geography discussion about derived or induced demand, where the notion of derived demand can be seen as viewing efficiency in isolation, and the notion of induced demand as connecting efficiency with productivity over time.

[3] http://www.miljomal.se/Environmental-Objectives-Portal/

## 2.6 Transport geography perspective on efficiency – derived or induced demand

The idea of transport as a *derived demand* is a common notion, for instance in Anderson et al. (2005) – so common that it often does not entail an explanation. The basic idea is (e.g. Rodrigue et al., 2009) that a consumer buying a product in a store will most likely trigger a new product in its place; this in turn generates production, resource extraction, and transport. However, an unsold good can be stored on the shelf until it is sold, with a possible discount of the price of the good if it is not sold. Nevertheless, unsold capacity in a lorry cannot be stored and the amount of transport offered simply exceeds the demand for it at a given point in time (Rodrigue et al., 2009). It is difficult to match the demand with an equal amount of supply and vice versa. Most often companies would like to have additional capacity that they may sell for higher prices at times when the demand exceeds the supply. For freight as a derived demand, every part of the chain necessitates movements of raw materials to products on different modes:

> "Thus, transportation is directly the outcome of the functions of production and consumption."[4]

According to this derived demand viewpoint, transportation does not exist for the purpose of movement but rather to accommodate a need for a product to be moved from a place of production to a place of consumption. Using this view, the shorter route is preferred if two routes are available, because less transportation is ideal; however if the same type of thinking accounts for the total costs in an international setting, the answer might not be as simple. More transportation could be an outcome of a different viewpoint – *induced demand* – in which transportation costs are related to other costs and where efficiency might reduce costs. Standardisation is one of the tools used, and the containerisation of freight, as argued by Hesse and Rodrigue (2006), could be an example of this development in transportation. What happens if transportation and products become cheaper because of an efficiency improvement? Considering this question, it is important to take a deeper look at the relationship between productivity and efficiency.

Rodrigue and Hesse (2006) discuss derived demand and implicitly also discuss efficiency and growth (globalisation) in a "chicken and egg" manner, advocating the view on logistics as an integrated demand, both induced and derived, rather than just a derived demand. Does cheap and standardised transportation induce demand or do other factors affect the demand for products and therefore increase the demand for transportation? The basis of derived demand is that transport exists because it is a "spatially differentiated function of supply and demand and is thus considered to be 'derived' from other activities." Hesse and Rodrigue (2006) put it another way: "If transportation is a subservient function of other processes and exists as an outcome of the physical flows they generate" (p 503) why should researchers care? A derived demand is one of the core concepts in logistics that Rodrigue (2004) and Hesse and Rodrigue (2006) try to challenge. According to Hesse and Rodrigue (2006), global production networks are engines of efficiency and productivity that were expanded from existing production systems and were more regional from the onset. The rationale of these systems is quite simple: growth from which additional value is generated. They argue for the induced demand viewpoint, that a "greater importance be placed on distribution as a factor of production and

[4] http://people.hofstra.edu/geotrans/eng/ch1en/conc1en/deriveddemand.html.

consumption, as it is not a mere consequence of economic processes, but often a force actively shaping them" (Rodrigue, 2006, p 15). Moreover, "distribution should be considered as more than a space of flows, but also an economic process that adds value beyond mere transport costs" (ibid). On the notion of integrated demand, Rodrigue (2006) offers a possibility to view the concept as derived on an operational level, considering that it is a controversial topic. He calls it closely derived, when it is perceived as more imbedded in the process. He argues that, from an operational point of view, the concept of derived demand still holds. The interaction that takes place is the outcome of a process generating a surplus at the origin (supply), and this surplus is used (demand) to a destination, with an underlying operational use of modes, terminals, and distribution centers. Hesse (2008) continues this type of reasoning by suggesting a close integration between distribution via logistics and material management, where the induced transport demand of physical distribution and the derived demand of materials management are proposed to be the integrated demand of logistics, as also suggested by Rodrigue (2006). This means that distribution is derived from production and that these activities are shaped by distribution capabilities:

> "Production, distribution and consumption are therefore difficult to separate" (Hesse, 2008 p 6).

A common argument for proponents of transport as a derived demand is that transportation is not valued in and of itself, but as a means of reaching a destination. However, it is difficult to ignore that transportation constitutes a large proportion of GDP and the workforce and GDP and employment are considered to be important.

The point of the next sections is to further investigate the relationship between efficiency and productivity, as this seems to have been forgotten in the debate about freight transport efficiency in a sustainability context. However, it would be a misconception to believe that this link always nullifies any efficiency gains in terms of emissions, only that it is important to study this connection more carefully.

## 2.7 Business administration perspective on efficiency

Eliasson and Samuelson (1991), who studied performance measurements in the public sector define efficiency as a relation between output and input that is normally expressed in terms of financial value, although it can also be expressed in non-financial terms. Efficiency is how well the organisation is running its operations and the extent to which the greatest benefit can be obtained from a given amount of resources or, in other words, doing things right. According to Ax et al. (2009), a high degree of internal efficiency is often associated with a high degree of productivity and cost effectiveness. *Effectiveness* is defined as the level of goal completion, such as the extent to which the organisation is achieving these long term goals, or doing the right things. Measures of efficiency and effectiveness are often designed as specific ratios, but can be expressed as absolute values.

Another definition of efficiency is a company's economising with limited resources (Ax et al., 2009). They define efficiency as the "degree of fulfilling a goal" and the *degree* is a relationship between what has been accomplished in terms of value to what has been put into process, also in terms of value. They highlight a series of problematic aspects of efficiency:

1. Efficiency is not an objective term of how well a company performs its business. The degree of efficiency is decided in relation to a goal; if the level of the goal is decreased, efficiency is increased.

2. It might be difficult to determine if a company is efficient on its own merits only. An increase in efficiency might be due to an increase in demand or a technology change.

3. The company might have several goals that contradict each other. Profitability and high wages is one example of such a trade-off. Therefore, it is important to identify if several goals are present and if these goals are in line with each other.

4. The time horizon is important. Short term, the company might be able to "squeeze" the maximum amount of efficiency by using all resources. This might jeopardise long-term profitability, where development and renewability are important factors. Available resources in the short term are important, even though this means lower efficiency levels. The authors argue that the companies that value these factors are the most efficient in a long-term perspective.

These difficulties have made some come to the conclusion that it is impossible to establish a company's efficiency level. The company's ability to survive has been proposed as the ultimate level of efficiency (Ax et al., 2009). In terms of productivity, Ax et al. (2009) acknowledge the same relationship as efficiency, but what has been achieved (output) and the resources used (input) are discussed in terms of quantities and not in terms of value. All the examples given are with respect to a specific time period. However, they mention that the two concepts are closely related, but not exactly how they are related. Efficiency expressed in physical rather than financial terms is sometimes called productivity (Eliasson and Samuelson, 1991). Productivity is expressed as output divided by input, a measure that does not provide any useful information unless it is put into relation to productivity from another time period, company, or subdivision.

For a review of a business administration and production view on efficiency, the author recommends Sjögren (1996), who states that efficiency can either be a relative or an absolute measure. In quantitative or value terms, the difference between what is utilised and what is achieved is a measure of absolute efficiency. Relative efficiency is the ratio between resources used and production output. For the measure to make sense, it needs to be set in relation to a goal, and the choice of input and output varies depending on this goal.

For an analysis of the business administration view on efficiency, Sjögren (1996) points out that it usually has the goal of profit maximising. The assessment of input and output usually is in monetary terms. In the study of production processes, the term productivity is defined:

> "Productivity, which also can be called 'internal efficiency' (inre effektivitet), is the relationship (ratio) between what is physically produced and physically sacrificed" (Berg and Karsson, 1991, p. 97).

Sjögren (1996) highlights that no distinction is made between productivity and efficiency in an analysis of a production process. Bohm (1986) explains that the difference between business administration efficiency and efficiency on a societal level is that the latter takes all individuals' preferences into account. He also points out that these two efficiencies are not necessarily the same in all instances.

One of the core features of companies is the strive for efficiency (Coase, 1937) and few companies are self-sufficient in terms of their resources. So far, theories from different areas have been used to demonstrate a critical perspective on transport efficiency. A reason for this approach may lie in the definition of business administration. Different ideas about efficiency from a business administrative perspective are presented below, along with a few definitions of BA. It is interesting to critically analyse a concept through the lens of a topic area that axiomatically assumes something ambiguous without further ado:

> In business, administration consists of the performance or management of business operations and thus the making or implementing of major decisions. Administration can be defined as the universal process of organizing people and resources efficiently so as to direct activities toward common goals and objectives. (Business Administration, Wikipedia retrieved 2010/11/12, a revisit to the topic site in 2013/03/03 the topic site has been reported as outdated and is generally quite messy, however the gist of the definition above is still the same)

There are numerous ways to define business administration; one definition presented by Brunsson, 2010) defines BA as "the management of organisations." Fournier and Grey (2000, p. 17) propose a series of criteria, one of which is presented here to show the difference between critical and non-critical management studies. First, they suggest that critical management studies are not governed by principles of efficiency and productivity, at least not if subordinating knowledge. They do not try to contribute to "the effectiveness of managerial practice and organisations." The use of power, control, and inequality usually means some sort critical approach, whereas efficiency, effectiveness and profitability do not (Shenhav, 2009). These actions lead to means-ends calculations where the focus is on the means, with little attention to the ends (Spicer et al., 2009).

Another way of looking at efficiency is through organisational efficiency and effectiveness (Pfeffer and Salancik, 2003). They define the effectiveness of an organisation as its ability to create acceptable outcomes and actions. How well an organisation meets the demands from actors that are concerned with its activities is an external standard. Organisational efficiency is an internal standard of performance. The question of what is being done is not posed, merely how well it is performing. Efficiency is relatively value-free and is measured as the ratio between utilised resources and production output. It involves doing things better than what is currently performed. External pressure on the organisation is often expressed in terms of doing things more efficiently. Borgström (2005) refers to Pfeffer and Salancik when she concludes that efficiency has changed from an internal measure used to find waste to a measure of goal fulfilment. She concludes that efficiency is the internalisation of effectiveness, which is related to Liljegren's notion (1988) that efficiency is an operationalisation of effectiveness, which in turn is a co-creation of goals.

> "No one can be found who will deny that in the case of any single individual the greatest prosperity can exist only when that individual has reached his highest state of efficiency; that is, when he is turning out his largest daily output." (Taylor, 1911, Chapter 1)

In marketing, Alderson 1954 pinpoints the same problem as Sjögren (1997), Lumsden (2006), and Ax et al. (2009). Any efficiency measure in performance must start from job specifications. If the job, which the marketing system is supposed to perform, is not defined it is difficult to measure it. A crude measure of efficiency is how much of a customer's dollar makes up the marketing channel. Despite an improvement in marketing efficiency, this figure could go up, such as if production costs decrease faster than marketing costs. At a quick glance, one may come to the conclusion that marketing has become less efficient, yet in reality the decline in production costs might even be due to implementing innovative marketing strategies.

## 2.8 Operations management and logistics perspective on efficiency

Operations management and logistics are usually considered a part of business administration, but in this instance these areas are divided in order for the reader to get a more comprehensive view of different perspectives of efficiency, as well as the relationship between efficiency and productivity. One could say that the two are merely two sides of the same coin. Skinner (1969) argues that many managers focus on "total productivity or the equivalent, efficiency". According to Skinner, they seem to seek a combination of "low costs, high quality, and acceptable customer service". If this is the case, the company is a good company and will perform efficiently. He continues with bringing up trade-offs and asking, "but what is a good plant and what is efficient performance?"

From the field of operations management, Stevenson (2001) views efficiency as a tool to improve productivity, but efficiency should not be confused with productivity, according to him. Efficiency is a more narrow concept that "pertains to getting the most out of a fixed set of resources; productivity is a broader concept that pertains to effective use of overall resources". According to Stevenson (2001), productivity is usually expressed as a ratio of output to input. He also claims that measuring productivity is more straightforward in manufacturing due to the high degree of uniformity. In service operations, variations in requirements and demand intensity, from one job to another, make measurement considerably more difficult. As an example, consider the productivity of two doctors during a day. One has a vast number of routine cases whilst the other does not, resulting in a difference in productivity. Heizer and Render (1999) define productivity as the ratio of outputs (goods and services) to inputs (resources, such as labour and capital). The creation of goods and services requires changing resources and "the more efficiently we make this change the more productive we are" (ibid, p 16). The job of the operations manager is to improve this ratio, where "improving productivity means improving efficiency" (ibid, p 16). Chase et al. (2006) defines efficiency as "doing something at the lowest possible cost." Later they define it as a ratio of actual output of a process relative to some standard, or to measure the loss or gain in a process. They also recognise productivity as being a relative measure. Lumsden (2006) defines efficiency as the degree of fulfilment to a certain goal. Chase et al. (2006) and Mentzer and Konrad (1991) define efficiency in a logistics performance context as "[a] measure of how well the resources expended are utilized" (p 34) and "the ratio of resource utilized against the results derived" (ibid). According to Caplice and Sheffi (1994), there is no need to create new metrics because the critical elements of logistics management remain the same: time, distance and money. Samuelsson and Tilanus (1997) formulate the efficiency dimensions as time, distance, speed, and capacity. Caplice and Sheffi (1994) propose a series of ratios as indicators for performance measurement in logistics. These logistics metrics were later reworked by McKinnon (2004) and proposed as a base for transport efficiency measures. The three types of logistics key indicators are:

1. Utilisation, which measures input usage and is usually expressed as a ratio of the actual input of resources to a norm value.
2. Productivity, which measures transformational efficiency and takes the form of output/input ratios.
3. Effectiveness, which measures the "quality of process output" as a ratio of the actual quality achieved to some norm.

McKinnon and Ge (2004) springboard from these types when constructing a series of indicators together with senior managers of manufacturing, retailing, and logistics firms: vehicle loading, empty running, fuel efficiency, vehicle time utilisation and deviations from schedule. The first three indicators are utilisation measures, the fourth is a productivity measure and the last assessed the effectiveness of the delivery operation. These measurements were constructed to measure the effectiveness in a food supply chain in the U.K. Several restrictions in this structure were mentioned; the indicators were constructed to measure operational, rather than commercial performance due to a lack of an accounting of costs from the study participants. The main goal for green logistics should be to decouple economic growth from freight-related externalities, rather than the growth of transport work (McKinnon et al., 2010) by affecting the parameters above. Similar ratios are also presented in the REDEFINE (1999) project: value density, modal split, handling factor, average length of haul, vehicle carrying capacity, load factor, and empty running. The same report presents a series of options for reducing road freight transport or its externalities. Such as to reduce transport intensity, modal shift, increase efficiency, better vehicles/fuels, better use of vehicles. All this, as an attempt to decouple economic activity and $CO_2$ emissions in road freight transport, as also proposed by the Commission (CEC, 2001a, 2001b). Moreover, Samuelsson and Tilanus (1997) define efficiency as ratios, fractions, or percentages. They describe transport efficiency as being a subset of supply chain efficiency, where supply chain efficiency is not only focused on "transformations of place" transportation, but also as a transformation of time (storage) or form (assembly). They point out that starting points will have to be developed in the future for these other efficiencies. Supply chain efficiency should be seen in a greater context; different actors might have objectives that conflict with one another.

Caplice and Sheffi (1994) define a series of metrics useful when producing performance measures, but also outline the objective of the manager in the transport function. The overriding objective of the manager is to "maximize the output (in terms of quantity, quality, or both) while minimizing the input consumed". The transport function is often modelled as converting labour, equipment and other resources into tonne km. The prime objective of the transport manager is to produce the requested tonne km to a certain service level at the lowest possible cost, (ibid, p 18). Caplice and Sheffi (1994) also elaborate on the definition of productivity, as defined by the National Commission on Productivity as "the return received for a given unit of input" (ibid, p 18). They also note that among managerial accountants the term has been so popular, and misused, that it is now equated with efficiency, effectiveness, work measurement, cost reduction, program evaluation, and most any other related concept.

"Productivity measures capture the efficiency of a process" (ibid, p 22).

McIntyre et al. (1998), on the contrary, stress the importance of not focusing too much on performance measurements unless they incorporate a more long-term point of view. In the article, they analyse and debunk more than twenty different researchers' and professionals' suggestions of how to "green" the supply chain. Most techniques were found to be time and cost focused, centring on "financial climate change." This approach tends to promote a short-term perspective. They further argue that work on greening the supply chain benefits from a more long-term perspective. These two mind-sets seem to diverge, developing in different directions, and this is rather worrying from an environmental point of view. The suggestion is to amalgamate both perspectives so that the long-term is represented in performance measurement.

Performance measurements ratios in logistics reflect an accounting or management-science orientation for identifying inputs of some form with outputs in another form. Mentzer and Konrad (1991) put forward one problem with using ratios in this respect—the measures do not measure all the aspects of the actual inputs and outputs. For example, waiting for a vehicle to leave the terminal until the vehicle is full may improve the utilisation efficiency, but the measurement will not disclose the damage done to customer service. Customer service measures in turn would not reveal the anger of a customer over the delay, or depict the potential future loss of customers or orders. These measures are by definition fragmented and represent only a part of the reality. If these flawed measures are used for decision making, it is important to establish and select these measures carefully. Mentzer and Konrad (1991) state that it is not sufficient to measure efficiency alone and they make the following argument to support the statement: if a goal is partially achieved, the effort is only partially successful regardless of whether the portion achieved was done so with prudence with respect to resource utilisation. Therefore, performance is the sum of effectiveness (where the goals are incorporated in terms of outputs) and efficiency (incorporating inputs), where the evaluation of the overall process is needed to merge these two measurements.

## 2.9 Economics perspective on efficiency

A more efficient use of resources is one of the fundamental issues when sustainable development is discussed in research and society. However, efficiency may also have a rebound effect that may oppose the efficiency aim, a tendency to increase emissions in some cases. This is a dilemma that science and society has to take into account when discussing efficiency.

The rebound effect is commonly described by economic literature as a counterbalancing effect on the conservational results expected by the evolution of more efficient technology (Saunders, 1992; Sanne, 2006). It was postulated for the first time in 1865 by William Stanley Jevons in his book, "The Coal Question," as a response to the new steam engine that was fuelled by coal. He proposed that the innovation would make coal more cost effective as a power source and lead to an increase of the use of steam engines in a wide variety of industries. This would increase total coal consumption, even though—and because—the amount of coal needed per unit work fell. He argued that every additional increase of efficiency of the steam engine would increase the coal use, and would thus increase the rate of depletion of England's coal deposits (Jevons, 2001; see a thorough historic review in Alcott, 2008). While Schipper and Grubb (2000), Schipper et al. (1996, 1998), and Barker and Foxon (4CMR, 2006, 2008) argue that the rebound effect is small, and they did not find any substantial rebound effects when comparing energy use over time, however, Barker et al. (2009) show larger rebound effects.

Today, in the discussion pertaining to the rebound effect, efficiency and growth regards the size of the total rebound. Is the size large enough to speak against efficiency as a resource-saving strategy? What happens with the energy saved by efficiency strategies? The total rebound is the sum of three parts. 1) direct rebound in transport, constituting the amount of increase in driving or purchase of transport services after an efficiency increase that might induce a price drop. 2) Indirect rebound, an income effect. 3) Macro-economic rebound, if the price adjustment is significant, more competitors might enter the market. Altogether, these different parts are called economy wide effects. If the direct effect is limited (less than unity) the lowered price also leads to a possibility of spending money on other products. A transport operator might decide to use the saved money to invest in other activities that might in turn generate a need for transport. If the direct effect is around unity, the indirect effect can be expected to be small and vice versa. Nearly all consumption leads to transport and saving could be merely delayed consumption. A serious problem in trying to resolve the debate is that it is futile to run control experiments in order to see the changes in energy use, with and without the efficiency improvement; after all, Herring (2008) concludes that there is only one past.

For more on the rebound effect see: Saunders (1992), Sanne (2006), Jevons (2001), Alcott (2005, 2008), Schipper and Grubb (2000), Schipper et al. (1996, 1998), Barker and Foxon (4CMR, 2006, 2008), Barker et al. (2009) and Herring (2008), as well as the forerunners Khazzoom, Brookes and Jevons. Everything boils down to the use of "elasticities," even in the macro rebound debate, according to Berkhout et al. (2000) and Dimitropoulos (2007), as concluded by Ruzzenenti and Basosi (2008, p. 3627).

Estimates of the size of efficiency rebound vary wildly from nearly zero (Lovins, 1988) to partly significant (Grubb, 1990; Von Weizsäcker et al., 1998; Howarth, 1997; Greening et al., 2000; Schipper and Grubb, 2000; Allan et al., 2006; and 4CMR, 2006) to greater than 100 per cent, what is normally called "backfire" (Jevons, 2001; Brookes, 1990, 2000; Greenhalgh, 1990; Giampietro and Mayumi, 2000; Rudin, 2000; Hanley et al., 2006; Herring, 2006). Further information can be found in Alcott (2008). Whether rebound is greater or less than unity is a matter of debate. Also, the earliest reference used in this presentation is from 1988 and the newest is from 2006.

The efficiency strategy theory holds that higher efficiency causes less resource consumption. Turning this argument around, lower efficiency would theoretically raise consumption. Therefore, whatever it is that explains consumption's rise must be strong enough to overcome this "shrinkage effect" of greater efficiency[5]. Machine work is one of the greatest contributors to enhancing labour productivity; it is made more economical through the use of energy efficiency (Ayres and Warr, 2005). In nearly all new products, machinery, processes, or material there is almost always a preceding efficiency improvement as an economical catalyst. Efficiency improvements are rarely pure, as many efficiency advocates commonly note (see Lovins, 2005). These improvements often come with simultaneous improvements in the productivity of other factors of production, multifactor productivity, as concluded in UKERC (2007).

[5] Most energy efficiency strategies, especially in the private sector, account for pure losses rather than economic feedbacks, such as energy efficiency in buildings from the use of isolation. These types of efficiencies are not part of this analysis since they deal with squandering to a greater degree rather than feedback mechanisms.

For more info on rebound and elasticities, see: Greene et al. (1992, 1999), Jones (1993), Haughton and Sarkar (1996), Small and Van Dender (2006) and Nässén and Holmberg (2009) for private transportation and for freight transportation; AEA (2008), Graham (2002, 2004), Graham and Glaister (2002), Beuthe et al. (2001), Bjørner (1999), Winston (1981, 1983), Maibach et al. (2008, p. 31), De Jong et al. (2004, 2010), Fiorello (2008), Graham and Glaister (2002), De Jong (2001), Hemery and Rizet (2007), Hanly, Dargay, Goodwin (2002), Johansson and Schipper (1997), Goodwin et al. (2004), and Stopford (2009).

## 2.10 Examining drivers of output and demand in a transportation context

So far, this paper has presented different views and interpretations of efficiency and transport efficiency. A potentially dangerous conclusion, a "regime of truth" as Foucault (1980) puts it, would be that transport efficiency is an inducer of demand in transportation through cost reductions or, worse still, the only inducer of demand. This is simply not true. This section will elaborate on other potential drivers (or non-drivers) of productivity in a freight transportation context and show one problem with linking productivity with demand increase through price.

McKinnon et al. (2010) present a detailed overview of research conducted on the potential drivers (and non-drivers) of freight traffic growth. A series of factors or trends are presented in relation to restructuring the logistics system (McKinnon and Woodburn, 1996; McKinnon, 1998; Cooper, 1998). They also state that applying cost efficient improvements does not always lead to a lower environmental impact, and they provide the lack of internalized cost of externalities as an argument. The cost and service trade-offs generally underestimate the environmental effects. "The resulting decisions may optimize logistics operations in economic terms to the detriment of the environment" (2010, p. 15). Drewes Nielsen et al. (2003) and McKinnon, (1998) indicate that the restructuring of production and distribution systems influence the amount of lorry traffic much more than the goods in the economy or changes between transport modes. More specifically, a range of other studies have studied some of the logistics system restructuring in detail with the conclusion that the environment might lose on implementation of centralization (Matthews and Hendrickson, 2002), just-in-time (Whitelegg, 1995), growth of geographical areas of interaction, spatial distribution or globalization (Hesse and Rodrigue, 2004; Rodrigue, 2004; Vanek, 2001) and standardisation (Rodrigue, 2004). Other studies have concluded the opposite—centralization leads to an increase in transport work but it also opens up a possibility for a modal shift, especially in the consolidated inbound flows (Kohn and Brodin, 2008) and just-in-time does not induce logistics costs (Tracey, 1995). Aronsson and Huge Brodin (2006) argue that strategies such as standardisation and centralization might not be drivers of growth of emissions in transportation.

There are numerous other macro factors than those presented above that play a part in greater energy consumption in transportation, such as rate of consumption, income increase, labour efficiency increase, new energy sources, population increase, the elimination of trade barriers, etc. An argument against linking cost reducing efficiency measures to increases in productivity and demand is that the transportation market could have features of market failures and barriers—a low priority of transport in general, split incentives, asymmetric information and the existence of externalities. In markets with these characteristics, cost reductions for one actor might not translate to reductions in price of the transportation service, at least not in the short term. If demand is considered fixed, sustainability could be argued to increase with efficiency.

## 2.11 Implications from theory

From a transport operator's perspective, many measures can be affected at a daily operational level, not just by tactical and strategic measures like customer demands. Many of the efficiency measures analysed in this thesis possess characteristics of affecting or affiliating to other levels, tactic and strategic. Sometimes an operational measure for one actor might be considered strategic from the perspective of another actor. For example, from a transport buyer's perspective, a modal shift could be seen as an operational measure (Aronsson and Huge Brodin, 2006), but from a transport operator's perspective, running a single modal lorry service is more of a strategic issue. If the operator decides to increase the service, by offering a multimodal service, the act of offering either of the two becomes operational and part of the daily routine. To clarify in the context of this thesis, *operational* refers to the measures the operator can affect in daily operations with available resources and in close proximity to these operations, alone and with other actors, without changing the structure of the transport system to a greater extent.

Transport efficiency could be argued as being a *fuzzy concept*. In short it means that it is not clearly defined and has multiple meanings, depending on whom you ask. Transport efficiency can be vague, but it does have meaning and definition that can vary depending on what actor you ask in the logistics system, ranging from simply encompassing eco-driving for some transport operators to a wide array of measurements as concluded by researchers, policy makers, and some transport buyers (see Paper 1). Another problem with fuzzy concepts is its lack of clarity and difficulty in measuring its effect, to operationalize it, as Markusen (1999) puts it. One of the goals is to reduce fuzziness in the fuzzy concept—transport efficiency—with the aim of attaining more certainty and knowledge of the concept by approaching it curiously, cautiously and critically from different directions. In this sense the concept could also be argued as being a *wicked problem* in a policy context, as well as for the transport operator, at least as long as transportation is predominantly high in carbon use. This is also suggested to invite the social dimension into the analysis. According to APSC (2007), a wicked problem is difficult to define, has internally conflicting goals, the nature and extent to which the concept applies is different, and is depending upon which stakeholder one asks. Usually these problems do not have clear solutions. The solutions are often "better or worse" or "good enough", rather than verifiably right or wrong. Furthermore, these problems are usually socially complex, not just technically complex. Solutions proposed by literature often include coordinated action from many stakeholders.

> In terrain which is politically contested, in which the resources to address difficult human issues are necessarily finite, there are rarely clear questions, let alone easy answers. Progress is nearly always marked by consultation, discussion, negotiation and iteration. (Australian Secretary of the Department of the Prime Minister and Cabinet, in APSC, 2007, p 17)

According to the same report, these problems are usually imperfectly understood and therefore it is important to approach them engaging in a discussion with all relevant stakeholders in order to ensure a full understanding of the complexity. The proposed changes cannot be imposed upon the stakeholders, but should be widely understood, discussed, and owned by the stakeholders that are affected by or targeted for change. Some argue that studying social complex problems is to be something to partly avoid (Silverman, 2001). Silverman also argues that "[it] can offer participants new perspectives on their problems" (ibid, p. 16) and he continues with a phronetic sentence, "[may be] able to contribute to the identification both of what is going on and, thereby, of how it may be modified in pursuit of desired ends" (ibid, p. 16).

As already mentioned, I argue that transport efficiency is related to energy efficiency – both could be seen as a union of two sets. Most transport efficiency measures have an element of energy pertaining to these measures, but there are discernibly energy efficiency measures that are not related to transportation and transport efficiency measures that are not directly related to energy efficiency (for further elaboration and examples see section 2.4 Energy efficiency or transport efficiency?). As has been shown, there are different definitions of what efficiency and productivity are, as well as how they relate to one another.

It is important to mention that many of the quotes from the theory section are from literature from the end of the past century, and the environment was not on the agenda to the same extent as it might be today. Today the message is somewhat more multifaceted. According to one report made by the EEA (2008), the concept is shown not to be so simple, while at the same time it paints a graphic picture of the duality of efficiency in transport:

> "[Governments] could improve the transport efficiency of the economy, effectively decoupling transport growth from economic expansion" (Transport at a crossroads TERM, 2008).

While the message is dialectically different later in the same report:

> "Freight transport activity has grown faster than the economy during most years of the last decade. Freight transport growth can be attributed to improved transport efficiency[!]..." (ibid, 2008).

The European Commission (2009) states that transport is closely related to the rest of the economy and transport demand is closely linked to economic growth. "Transport allows competition and, through it, it fosters competitiveness and innovation, and facilitates economic growth" (ibid, p 6). It somewhat ambiguously states in a section on urban sprawl that "urban quality and efficiency are key variables for economic growth as for compliance with the requirements of sustainable development" (ibid, p 15).

The Economist recently published a series of articles on an important transport efficiency measure, containerisation[6], stating that containers have been more important for globalisation than free trade. The Economist includes a study by Bernhofen et al. (2013) on a set of 22 industrial countries, which outlines that containerisation accounts for a 790 per cent increase in trade over 20 years, whereas a GATT membership adds 285 per cent.

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[6] http://www.economist.com/news/finance-and-economics/21578041-containers-have-been-more-important-globalisation-freer-trade-humble

http://www.economist.com/blogs/economist-explains/2013/05/economist-explains-14?fsrc=scn/fb/wl/bl/ee/containers

To sum up the literature on productivity and efficiency, productivity usually focuses on the numerator/output and could be defined as the amount of output in relation to the input that can be produced in a specific time period. Efficiency usually focuses on the denominator/input and is commonly defined as the input used relative to the value/quantity of output, or a goal. Figure 4 is an attempt to explain the differences between productivity and efficiency; it is an extrapolation of the validity and reliability pictorial presentation. Note that a problem arises when the goal (middle) is not the same, as can be the case when environmental goals sometimes do not align with economic goals, as suggested by McIntyre (1998) or when social goals do not align with environmental goals, as suggested by Thynell et al. (2010) (see paper 4 for further details). How should the "norm value" be chosen? What is the best practice frontier? As an example, let us use the presentation for two transport operators. The first target could be seen as an operator who manages many lorries with goods travelling to various locations. Unfortunately, the goods are not delivered on time despite a generous time window, the lorries are not full, the vehicles used are old, the trip length is longer than necessary, and the driver is not educated in eco driving. The second target could be a lorry operator who has extensive eco driving training, modern lorries fit for the transport purpose, uses a routing software, and makes sure the vehicles are as loaded as possible without making unnecessary detours In general, performs a service that the customers are satisfied with by utilising the available resources in a sound manner.

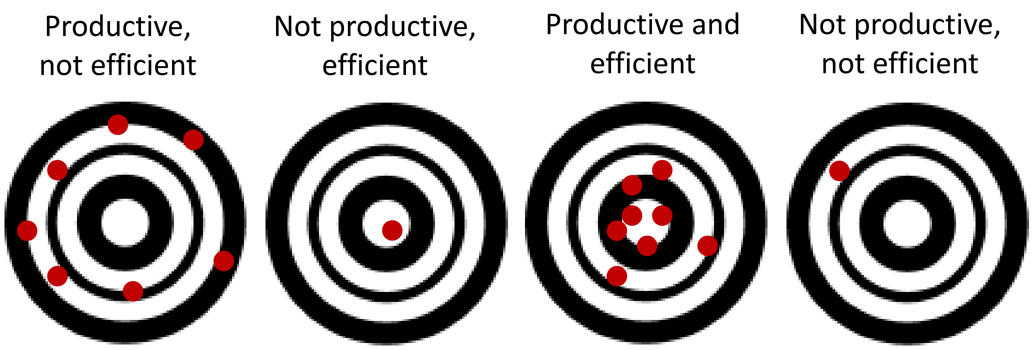


**Figure 4 A pictorial presentations of the differences between efficiency and productivity.**

To conclude this section, let us look at Figure 4 in relation to Table 2, which is a summary of some of the researchers' definitions of efficiency, productivity and whether they acknowledge a relationship between the two. What if there is no middle (goal) in the targets above? Or, what if the middle is divided in two, spatially separated, goals? Where should one aim? Clearly, one cannot speak of efficiency as a goal of itself. One can be efficient in working for a bad end just as well as in working for a good one.

**Table 2 Researchers different definitions of efficiency and productivity and possible links**

| Researcher(s) | Efficiency as described in the article/book | Productivity as described in the article/book | Relationship between efficiency and productivity |
|---|---|---|---|
| Taylor (1911) | Largest daily output | Prosperity/Output | + |
| Alderson (1954) | A tool to achieve productivity | Is meaningless without a job description | + |
| Mentzer and Konrad (1991) | [a] measure of how well the resources expended are utilized | | |
| Bohm (1996) | Difference between business administration efficiency and efficiency on a societal level is that the latter takes all individuals' preferences into accont. | | |
| Berg and Karlsson (1991) | | 'Internal efficiency'. Ratio between what is physically produced and physically sacrificed. | |
| Eliasson and Samuelsson (1991) | A relation between output and input. How well the organization is running its operations and the extent to which the greatest benefit can be obtained from a given amount of resources or doing things right | Efficiency expressed in physical rather than financial terms is sometimes called productivity | |
| Caplice and Sheffi (1994) | | "The return received for a given unit of input". Productivity measures capture the efficiency of a process | + |
| Sjögren (1997) | A relative or absolute measure that needs to be set in relation to a goal. The difference between what is utilized and what is achieved is a measure of absolute efficiency. Relative efficiency is the ratio between resources used and production output | No distinction is made between productivity and efficiency (for a production process) | + |
| Samuelsson and Tilanus (1997) | Efficiency dimensions are: time, distance, speed and capacity | | |
| Heizer and Render (1999) | "A measure of actual output over effective capacity." "Improving productivity means improving efficiency" | The ratio of outputs (goods and services) to inputs (resources, such as labour and capital) | + |
| Stevenson (2001) | A tool to improve productivity. Efficiency is a more narrow concept than productivity that "pertains to getting the most out of a fixed set of resources" | "Productivity is a broader concept that pertains to effective use of overall resources… usually expressed as a ratio of output to input" | + |
| Waters and Waters, (2002) | Is the ratio of actual output to possible output | Is the amount produced in relation to one or more of the resources used | + |
| Pfeffer and Salanicik (2003) | Organizational efficiency is an internal standard of performance, value free and the ratio between utilized resources and production output. | | |
| Borgström (2005) | Changed from an internal measure used to find waste to a measure of goal fulfilment | | |
| Chase et al. (2006) | "Doing something at the lowest possible cost." Also a ratio of actual output of a process relative to some standard or to measure the loss or gain in a process. | Ratio of output to input | |
| Greasley, (2006) | The amount of time a process is in use compared with its effective capacity | Divides the value of the output by the value of the input resources consumed | |
| Lumsden (2006) | The degree of fulfilment to a certain goal. | | |
| Ax et al. (2009) | Degree of fulfilling a goal. A company's economising with limited resources. A company's ability to survive has been proposed as the ultimate level of efficiency | Close relationship with efficiency, but what has been achieved (output) and the resources used (input) are discussed in terms of quantities and not in terms of value. Productivity is expressed as output divided by input, a measure that does not provide any useful information unless it is put into relation to productivity from another time period, company or subdivision. | + |

*"Any job that involves interaction with other people is moral work, and all moral work depends on practical wisdom"*
*Barry Schwartz (TED.org), "On our loss of wisdom."*

*"In modern society there is no other leadership group but managers. If the managers of our major institutions, and especially of business, do not take responsibility for the common good, no one else can or will." Peter Drucker (1973)*

# 3 Methodology

Logistics and transport research has traditionally been dominated by the natural sciences and quantitative-based economics. Logistics research has no discipline of its own, and it could be argued that it includes the application of research inspired by different traditional disciplines, according to Thomsen et al. (2005) and Solem (2003). This development through multidisciplinary studies call for the use of a wide variety of research methods (Carter et al, 2008), for a purchasing context (Dubois and Araujo, 2007), and for an operational context (Meredith et al., 1989). Methodological choices cannot be divorced from theoretical points of departure, as highlighted by Dubois and Araujo (2007). Coming from a purchasing background, they argue that theories are not method neutral; often theoretical approaches are developed in conjunction with method and not independent of theory. Meredith et al. (1989) present a generic research framework (Figure 5), which also shows the close relationship between critical theory and phronesis (≈interpretive). In this context, Popper can be viewed as pertaining to the rational dimension, and Flyvbjerg and Alvesson as more to the existential dimension. Phronesis, as explained in this section, is argued to be a methodology in the sense that it is a problem-driven approach, but also an ontological position and even a viewpoint.

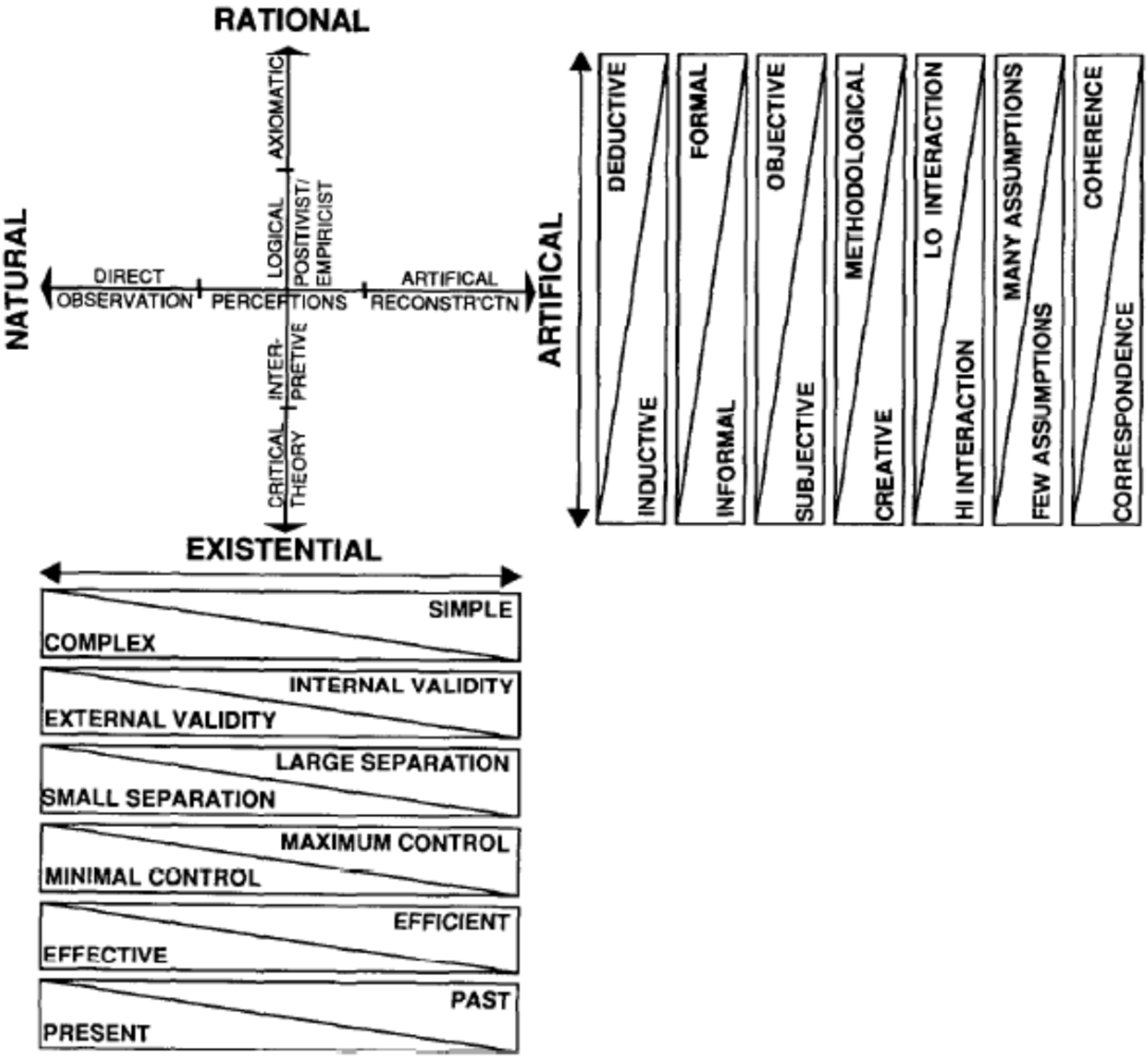


**Figure 5 A generic research framework Meredith et al. (1989).**

Croom et al. (2000) argues that logistics research has a relative lack of theoretical work compared to other areas and to the amount of empirically-based studies (Figure 6). A concern is the lack of a significant body of a priori theory, a point that Cox (1997) argues. This is also supported by Vafidis (2007, p. 181), who concludes that many of the most cited authors are not logisticians, reinforcing the argument that the logistics discipline lacks strong theoretical foundations and is very much an applied discipline with much of its roots in other areas. The idea that this research area is mainly empirical-descriptive makes the argument that a theoretical development is crucial to the establishment and development of logistics or supply chain management studies. The authors stress that their intention is not to state that empirical studies are valueless. As Flyvbjerg (2001) stated, the “both and” perspective rather than the “either or” could be preferred. The analysis of the supply chain literature made by Croom et al. (2000) highlights contrasting themes, and this constitutes a great challenge for the field. They continue to argue in line with Thomsen (2005) and Holmberg et al. (2009) recognizing that developments in our understanding of supply chain management require a multidisciplinary perspective in order to address these contradictions and to explore the subject from a multitude of perspectives. Specific theoretical schools or disciplines mentioned in the article are transaction cost economics, inter-organisational theory, systems thinking, information technology, industrial dynamics, production economics, social theory, production engineering, marketing, and strategic management. The same recommendations are put forward by Stock (1995), who suggests using theories from philosophy of science, psychology, organisational behaviour, consumer behaviour, political science, sociology, geography, economics, and management, proposing the argument that logistics is a boundary-spanning activity in practice and should also be so in theory. Lammgård (2007) reasons along the same lines and suggests applying marketing, purchasing, and environmental management in a logistics context. It is therefore important for researchers to be aware of complementary studies outside their own field of expertise. Perhaps as Dietrich (1994) pointed out, a future development of theory may require and benefit from a *cosmopolitan approach* that incorporates a wide range of contrasting technical and social disciplines. Vafidis (2007), who made an empirical analysis of Swedish and Finnish logistics dissertations between 1994-2003, argues that logistics research remains in its infancy and at a rather scattered stage. He goes on to describe how research documents appear to be more like individual reports, rather than an accumulation of a knowledge-creation and methodological tradition offering two orientations to choose from: either a disciplinary orientation with a focus on disciplinary contribution and academic discussion, or a practitionary orientation with a focus on practical contribution and practionary discussion. With respect to this divide, Holmström et al. (2009) ask the question; "What makes a theory practical, and how are practical theories generated?" They argue that this question is critical by the "boot in the face" argument that, at least for the field of operations research, it is not quite clear whether anything would change in practice if all of the Operations management academics suddenly disappeared. It is very possible that this scientific community has a skewed view of its relevance to practice, according to Holmström et al. (2009).

| | PRESCRIPTIVE | DESCRIPTIVE |
|---|---|---|
| THEORETICAL | 6% | 11% |
| EMPIRICAL | 27% | 56% |

**Figure 6 Framework for classifying literature according to the methodology oriented criterion, (Croom et al., 2000).**

According to Frankel et al. (2005), research methods are merely a tool to solve a specific problem. They conclude that if we would like to develop and test new theories in logistics, we should start by questioning our paradigms and methodologies, continuously debating them with open minds. The following section is inspired by Flyvbjerg's recommendations in producing phronetic social science. Flyvbjerg himself, now a professor at Oxford University, has performed research in the area of logistics, city planning and sustainability. In his book, "Making Social Science Matter: Why Social Inquiry Fails and How It Can Succeed Again" (2001), there are many similarities with this research within "Sustainable Logistics." The section consists of three parts. First, there is an introduction to phronesis, followed by a brief exposition of case studies, and finally an account of how the papers have been constructed.

Flyvbjerg starts out by stating that the war between the sciences, natural and social, is unnecessary. They both complement each other. Where social science is weak in explanatory and predictive theory, natural science is stronger. In terms of reflective analysis and discussion of values and interests, social science could be argued to be stronger.

> "Where science does not reach, art, literature and narrative often help us comprehend the reality in which we live" (Flyvbjerg, 2001, p 18).

He also uses the hermeneutic-phenomenological argument, stating that the fundamental difference between the sciences is that natural science studies an object while social science studies self-reflecting humans and must therefore take into account the changes in interpretations of the objects of study. Or put another way, in social science the object is a subject. Flyvbjerg argues that "the problem for social science is that the background conditions change without the researcher being able to state in advance which aspects one should hold constant in order for predictions to continue to operate" (p 45). In this respect and for constructive reasons it could be worth mentioning similarities with action research, participatory action research, action innovation research, design science, academic-industry partnerships (like the Marie Curie IAPP), or as Holmberg et al. (2009) state: "the common goal in all these endeavours is the same: the researcher is interested in developing "a means to an end, an artefact to solve a problem".

## 3.1 Introducing phronesis

Greek philosopher Aristotle distinguished between three intellectual virtues. These are *episteme*, or knowledge production based upon analytical rationality; *techne*, or concrete activities according to practical rationality; and *phronesis,* which stands for context-dependent, practical common sense based upon ethics or practical wisdom—the moral will and skill to figure out what is better or worse. Therefore, phronesis emphasizes values, prudence and what is better or worse for humans as the starting point for action. For Aristotle, phronesis was the most important of the three virtues and thus the all-important basis for social and political praxis (Flyvbjerg, 2001). The key properties of phronesis that are particularly valuable for social science are its emphasis on value-rationality and its embrace of context and focus on power relations. This has important implications for finding a ground on which social science's mission could be redefined and action taken. Ghoshal (2005) also mentions how it is not only morality that has been a victim of this endeavour of business academics to make management a science (see critical theory section), common sense, too, has suffered. It is to this loss of wisdom of common sense that Campbell (1988) refers to when providing numerous examples of how the application of social theories led to poor public policy decisions in the United States. Along the same lines, Rorty (1991) proposes his alternative look at science, to see it as solidarity. He advocates that science should seek to look for what is "sane or reasonable" instead of what is rational or methodological.

Phronetics is concerned with both understanding and explaining. Social scientists tend to generate either macro-level or micro-level explanations, often ignoring the critical connections. Instead of research that attempts to link macro-level factors such as structure, scholars dichotomise with micro-level actors' choices in different settings. Flyvbjerg argues that structural analyses and studies of actors each get their share of attention, but often in different projects by different researchers. This is likely not the case in the logistics project the author is currently affiliated to, where actors in the logistics system, the connection between them, and the logistical structure in general are studied.

Phronetic research is “dialogical,” as Flyvbjerg puts it, in the sense that it includes a multitude of voices, not one voice claiming final authority. The goal is to produce input to the on-going social dialogue and praxis in society, rather than generating verified knowledge, this approach can be compared to Vafidi’s (2007) disciplinary or practitionery contribution and Holmström’s (2009) problem-solving-oriented design science research approach. On objectivity, the more techniques one uses for observing a particular thing, the more complete our concept of that thing will be. Objectivity in phronetic research is not “contemplation without interest,” but employment of a variety of perspectives and affective interpretations in the service of knowledge. The result of phronetic research is a pragmatic interpretation of the practices studied. Phronetic research is an analytical endeavor, not a theoretical or methodological one.

> Phronetic social science explores historic circumstances and current practices to find avenues to praxis. The task of phronetic social science is to clarify and deliberate about the problems and risks we face and to outline how things may be done differently, in full knowledge that we cannot find ultimate answers to these questions [...]. (Flyvbjerg, 2001, p 140)

In this section, this thesis has attempted to contribute to the scientific conversation. It also offers an operational suggestion of how things could be done differently.

## 3.2 Case studies

A case study is an empirical inquiry that investigates contemporary phenomena in its real life context. Case studies are particularly useful when the boundary between phenomena and context is not apparent. It is especially suited for new research areas and when "how" and "why" questions are being posed (Yin, 2009). Case studies can be either single or multiple case studies. Flyvbjerg (2006) is a proponent of the former, arguing that a case study is a good way of gaining a sharpened understanding of why instances turned out the way they did by stating that a case study ought to involve an in-depth and over-time examination of a single instance or event. This thesis will deviate from this single case strategy; what will be studied in plurality is the concept of operational freight transport efficiency. As Thomas (2011) proposes, a case study is “analyses of persons, events, decisions, periods, projects, policies, institutions, or other systems that are studied holistically by one or more methods” (p. 513). In this sense, the concept could be related to a phenomenon, event, decision, and/or a policy.

In the famous example by Karl Popper (1963), “All swans are white,” he concluded that it would only take a single case of a black swan to falsify the hypothesis mentioned. The proposition would then be considered invalid and be either revised or rejected. A case study could, in the same manner, have general significance and stimulate further investigations and theory-building. In this respect, the case study is well suited to identify “black swans” because of its in-depth approach: what appears to be white often turns out to be black at closer examination.

Case studies can be used for learning something rather than for evidence finding. Beveridge (1951) observed, before the breakthrough of quantitative studies in social science that “more discoveries have arisen from intense observations of very limited material than from statistics applied to large groups" Beveridge argued this without saying that large random samples are without value. The advantage of large samples is breadth, while their predicament is one of depth. For the case study, the situation is the opposite. Flyvbjerg argues that Eckstein (1975) goes even further than Beveridge by stating that case studies are better for testing hypotheses than for producing them. Case studies, according to Eckstein, "are valuable at all stages of the theory-building process, but most valuable at the stage of theory-building where least value is generally attached to them: the stage at which candidate theories are tested". Flyvbjerg continues with a discussion regarding the power of the good example in which he argues that:

> One can often generalize on the basis of a single case study, and then the case study may be central to scientific development via generalization as a supplement or alternative to other methods. But formal generalization is overvalued as a source of scientific development, whereas the 'power of the good example' is underestimated (Flyvbjerg, 2001, p 77).

To exemplify, Siggelkow (2007) uses the metaphor of a talking pig, as adopted from Ramachandran (1999). What if you tell me that you have found a talking pig? You show it to me and I do see that it talks. I suggest that you write a paper about it. What will the reviewers tell you? That it is interesting, but it is only one pig and you ought to find more in order for them to believe you? If you think that is a silly response, it might show the power of the single case. As far as the author knows, however, there are no talking pigs.

This thesis will use falsification methods as a case of criticisability (see Radnitzky et al., 1987), but not necessarily through positivism, mixing them with Eckstein's and Flyvbjerg's notions of how case studies can be used as a tool to refute an existing hypothesis. Flyvbjerg stresses the importance of choosing these case studies by means of different strategies, as in choosing the "extreme or deviant" case in order to shed light on a problematic situation, or for "getting a point across in an especially dramatic way", as in Foucault's "Panopticon."[7] The following methodical guidelines are derived from a case study by Flyvbjerg and they constitute the basis of this thesis. Flyvbjerg (2001) proposes methodical guidelines for phronetic social science by using Aristotle's theories on the first, third, and fourth questions, complementing them with theories of Foucault on the second. All of the questions are original except that the word *democracy* has been replaced by the word *transport efficiency*. It is argued that the substitution is valid on the basis of similarities such as complexity, actor dependent, and that most scholars see transport efficiency and democracy as something for which to strive.

Questions:

1. Where are we going with [transport efficiency] in Sweden?
2. Who gains, and who loses, and by which mechanisms of power?
3. Is it desirable?
4. What, if anything, should be done about it?

Three research questions presented earlier are created from these questions. The first question emanates from the simple fact that the concept under study is unclear and needs to be semantically defined, since a phenomenon that is not defined cannot be scientifically studied

[7] http://en.wikipedia.org/wiki/Panopticon.

(Schroeder et al., 2008). For Flyvbjerg, this is not a problem; the definition of democracy is rather well founded.

RQ1: What should be included in the concept of operational freight transport efficiency for the transport operator?

The second and third research questions stem from question 1 and 2 above, but not by studying mechanisms of power, per se, and by including the purpose of the thesis. Questions 3 and 4 are briefly treated in the concluding discussion.

RQ2: From the perspective of a transport operator, what are the likely economic and environmental effects of operational freight transport efficiency measures in terms of opportunities, barriers, and implications?

RQ3: What is the status of transport/energy efficiency indicators for freight operations in the Nordic countries?

Flyvbjerg supports the use of a problem-driven approach rather than a methodology-driven one, in that it employs those methods that best help answer the research questions. Insights from many different theoretical areas are used for shedding light on the problem at hand and to answer the research questions, as well as to form a hypothesis that attempts to negate some of the existing theory falsified by the power of the good example à la Flyvbjerg. Induction and deduction will be used in an iterative and reflexive process; the author is interested in the particular and the general.

## 3.3 Data collection and research process

It is important to match the research process with the data collection methods used. Interviews are probably the most widely employed method in qualitative research (Bryman and Bell, 2007). They are a viable option for studies with a more interpretive assertion, serving as the main source of empirical evidence for this study. Semi-structured interviews were conducted, since it is important to understand the specific respondent's context and to include open-ended and follow up questions. In addition, semi-structured interviews allow one to be flexible about the order of questions, as well as to include questions of interest depending upon the specific respondent (Bryman and Bell, 2007). Observations are a good way to find out how things work and it is also a good step toward experiencing the subjectivity of the subjects under study, or, in other words, to experience reality as the participants experience it. An attempt to oscillate between analysis and data collection will be made to build theory from case studies as ''frequent overlap of data analysis with data collection'' (Eisenhardt, 1989) is one way to go about this process. The interviews conducted so far have been a number of interviews with actors in the transport industry, transport operators, freight forwarders and transport buyers. A case study in Amsterdam has moreover contributed to this thesis. The observations conducted have consisted of the following: loading and unloading operations at distribution centres in the outskirts of Gothenburg, meetings held by the traffic office, the annual meeting in Gothenburg held by transport operators of the western part of Sweden, and meetings conducted by Chalmers and the University of Gothenburg, as well as workshops. These have been used to complement the interviews in an attempt to increase understanding and to provide different viewpoints. Group interviews have also been conducted at workshops conducted by Chalmers and University of Gothenburg as well by Volvo and Scania. Workshops are referred to as focus groups by Bryman and Bell, 2007 and are a good way to identify factors of importance, and to compare the viewpoints between two actor groups. Focus groups were chosen for their advantages in capturing the dynamics in viewpoints from several participants in the groups (Kvale and Brinkman, 2009). Also, focus groups are useful for orienting oneself in a new field, such as for generating hypotheses based on informants' insights and for evaluating different study populations (Morgan, 1988).

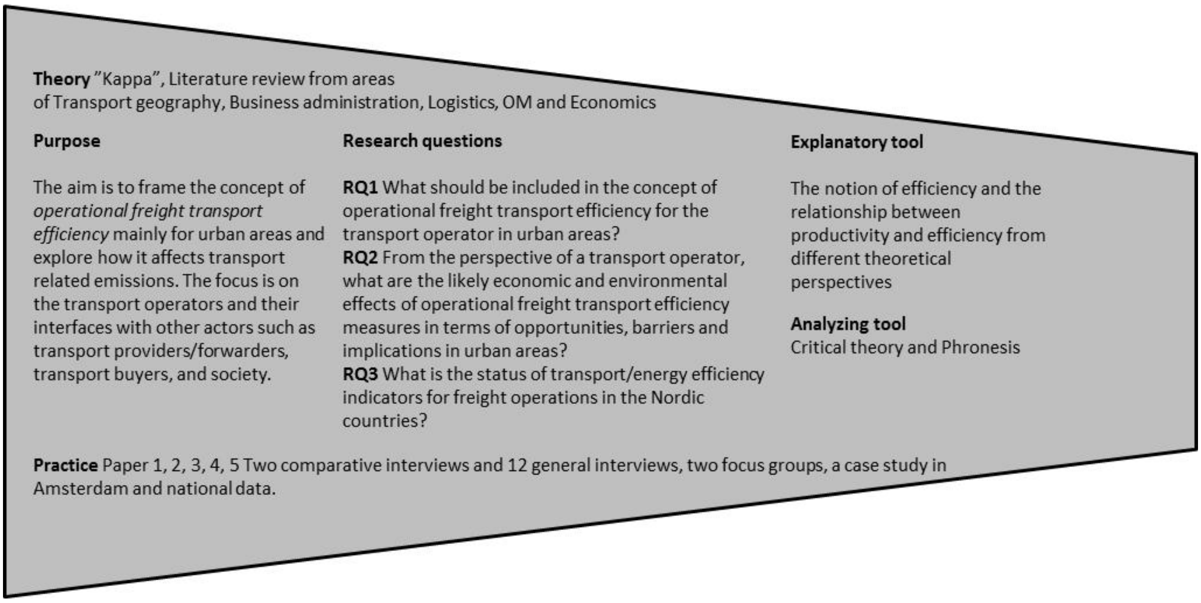


**Figure 7 Research process.**

Figure 7 is a pictorial presentation of the research process of this thesis. The concept of efficiency is illuminated from a range of different disciplines in a *funnel fashion*. To answer the second part of the purpose of this thesis, likely economic and environmental effects for the transport operator in RQ2, it is imperative to come to terms with what transport efficiency is and the potential for reducing transport emissions. When this has been achieved, a battery of recommendations for the operators, springing from this baseline, is possible. This thesis takes the perspective of the operators, and as concluded, Paper 1 presents some recommendations after phronetically testing these efficiency measures. Paper 2 provides a suggestion on decarbonisation, Paper 3 shows the attitudes among some of the actors, Paper 4 presents a paradox, and Paper 5 presents the status of some key indicators for a Nordic context.

It is also important to know how the Kappa, RQs and papers are related (see Figure 8).

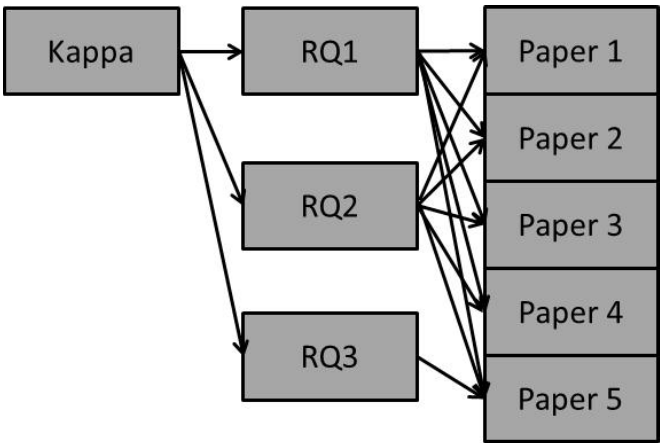


**Figure 8 Relationships between Kappa, RQs and papers.**

Further connections between papers and RQs are presented in Figure 9.

| RQ\Kappa+papers | Kappa | Paper 1 "Measures" | Paper 2 "Urban intermodality" | Paper 3 "Different viewpoints" | Paper 4 "Paradox" | Paper 5 "Efficiency indicators" |
|---|---|---|---|---|---|---|
| RQ1: What should be included in the concept of operational freight transport efficiency for the transport operator? | Theory -a semantic definition | Empirical - interviews -literature review -trade offs | Empirical -case study | Empirical -workshop | Conceptual -trade offs | Empirical -data set analysis and a framework |
| RQ2: From the perspective of a transport operator, what are the likely economic and environmental effects of operational freight transport efficiency measures in terms of opportunities, barriers, and implications? | Possible implications | Opportunities and barriers | Opportunities | Opportunities and barriers | Implications | Opportunities |
| RQ3: What is the status of transport/energy efficiency indicators for freight operations in the Nordic countries? | | | | | | A comparison amongst the Nordic countries |

**Figure 9 Relationships between papers and RQs.**

## Paper 1—Method

The empirical basis of the first paper were recorded expert interviews with CEOs at two major operators in Gothenburg—Björn Tynelius at GB Framåt and Roger Nilsson at TGM—and 10 general interviews. Eight of these interviews overlap with Paper 3, while the other two were interviews with local and national government officials. Triangulation was performed in order to create the matrix and to increase reliability. The literature review was conducted by the author of this thesis and later compared with the empirical findings. The interviews were recorded and transcribed, and the relevant data to be included in the paper was cross examined by all three authors of the paper: Niklas Arvidsson, Johan Woxenius and Catrin Lammgård. The first author created the majority of the paper.

## Paper 2—Method

The background to this paper was the phronetic notion that it must be possible to do things differently within the area of operational freight transport efficiency. What about operating trams for goods deliveries? Literature review was performed on similar projects from Dresden, Vienna, Zurich, and a case study in Amsterdam. The Amsterdam section is based on a literature review, as well as five recorded interviews in Holland conducted in January 2010 with the CEO of Cargo tram, the financial manager at Cargo Tram, a person in charge of public affairs at Cargo Tram, a municipality project manager involved with the project, and two journalists writing about the project at MindsinMotion.net. The respondents were approached using Linkedin.com and were later sent a draft document so that they would have the opportunity to comment on the interview results in order to avoid misinterpretations and increase reliability. One respondent came forth with suggestions on changes and these changes were applied. I would like to thank the students, Fawad Awais, Patric Lindquist, and Rafael Serrado for their input in the paper. They helped in transcribing parts of the literature review for Dresden, Vienna, and Zurich.

**Paper 3—Method**

The method for this paper was two full day focus group seminars, with eight and ten participants, respectively. The transport buyers originated from different branches including food, pulp, agriculture, construction, vehicle production, clothing, and personal care. The transport companies were larger forwarders. They all have their base in Sweden. The researchers, Vendela Santén and Niklas Arvidsson, were moderating the focus group discussions with the aim of creating informality in the discussions and to encourage all members to speak openly, while simultaneously keeping the discussion within the different subject areas. During the focus groups, notes were taken continuously. The notes were then summarised and sent out to the participants for their comments. The concept of transport efficiency was not defined by the facilitators of the focus groups, ex ante. Interviews were performed with five transport providers and three transport buying companies. Two researchers conducted the interviews, lasting about one to two hours each. The interviews were recorded and later transcribed. The factors were produced via coding and data was analysed and compared from the interviews, forming subject areas that were included in the discussions in the focus groups. Open coding was carried out, which is "the process of breaking down, examining, comparing, conceptualizing and categorizing data" (Strauss and Corbin, 1990). The outcome from the process was the identified common factors, and the relationship of these factors vis-à-vis the actors was explored further. The majority of the paper was created by Vendela Santén; I contributed with approximately 40 per cent of the work in the paper.

**Paper 4—Method**

This paper is a conceptual paper – no empirics are presented. It is an argument about why it is important to look at several measures from different point of views, a situational irony with transport efficiency. The method is simply to present the Milk-run load paradox.

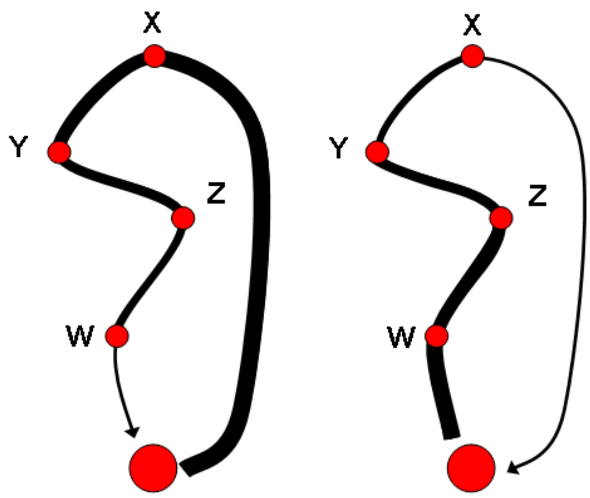


Figure 10 An example of potential sub-optimization of load factor.

It is shown that a lorry on a milk run returning to the point of origin after deliveries could be sub-optimised if the main indicator ruling the vehicle routing is the load factor. If this was the case, the left route would be chosen, i.e., the lorry would start full, choose the counter-clockwise route and deliver to customer "x" first and successively deliver to customers on its way back. This would lead to a higher average load factor than the right side alternative and a much higher $CO_2$ effect (25 per cent), since the lorry is full half of the way (left) rather than empty (right). Traffic work is constant and transport work is different comparing the two cases. Vehicle routing and the travelling salesman problem have been extensively studied, but applying the paradox to this problem calls for minor adjustments in the algorithms if these are to be used in the field of sustainable logistics. The paper also puts the paradox in an urban setting with access restrictions and elaborates on the consequences for the local authorities and operators.

**Paper 5—Method**

A joint analysis method was developed for the purpose of data comparison. Quantitative data was used to conduct a decomposition analysis for various sectors, taking several indicators into account, such as $CO_2$ intensity, transport intensity, and energy efficiency. Statistics from Denmark, Finland, Norway, and Sweden include continuous road haulier surveys, national accounts data and fuel consumption data. The analysis was based on the work of McKinnon and Woodburn (1996).

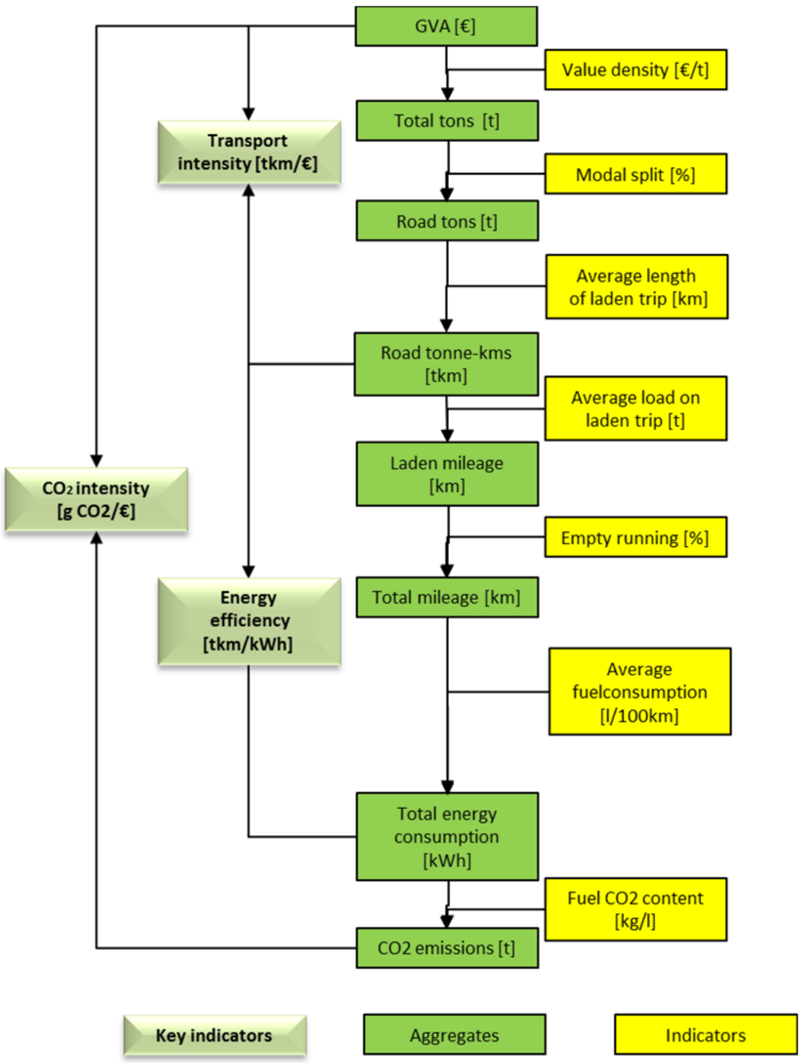


Figure 11 Framework used in Paper 5

The widely accepted framework for analysing the relationships between the economy and road freight transport was introduced by McKinnon and Woodburn (1996) and further enhanced in an expansive European research project on the subject (REDEFINE, 1999). Cooper et al. (1998) extended the framework to include the environmental effects. The basic structure of the framework has, however, remained the same. For this study, the framework is slightly altered, where the focus is on acquiring an in-depth understanding on energy efficiency and $CO_2$ emissions. The framework is thus similar to the one Piecyk (2010) used, but with an addition of three key indicators and a replacement of the 'lading factor' with average load on laden trips and thus an addition of laden mileage 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 the data.

## 3.4 Critical theory

Historically critical theory has been linked with social science and humanities. According to Stanford (2005), critical theory provides a base for social inquiry, both descriptive and normative, aimed at decreasing the domination and increasing freedom of all its forms. Put in another way, Alvesson (2003), formulates it as a process of reflection on established ideas, ideologies, and institutions to liberate these from confinement and relations of dominance. Similarly, Foucault (1986) takes a critical perspective when one "places [oneself] neither beyond, nor within, but on the boundaries between the seemingly possible and impossible with clear intention of shifting these boundaries". Karl Popper, (1963) describes it as "Criticism, I said, is an attempt to find the weak spots in a theory, and these, as a rule, can be found only in the more remote logical consequences which can be derived from it, it is here that purely logical reasoning plays an important part in science" (p. 67).

According to Marshall (1998), the Frankfurt School was for the first part of the past century pioneering critical theory, with Adorno, Horkheimer, Fromm, Apel and Marcuse. After 1960, Jürgen Habermas has essentially been synonymous with critical theory. His view is somewhat different than the Frankfurt school's early founders; his view is one of language. The "ideal speech situation" is a utopia in which all have equal access to information and to public debate. Furthermore, Habermas discusses distorted communication; for example, powerful economic groups that have historically been able to attain their agency goals without excluding topics from the discussion, have instead used implicit non-deliberative means such as threatening to reduce investments. Critical theory works dialectically and does not juxtapose one set of truth claims in relation to another, instead searching for the internal contradictions and gaps in a system of thought, and pushing these contradictions as far as possible. This method is sometimes referred to as internal critique.

For the past fifty years, the term has drawn on a wide range of other influences such as sociology, systems theory, and psychoanalysis, via Max Weber, Vilfredo Pareto, and Sigmund Freud, respectively. The critique against critical theory is commonly phrased, as through Held (1980), using the term "philosophic-historical reductionism," a tendency to move in favour toward philosophy rather than the social sciences. Also on a more general note, any narrative or system of ideas is a "regime of truth" (Foucault, 1980) with its own exclusionary and possibly oppressive consequences. One of the main critiques of critical theory relates to this universalism, the lack of conceptualisation of power, and the difficulty critical theorists experience relating abstract theorising to empirical analysis.

Ghoshal (2005) problematized the use of management theories from a range of different angles. One of his criticisms resonates quite well with Flyvbjerg's focus on values.

Halldorsson (2009) also briefly mentions this criticism. Ghoshal argues that these theories lack ethics or morality, mainly because they shift morality to the individual away from the unit of analysis, organisations, or management. By doing this, Ghoshal points out that morality has had to be excluded from the management theories and the practices that such theories have shaped. Ghoshal concludes that management theories that focus on the economic aspects of man to the exclusion of all others might be incorrect. He denounces e.g. agency theories' explanatory and predictive powers by stating that numerous studies (ibid, pp. 80-81) showed little or no support for the predictions of these theories.

For logistics and transportation, the same type of quandary could be identified. The economic dimension is regarded as the most important. According to Wagner (2005) in Wolf and Seuring (2010), many companies strive for win-win situations with regard to the economic and environmental dimensions. However, if trade-offs between environmental and economic criteria are present, decision-making is usually dominated by the economic dimension, according to e.g., Schaltegger and Synnestvedt (2002), Wagner (2005), and Wolf et al. (2010).

Halldorson et al. (2009) make similar invitations to Ghoshal's critical reasoning on management theories when they state that instead of calling for more focus on attributes of the supply chain as a solution, like integration, performance, collaboration, and centralisation. Maybe the way to go forward is to take a step back [this also goes for the transport operator] and explore the operational intersection or boundaries with sustainability, society, and SCM.

## 3.5 Critical theory in transportation

As the previous section has tried to show, critical theory signifies a heterogeneous array of different bodies of work and a wide range of different researchers who share a common critical sensibility. One common critique is that critical scholars are more articulate about what they are against than what they are for. Others disagree. By critical theory used in transportation, the author of this thesis does not necessarily mean to portray a hypercritical negative view, but rather to acquire and maintain a critical spirit, or as Facione et al. (2010) puts it, "use the metaphorical phrase *critical spirit* in a positive sense. By this they are referring to showing 'a probing inquisitiveness,' a keenness of mind, a zealous dedication to reason, and a hunger or eagerness for reliable information" (p. 9).

Alvesson (2003) considers "working with negations and counterpoints, seeing theory as provocation rather than a combination of concepts reflecting 'objective reality'". He continues by stating that, "critical theory consistently supports a dialectic way of interpreting society", and argues that "social phenomena must be understood in a historical context". Alvesson and Kärreman (2007) suggest the use of mysteries. This involves being open to unexpected insights that come from engaging in research, like deviation from common assumptions or the use of theoretical paradoxes. "It is broadly recognized that it is fruitful to observe organizations based on metaphors that suggests alternative points of departure and foci" (Morgan, 1980; 1997; Grant and Oswick, 1996; Alvesson, 2003, p. 166). This is much the same way as Flyvbjerg argues (see Methodology), but phronesis also focuses on a value-induced course of direction. In a transportation context, I interpret this as fewer emissions from transportation. I try to take advantage of the umbrella characteristics of critical theory by using a method of critique or doubt of the concept of operational freight transport efficiency, putting it in a greater, and to some extent historical, context. I try to show how closely related cost reducing efficiency is with productivity, giving examples of paradoxes like the load factor paradox and trade-offs between actors. I wanted to use the word *critical* early in the thesis to prepare the reader for an attempt of a rebuttal of the cost-reducing measures under study, but to also positively and phronetically come forth with suggestions of ways to operate differently.

According to Eurostat (2009) and the European Commission (2009), one could argue that it is problematic, as stated earlier, that GDP growth correlates directly proportionally to $CO_2$ emissions. As shown in Figure 1, transportation is the only major contributor to $CO_2$ emissions that has experienced a relative increase over the last 20 years, while also being an industry that have worked hard on efficiency measures and on improving technical performance, engines, and IT. It is important to mention that the shape of the diagram can most probably also be explained by the outsourcing activities of some of the other sectors. Nevertheless, on a company level, how should managers for transport operators choose measures that are cost neutral or that even increase the supply chain costs for the sake of sustainability? Do managers have the necessary tools to do that and is it really desirable?

In the past decade, or at least since the beginning of the financial crisis in 2008, research in logistics has focused on redefining conventional logistics theories of how things work, at least those views that cannot be functionally applied in times of crises. In logistics, researchers are to some extent redefining and repositioning themselves to serve up to the changes in reality, how to “handle” or “tackle” sustainability in logistics (Belz and Peattie, 2009)? One of those examples is redefining the concept of *lean logistics*, in which *just in time* is an important component in terms of transport and of its potential effect on the environment, an aspect that will be further explored in this thesis. It is interesting that theories focusing on the interest rate of tied up capital gets such focus in times when interest rates are close to zero.

Schwanen et al. (2011) argue for a plurality in the use of research methods. They argue that social science perspectives also may open up new research questions. For critical social scientists questions about deep cuts in carbon use ultimately also create questions like the organisation of contemporary societies, the role of transport in these socieites, justice, and ethics.

When a decrease of emissions from transportation is referred to in this text, it is not necessarily meant as a radical lowering of total transport emissions, at least initially. Rather, it refers to an abbreviation of the more lengthy “lowering the rate at which emissions from transportation are growing”. To say that tonne km (transport work) should be minimised is highly controversial, since it is generating income for the transport operators. A growing amount of tonne km is argued to be litmus for the economic development, in general, and that the exchange between people is growing. To say that emissions from tonne km ought to decrease is less controversial and to say that the rate at which emissions from tonne km increases should be lowered could be argued as being the least controversial, but this may change in the future.

## 3.6 Research quality

A problem with partly delimiting the social aspect of sustainability is that the conclusions do not account for this aspect (per definition), and might be suboptimal or skewed from a triple bottom line/sustainability perspective. However, some of the trade-offs of a triple bottom-line analysis is explored more in detail in Paper 4. To theoretically explore a concept of operational freight transport efficiency by moving in on it from a perspective of more general “efficiency” to “freight efficiency” (by benchmarking “private transportation”) and then to “operational freight efficiency” calls for care, especially if the author intends to draw conclusions from this exercise. Since these conclusions can only be drawn on generalisations from previous researchers in areas that the author is at best considered a novice. That is why no conclusions will be drawn, only a presentation of different “viewpoints” in an attempt to create a scientific conversation. However, the use of a critical approach from the onset might have resulted in these “viewpoints” to be skewed for the purpose of depicting cost-reducing efficiency as closely related to productivity. Not only is it not possible to always make this connection, but, it is also highly controversial. If one uses a “problem oriented” approach, focusing on values, problematising and using critical theory it is almost inevitable to end up with a negation or something along the same lines of the concept studied.

To make the leap from cost-reducing efficiency measures to an increase (or at least not the desired decrease) of emissions, at least two assumptions must be made. The first has been treated in this thesis so far: 1) an assumption that transport efficiency can turn into transport productivity if a time perspective is taken into account; 2) an assumption that there is a link between a rise of transport productivity and a rise of transport demand. The link is price reductions and the relationship is determined by the use of elasticities (Economics perspective on efficiency).

This thesis has had many working definitions of operational freight transport efficiency. One of the last definitions before settling on the current one was “allocation and utilisation of resources”. It turns out that researching the background of that definition ends up in a 1964 article on productivity (Amey, 1964). Whether this is problematic or humorous is for the reader to decide.

**Research quality—credibility**

Patton (2002, p 569) argues that neutrality and impartiality are very difficult, if not impossible to achieve; this is particularly true of interpretive methods in which the researcher brings his/her preconceptions and interpretations to the problem under study. Therefore, it is important that the researcher state beforehand the prior interpretation of the concept under study. In this thesis, the author indicates from the beginning that the thesis will “critically elaborate” the perception of operational freight transport efficiency as a “free lunch.” This “view” is strengthened by the results in Paper 1, where transport efficiency measures are shown to be both cost reducing, neutral, and cost generating. The conclusions in Paper 2, 3 and 4 are similar, demonstrating that win-lose situations and trade-offs are plentiful in the areas of sustainable transportation and transport efficiency.

Contrary to Flyvbjerg (2001), Silverman (2001) suggests that the search for deviant cases should be aimed at overcoming any tendency to select a case that supports your argument. In this thesis, both strategies have been used. In Papers 1, 3, and 5 the interviews (1), focus group participants (3), and data (5) were chosen in such a way that no deviation or outlier case could be identified beforehand. The participants in the focus groups were selected by inviting people from different companies and using snowball sampling by further asking the subject recruits to recruit their acquaintances. Initially, the idea for the Paper 3 was to interview only one group, the operators, but both researchers identified the importance of looking at the differences in the attitudes of the two actor groups and managed to convince the people from Scania and Volvo, who were in charge of the funding, to make two focus groups. Paper 2 and 4 are exceptions; the cases chosen were deviant with regard to simply attempting an unusual way of freight distribution in cities. The results reported in the paper are in line with previous research, with two cases being successful and two being unsuccessful. Paper 4 is a selected deviant case, a paradox, which supports the trade-off argument. As one anonymous reviewer put it; “The paper states in a fairly simple a straightforward manner an issue which, evident as it might be, has not been addressed so far in the transportation scientific literature.”

Patton (2002) advocates multiple methods and multiple theories in a “triangulation” fashion, including using both quantitative and qualitative methods. Four types are known, of which at least three have been used in the papers to varying degrees:

*Data triangulation*: In all papers, except in Paper 4, data was gathered from at least two independent samples. In Paper 1, two main interviews were independently conducted asking the same questions. Paper 2 studied four cities, but only one city was studied using primary data. Paper 3 was mainly based on information from two focus groups. In Paper 5, data was collected from four Nordic countries, specifically from the national statistical agencies in charge of transport data. Data triangulation is related to Yin’s (2009) multiple sources of evidence, an important part of construct validity. Paper 4 is a conceptual paper.

*Investigator triangulation*: Papers 1, 2, 3, and 5 were co-authored by other researchers. However, mainly the author of this thesis gathered data in Papers 1 and 2. All other interviews were always conducted by at least two interviewers.

*Theory triangulation*: The theoretical or methodological positions used in the thesis are critical theory and phronesis. However, these two approaches are related and the relationship may not provide two independent theoretical positions. Another point is that these positions have mainly been used in the Kappa, in choosing the topics of the papers, and to a lesser degree in the actual papers. The theoretical underpinnings of the papers are critical in the sense that they display internal contradictions as well as gaps and phronetic by highlighting problems and risks, thereby suggesting how things might be done differently, even though the latter could also be argued to be an analytical endeavour.

Phronesis has however received some critics in the so-called "The Flyvbjerg Debate", instigated by Laitin (2003). Laitin argues that Flyvbjerg attempts to separate out phronesis (as a kind of a narrative) from its statistical and formal complements, and that this undertaking is radically incomplete, as well as subject to uncontrolled bias. Flyvbjerg counters Laitin’s critique by arguing that his equating of phronetic disciplines with qualitative and narrative methods is ill-founded; Flyvbjerg goes on to state that his work has been misrepresented as “either or” and unethical in the sense that Laitin tries to discredit phronesis and to promote his own methodology as science (Flyvbjerg, 2004). Schram (2004) and Schram et al. (2008) accordingly state that “the special thing about Flyvbjerg's challenge to social science is the way it bridges theory and practice in a way that unites philosophical and empirical subdivisions in the social sciences” (p 1).

*Methodological triangulation*: Different methods have been used, as is the case with most research. A valid criticism to using different methods is that the main ones that have been used so far are mostly qualitative, e.g., literature review, interviews, and focus groups. In Paper 1, for instance, a literature review was conducted, followed by a series of interviews supporting or opposing the findings from the literature review. Paper 5 is an exception, where an analysis of the data was conducted. However, the two methodologies or ontological positions, critical theory and phronesis, are rather closely related in which the latter can be viewed as a lighter version of the former.

However, triangulation is partly challenged by Silverman (2001), even though he does not refute the method. He states that it might be tricky to aggregate data in order to arrive at an overall truth. It might be wise not to adopt an overly naïvely optimistic view that the aggregation of data from different sources will end up in a production of a more complete picture; this is partly because actions and accounts are situated and dependent on different contexts.

**Research quality—empirical validity and reliability**

Yin (2009) suggests four types of tests to measure the quality of empirical social research: construct validity, internal validity, external validity, and reliability.

*Construct validity*: measures how well the concept has been operationalised. It is important to reiterate Bridgman's (1927) statement, "we mean by a concept nothing more than a set of operations; the concept is synonymous with the corresponding sets of operations." How do we know that the definition proposed in this thesis is the correct one? We do not. However, by not moving too far away from the original ratio definition, I try to define what is part of the concept and what is not by using triangulation, an attempt to establish a chain of evidence in terms of how the ratio definition was created, and gathering input from key informants. As has been noted previously, the definition deliberately lacks a goal. This goal needs to be (re)defined but falls outside of the scope of this dissertation.

*Internal validity*: to what extent the causal relationships are well founded. Some causal relationships have been put forward in the papers, but they are more descriptive and exploratory. The Kappa tries to make causal inference but also rival explanations have been addressed. This validity is further elaborated upon at the end of this thesis.

*External validity*: to what extent the case studies can be generalised beyond the case studies themselves. Usually other types of studies, such as surveys, are easier to generalise (Yin, 2009). One aim of the papers in this thesis has been to provide deviant cases. In this context, that can be translated to take a perspective that has not been researched much before, exceptions from the norm. The perspective is that of the operators', and the papers show that this perspective is worth examingin in more detail, preferably with the help of data analysis, in order to revise, broaden, and potentially confirm the findings that suggest that economic and environmental dimensions are not always aligned.

*Reliability*: measures how well the research conducted can be repeated and the same results acquired. An interview guide used in the interviews of the two operators can be found in Appendix B. This is a shorter version of the interview guide used for all of the interviews conducted for this thesis. In terms of transcription reliability (Kvale, 1996, p 163), the interviewer was chosen to record the interviews to increase the reliability, but for Papers 1 and Paper 2 there was only one transcriber of the interviews, rather than two people independently typing the same passage of the taped interview. This method decreases reliability, according to Kvale (1996). Although the data in Paper 5 lacks reliability, significant details on the shortcomings of the data are detailed for each country.

**Research quality—theoretical validity and reliability**

Despite, or maybe because of, the delimitation of the social aspect of sustainability, the author devises a hypothesis that it is important to study the problem from this perspective, too. Much of the theory of the debates presented in the theory section and future research is difficult to scientifically resolve, since it is futile to run control experiments to see changes in energy use at all levels, with and without the efficiency improvement. After all, there is only one past and it is very difficult to run double-blinded studies outside of a lab setting. Again, all of the correlations presented in the thesis do not imply causation. Perhaps a way forward might be to study the concept of elasticities and the rebound effect, further elaborated on in the Economics perspective on efficiency section. However, this effect is not mentioned at all in Stern (2007) and McKinsey & Company (2009) or to any greater extent in IPCC (2007), as concluded by UKERC (2007). A very important point that is concluded by, e.g., UKERC (2007), Alcott (2005), 4CMR (2006), and Ruzzenenti (2008) is the lack of consensus among the vast selection of different studies achieved to date, despite three decades of empirical work. Several studies reach different conclusions for the same sector and for the same time period.

*"A good city is one where we invite people out in the public space." Jan Gehl*

*"Products are paid for with products" Say (1803)*

*"The sin of the academic is that he takes so long in coming to the point. Nevertheless, there is some virtue in his dilatoriness; what he has to offer may, in the end, be no great matter, but at least it is not unripe fruit, and to pluck it is the work of a moment." Michael Joseph Oakeshott (1991)*

# 4 Results

The following section elaborates on the research questions and summarises the conclusions of the dissertation. A formulation of the thesis's results will follow from the empirical and theoretical material. This is represented by answering the formulation of the research questions. The section is divided into: "Defining operational freight transport efficiency," which tries to answer RQ1, RQ3, and "Opportunities and barriers," summarised paper by paper, as well as "Possible implications." The two latter captions are mainly focused on RQ2.

## 4.1 Defining operational freight transport efficiency

A semantic definition of the concept of operational freight transport efficiency is difficult to find in transportation literature. It is defined by McKinnon, Browne, Allen, etc., in a series of relative measurements involving energy, time, distance, weight, or combinations, such as tonne km and vehicle km or ratios such as tonne km/vehicle km (utilisation). The author found few attempts at a clear semantic definition. The definition of transport efficiency has been construed and constructed in the following way: a literature review of how other researchers define the concept was made in Paper 1 and in the "Kappa." Second, definitions were collected from the actors through interviews. Third, these definitions were put together to try to accommodate all of the definitions. In this sense, a quantitative definition is transformed into a qualitative definition.

RQ1: What should be included in the concept of operational freight transport efficiency for the transport operator?

According to Wikipedia, this is a definition of *transport efficiency* as of 11/03/01 (this definition was deleted on 11/08/1 in accordance with PROD, since the definition was not sourced and Wikipedia is not a dictionary or publisher of original thought):

> Transport efficiency is a measure of how much it costs (in dollars, time, energy, or other kinds of overhead) to move a certain amount of something (goods, people, other types of load).

As mentioned, Mentzer and Konrad (1991) define efficiency in a logistics performance context as "[a] measure of how well the resources expended are utilized" and as "the ratio of resource utilized against the results derived" (p 34). Caplice and Sheffi (1994) highlight their view on the critical elements of logistics management—time, distance, and money. Samuelsson and Tilanus (1997) advocate the following efficiency dimensions—distance, speed, and capacity. According to Hokey and Seong (2006), the operational efficiency (equipment utilisation or labor productivity) of third party logistics providers dictates the competitiveness (and even survival) of the company. Ax et al. (2009) define efficiency as the "degree of fulfilling a goal".

Caplice and Sheffi (1994) identify utilisation, productivity, and effectiveness as important improvement indicators in logistics, and McKinnon and Ge (2004) use vehicle loading, empty running, fuel efficiency, vehicle time utilisation, and deviations from schedule when constructing a series of key indicators. McKinnon (2010, p. 22) also defines operational level as scheduling of production and distribution operations, and the functional level relating to the management of logistical resources.

The definition consists of measures of resources or utilisation of these resources (Mentzer and Konrad, 1991; Hokey and Seong, 2006). To be operational in character, the definition should include a time component and not include any structural changes (strategic), the trading links are considered set (tactic, commercial), as outlined by McKinnon (2010c). The resources should reflect some of the five key indicators suggested by McKinnon and Woodburn (1996) and McKinnon and Ge (2004), and in turn derived from Caplice and Sheffi (1994), since it is commonly used in logistics literature. Let us divide these indicators into a series of resources. Vehicle time utilisation and deviations from schedule is *time*, vehicle loading and empty running are *space*, and fuel efficiency is *fuel*. What is missing from an operator's perspective is the *vehicle* and *driver*. This results in the following suggestion on a semantic definition of the concept of operational freight transport efficiency for the operator:

> **"A set of utilisation measures of time, space, vehicle, fuel and driver in the movement of goods"**

Possible and adequate measures include vehicle routing and scheduling, consolidation, back-haul, vehicle maintenance, modal shift, and driver training. The definition does not contain the word "cost" to accommodate a cost neutral analysis of the different efficiency measures, but the cost is implicitly included, e.g., "cost of time," etc. "Time" could be economically interpreted as "as quickly as possible," but in order for it to survive future analysis it might benefit from being interpreted differently, considering that this phrase could also affect space utilisation, as concluded in Paper 1.

Possible limitations: This definition does not take into account the trade-offs between resources and between actors. It also focuses on inputs, not outputs, which could be argued to be misused from a short-term micro perspective, as concluded by McIntyre et al. (1998). How does one deal with the output of one resource as an input to another resource? This definition does not depict a goal, as proposed by Ax et al. (2009) and Sjögren (1996), nor does it contain a norm value, as suggested by Caplice and Sheffi (1994). The definition lacks a measure for some overhead costs such as order administration. The lack of a goal merits further discussion. To speak of efficiency as a goal of itself is unmerited, a contradiction in terms. One can be efficient in working for a bad end just as well as in working for a good one. It is important that this goal is useful in some ways to humans and organisations, as pointed out by Moriarty and Honnery (2012), today and tomorrow.

A mathematical definition dictating the relationship between the economy and road freight transport complements the semantic definition, adhering to the aim of answering RQ1 and is presented in Paper 5. The framework was introduced by McKinnon and Woodburn (1996), and further enhanced in a collaborative European research on the subject (REDEFINE, 1999). Cooper et al. (1998) extended the framework to include the environmental effects and McKinnon (2010a) introduced monetary valuation of the environmental effects for determining the external costs of logistics operations, but the basic structure of the framework has remained the same. The paper aggregates three key indicators called $CO_2$ intensity, transport intensity, and energy efficiency.

## 4.2 Opportunities and barriers

This section will focus mostly on RQ2, opportunities, and barriers. Implications are treated in the end of this section, but also at the end of the discussion section.

RQ2: From the perspective of a transport operator, what are the likely economic and environmental effects of operational freight transport efficiency measures in terms of opportunities, barriers, and implications?

**Paper 1—Opportunities and barriers**
This paper attempts to address research questions 1 and 2, defining the concept as well as how the barriers and possibilities affect operational and to some extent strategic decision-making in the transportation industry. The paper presents some of the literature within the area of transport efficiency. It also presents potential transport efficiency improvements for environmental performance, case studies, and a concluding matrix presenting costs and/or benefits for the actors. The efficiency measures are divided into driver, vehicle, ITS, utilisation, packaging, order, mode, regulatory/incentives, and coordinated distribution.

The paper depicts a rather gloomy picture of the situation. In the paper, the authors show that the basic criteria for sustainability are not satisfactory for transport efficiency measures, especially not for transport operators. It seems that economic and environmental sustainability is not the same thing for some measures. Also, if all the environmental efficiency measures were to be economically profitable, they would be fully implemented, but are not. As can be derived from Table 3, load factor efficiency and improved packaging could lead to a reduced amount of shipments for the freight industry, but would be considered a benefit for transport buyers and society. Consequently, transport companies have alternatives in implementing the efficiency measures to reduce their impact of emissions. Either they can obtain an economic benefit from this change in behaviour, the first efficiency measures, or they can improve their market share as a result of their environmental position and added goodwill by supporting the latter efficiency measures.

**Table 3 Transport efficiency measures in distribution and the effect on actors in the system.**

| Measure/actors | Decision maker | Road hauliers | Transport providers | Transport buyers | Society |
|---|---|---|---|---|---|
| Driver efficiency | RH | + | + | + | + |
| Vehicle efficiency | RH/VM | + | + | + | + |
| ITS and route efficiency | RH/TP | +/- | + | + | + |
| Utilization efficiency—back-haul effect | RH/TP/S | + | + | + | + |
| Utilization efficiency—load factor | RH/TP/TB/S | +/- | +/- | + | + |
| Packaging efficiency | RH/TP/TB | - | - | + | + |
| Order efficiency | RH/TP/TB/S | - | - | +/- | + |
| Mode efficiency | RH/TP/TB/S | - | +/- | +/- | + |
| Regulatory and incentive efficiency | RH/TP/TB/S | +/- | +/- | +/- | + |
| Coordinated distribution | TP/TB/S | +/- | +/- | + | + |

(-) cost, (+) benefit. RH: road haulier, TP: transport provider, TB: transport buyers, S: society, VM: vehicle manufacturer.

At first glance, Table 3 could lead to the conclusion that transport efficiency measures, reduced environmental impacts, and cost reduction for all actors do not always go together. One could argue that individual freight transport operators would not be able to achieve adequate system-wide improvements in urban freight efficiency by themselves. Furthermore, there may be a lack of concern about freight costs by the transport buyers, since these costs are often a small proportion of the total product cost. In some instances, there may be reluctance toward coordinated distribution in cities among transport operators and providers, since there are conflicting corporative interests in this respect. In the interviews, we asked all of the actors who they thought would be the most likely one to take the first step toward a more sustainable transport system and consequently to rank the rest of the actors in descending order. All actors above were mentioned as potential first movers, but nearly no one picked themselves first. This is a strange result, if transport efficiency is a "free lunch", a "win-win" situation. From the viewpoint of the road haulier, one paradoxical result of many of the environmentally beneficial transport efficiency measures presented in the matrix is a decrease in the number of total shipments. Therefore, implementing all of these measures would not be beneficial from an economic perspective, at least not in the short-term and for all actors. This could partly explain the resistance to change within the freight industry. Nevertheless, the reluctance might be equally explained by the fact that the road hauliers are hardened after many years of improvements that they have not been able to attain the benefits from these improvements, due to the strong market pressure. Let us recite the argument, "Those measures which yield economic as well as environmental benefits generally command the greatest support and are the easiest to implement" (McKinnon, 2003b). Turning this argument around, one rather pessimistic but also potentially premature conclusion could be that as long as the environmentally and economically sound do not point in the same direction, little more can be expected to happen in terms of transport efficiency, considering that there seems to be a difference in interests that creates major difficulties in practice. A combination of company initiatives, efforts by local authorities, and government policies might be necessary in order to develop a sustainable urban freight system. The importance of this public-private cooperation is also acknowledged by e.g. Allen et al. (2010) and Crainic et al. (2004).

**Paper 2—Opportunities**

This paper aims to analyse the potential use of trams and electric distribution vehicles (EDVs) as cargo carriers in intermodal urban freight distribution. Transporting goods in urban areas, where most logistics chains start or end, is an activity that increasingly generates severe problems for many stakeholders. New transport solutions are necessary in order to decrease traffic congestion, noise, and traffic pollution, such as emissions of greenhouse gases and air pollutants in urban areas. A possible solution to these problems is to transform the current freight distribution system within cities, for example by favouring the enhancement of intermodal transport alternatives like combining road and rail transport. If electricity is used, it is important to make sure that the production is not fossil-based. The results are presented in Table 4, a summary of various cargo tram projects in Europe, as well as a potential zero emission scenario using electric vehicles on trams in Gothenburg. This paper is a contrasting picture to Paper 1, which illustrates a different approach to what one part of operational freight transport efficiency could be for a transport operator/forwarder in an urban setting. As Flyvbjerg states, "The task of phronetic social science is to clarify and deliberate about the problems and risks we face and to outline how things may be done differently". Mode or modal efficiency indicates the proportion of freight carried by different modes of transport.

As stated before, the degree of transport by train has decreased in favour of more reliable and time-efficient transport, such as lorries and air. In terms of transport and energy efficiency, a modal change toward the increased use of train and ships is preferable. From the transport operator's perspective, this is considered a cost, or rather a loss in sales, unless offering a multimodal service. Nevertheless, this might be part of a feasible fossil-free freight fleet in the future.

**Table 4 Cargo tram projects in Europe.**

| City<br>Key factors | Amsterdam | Dresden | Wien | Zurich |
|---|---|---|---|---|
| Project owner | Private (City cargo) | Private (VW) | Municipality | Municipality |
| Funding | Banks/private | VW | Municipality | Municipality |
| Size of project | Large | Medium | Small demonstration | Small |
| Type of goods | Commercial, parcels etc | Automotive parts | Commercial, mainly retail | Electronic waste |
| Type of customers | Commercial | Private (VW) | Commercial/public | Public |
| Logistics character | Logistic service provider | Internal logistics | Commercial/recycling logistics | Recycling logistics |
| Infrastructure investments | Large | Small | Small | Small |
| Current status | On hold, bankrupt late 2008 | Ongoing | On hold | Ongoing |

Since it is rather costly to reload, goods that are transported greater distances are more likely to undergo a modal shift, which would make this a less likely efficiency measure for short-haul transport. However, some cities have implemented an intermodal city distribution by using the existing tram system, with mixed results. In theory this would be possible in many European cities, using existing cross-docking distribution centres operated by transport operators or by providers outside the city, adding an extra tram wagon suited for smaller electrical distribution vehicles, loading and unloading via Ro-Ro technique at the terminal station, and in the city centre or by independent tram distribution wagons—so-called "cargo trams"—servicing the city at low traffic hours. The technological and economic feasibility of such a system for full-scale operation, the safety and reliability, and the willingness of various stakeholders to participate in such an implementation require further studies. Nevertheless, a combination of rail and road is a way to decrease the external effects, while maintaining flexibility, according to Woxenius (1998) and Lammgård (2007), for example. Potentially, the world leading lorry manufacturers like Volvo and Scania could see the concept as a challenge and accordingly try similar approaches by substituting the tram with a lorry or trolleybus.

**Paper 3—Opportunities and barriers**

The purpose of this article is to describe and compare the transport buyers' and transport providers' views of challenges when improving transport efficiency, as well as reducing environmental impact from freight transport. By investigating the attitudes of the actor groups, an increased understanding of the different perspectives is made and factors that are important for improving transport efficiency and reducing environmental impact are identified. The role of the different actors and what could be expected from each actor is discussed. Time, competence/knowledge, competition, willingness to pay, priority of transport, demand/service, and follow up/measure are identified as important factors. The major similarities and differences from the viewpoints of the actors can be seen in Table 5.

**Table 5 Summary of the factors identified as most important when improving transport efficiency and reducing environmental impact from freight transport based on the transport providers' and transport buyers' perspectives.**

| Important factors | Perspective of the transport provider | Perspective of the transport buyer |
|---|---|---|
| Competence and resources | Lack of competence and resources to work with environmental issues within the organization. | Knowledge and information were discussed rather than competence and resources |
| Knowledge and information | Competence and resources were discussed rather than knowledge and information | Lack of knowledge about all their transport operations and its environmental impact. |
| Demands | Demands such as cost and time can be a limiting factor. Greater time windows at delivery are needed and more flexible solutions. | To keep the time, i.e. JIT, and robustness in deliveries is a prerequisite. |
| Priority of transports | Notice the low willingness from the transport buyers to pay extra for environmental better solutions. | Low priority of transport in transport buying companies. Agrees on the low willingness to pay for environmentally better solutions. |
| Service and offers | Would the buyers be more open in discussions about possible solutions? | Would like the operators to offer more environmental services and being more proactive. |
| Follow up environmental goals | Raises the need for measuring the fulfillment of the goals. | Raises many challenges in the area of measuring environmental impact, difficult to measure in detail. More information from the transport provider is needed. |

Table 5 provides possibilities by highlighting what factors are important for these actors in identifying key areas of interest. It also becomes an obstacle in the sense that not all factors have the same meaning for all actors. The transport buyers need to raise the focus of transport and environment in order to better understand the effects of transport in the system, and the transport providers need to be innovative as well as proactive in order to find business models that steer toward both efficient and sustainable transportation.

**Paper 4—Implications**

The Milk-run load paradox is presented in this paper. As Kara et al. (2007), Bektaş and Laporte (2011), and Xiao et al. (2012) all indicate, there might be a considerable difference between distance minimizing and energy minimizing solutions. All provide examples where energy usage increases with a decrease in distance. Bektaş and Laporte (2011) and Xiao et al. (2012) highlight the importance of taking energy expenditure into account, finding instances where the shortest distance is not the optimal solution due to variations in fuel consumption in differently-loaded vehicles.

Bektaş and Laporte (2011) introduce what they call the Pollution Routing Problem (PRP), an extension to the classical VRP with an objective function that accounts for distance, travel times, energy, and driver costs. They suggest incorporating the factor of mixed vehicles in future studies. This can be put in relation to the definition of operational freight transport efficiency: utilisation of space, time, vehicle, fuel, and driver. As mentioned, minimising emissions and distance unfortunately does not always provide the cheapest solution. As Bektaş and Laporte (2011) show, the cost of $CO_2$ emissions is less important than fuel or labor costs, as a decrease in distance does not always translate into a lowering of fuel or driver costs. Reversely, a cost-minimising solution is not always a solution in which energy expenditure is reduced. Extending beyond the implications of the paradox presented in this paper, the authors also include driver costs in the problem formulation, which turns out to be the most important cost component of the objective function. It is minimised by spending less time on route, which is achieved by driving faster.

Several researchers have called attention to the idea that time access restrictions may have a negative effect on the number of vehicles and total distance travelled. The paradox presented in Paper 4 neither supports nor challenges that finding, since the two routes provided have the same distance and only one lorry. However, it adds to the argument. Both time and load access restrictions might have a negative effect on fuel consumption due to factors unrelated to the amount of vehicles and distance. It might be important to consider factors such as whether the distribution centre is located on the outskirts of the city, and whether some of the customers included in the milk run are located outside the city centre, closer to the distribution centre. Since, a counterintuitive behaviour may trigger the operators to drive longer distances than necessary with a fuller load. It is nevertheless important to point out that time access restrictions fulfil a social sustainability objective; whether this is true or not for load rate access restrictions might require further studies.

Overall, it is important to consider the consequences of modifying a distribution network; local authorities should pay careful attention to how operators respond to changes to added restrictions and the different effects these changes have on economic, environmental, and social sustainability. For the operators, it is important not just to consider one performance indicator. Instead, operators in urban areas would benefit from applying multiple criteria when making strategic decisions, as suggested by e.g Nagurney and Dong (2001), so that they may minimise costs related to route choices, as well as emissions. As we have seen, this could perhaps be achieved by using a weighted objective function in vehicle routing, as also proposed by Quak and de Koster (2009) where fuel consumption (Xiao, 2012) and other costs (Bektaş and Laporte, 2011) as well as vehicles (Lin, 2011) are taken into account.

**Paper 5 – Opportunities**

To provide a framework that can easily be used for a nation or a company for calculating the key indicators, transport intensity (tkm/€), $CO_2$ intensity (g $CO_2$/€), and energy efficiency (tkm/kWh) historically, forecast future developments, and compare this with national or company goals.

## 4.3 Possible implications

This section will provide a few “counter-intuitive” examples. In the first, let us picture a transport operator and one of his/her employees creating a cost reducing (or resource-reducing) efficiency improvement of thirty per cent. The transport operator could choose to save thirty per cent on the efficiency improvement of the input or further capitalise on the improvement by increasing output (≈productivity) by 43 per cent. The example lacks a profit margin; the ex-ante relation is 1/1 of output and input for the sake of simplicity. Appendix A develops a similar reasoning. The manager may choose to save resources or to maximise profits. Numerically, because of the workings of ratios, the savings in terms of inputs are lower than the potential output increase, even when disregarding a profit margin (0,3<0,43). Put in another way, the numerator is greater than the denominator in absolute terms:

$$Efficiency\ ratio = \frac{1}{0{,}7} = \frac{\frac{1}{0{,}7}}{1} \approx \frac{1{,}43}{1}$$

**Figure 12 An example of the relationship between efficiency and productivity. A more mathematical elaboration is available in the appendix.**

Is there a link between efficiency and productivity on a company level? Is this inconsistent with common assumptions of practice and available theory of how firms usually work? The company has at least two reasons to capitalise on the improvement by increasing output from an efficiency improvement. The nominator in the right column is greater than the denominator in the left column. If a profit margin is applied, this difference is increased. Will the company save resources or capitalise on the improvement? To counter the argument, an increase in supply (output) might affect the price of the product or of the service, potentially motivating the transport operator to lower the price of transport in order to sell the excess units in terms of transportation services. This might drive transport buyers to promote production and distribution strategies (longer run) that increase the use of transport. These drivers also show that the types of policies that can curb transport demand growth could be principles that are based upon and/or influenced by the speed and price of transport towards slower, cost neutral, or even more costly transportation. The problem with this approach is that it would likely affect the economic sustainability of the transport operators. It is important to keep in mind that efficiency and cost effectiveness are an important part of the economical part of sustainability. Another potential problem with this reasoning is the linking of transport service demand growth to the efficiency improvement, as opposed to other economic factors, for example.

Here is another example from Paper 5 that points out the importance of some potential pitfalls when using ratios as indicators and looking at improvements over time. Take the example of Sweden and the energy efficiency of 4 tkm/kWh, which is the equivalent of 0,25 kWh/tkm. Now, consider that Sweden manages to improve the first indicator with an impressive 50 per cent, that is 6 tkm/kWh and the equivalent is 0,167 kWh/tkm. However, the kWh/tkm indicator “only” improves with 33 per cent in this example.

Researchers studying the development of energy efficiency indicators and $CO_2$ emissions in Finland reach the following conclusion: bulk goods sectors like forest and construction carry heavy loads on rural roads and are therefore transport intensive, but also energy efficient. A shift towards these sectors would improve energy efficiency, but at the same time increase the overall $CO_2$ emissions. A shift towards sectors with more parcelled goods, like technology and trade, would lead to lower energy efficiency, but also to a less rapid increase or even decrease of emissions (Liimatainen and Pöllänen, 2013).

*"You're trying to predict the behavior of complicated systems? Just model it as a simple object, and then add some secondary terms to account for complications I just thought of. Easy, right? So, why does your field need a whole journal, anyway? Liberal arts majors may be annoying sometimes, but there's nothing more obnoxious than a physicist first encountering a new subject." By Randall Munroe, also in Cullenward et al. (2011) http://xkcd.com/793/*

*"The best way to predict the future is to influence the conversation about what it could or should be." Corely and Gioia (2011)*

# 5 Concluding discussion

The main goal of this chapter is to interpret the empirical and theoretical findings. As appropriate, the aim of the thesis is to answer the purpose through the three research questions. Thus, a definition of the concept *operational freight transport efficiency* was created by consulting previous research literature in the area, along with asking practitioners like operators how they view this concept. The concept put in an urban setting was dissected in Paper 1 and each part was analysed in a matrix concluding whether the measures were a cost or a benefit for the actors. From the operator's point of view, many of the measures were difficult to reconcile with financial goals. The measures that are most likely to be implemented are those that offer benefits from a financial and environmental point of view. This is an important finding in the sense that previous work in this area has focused mostly on the transport buyers, where many more measures are financially viable. The conclusion of this paper is one of careful optimism; the increased focus on environmental issues and the cooperation among all parties involved could lead to positive changes in the transport sector, including city distribution. Another possibility is for the operators to become principle actors in making transport efficiency a trademark and positioning environmentally better transports as a strategic issue. There are transport operators and transport providers who have identified this business opportunity and are already moving in this direction, thereby possibly offering them a competitive advantage in the future.

## 5.1 Conclusions

After finalising the first paper, the author was momentarily feeling a bit weary. Are eco-driving, keeping the tyres at the right pressure or avoiding idling the only operational measures that the operators can do? Surely there are other possibilities? These questions paved the way for a study of cities in Europe that had implemented a low-carbon intermodal solution, with varied results that are presented in Paper 2. Currently, similar low-carbon research is going on in Gothenburg that is examining the opportunities to use busses or lorries connected to the electric grid. Also, evaluations of consolidation centres with electric distribution vehicles and cargo cycles have been made (Browne et al. 2011).

The third paper showed similar (possibilities) and dissimilar (barriers) views from the actors studied. The discussion at the workshops quickly honed in on two themes when demands were discussed in the focus groups: cost and time. The literature (e.g., McKinnon 2003a; Halldórsson and Kovács, 2010) has questioned whether the trends toward shorter lead times, more frequent shipments, and smaller delivery windows really reduces the environmental impact. Wolf and Seuring (2010) state that there is *"limited evidence of environmental issues constituting a buying criteria for 3PL services"*. However, Rogerson et al. (2011) mention that the transport operators' ability to respond to environmental demands will affect the transport buyers' interest for them as a supplier.

The difference in *priority of transport* issues in the two actors' systems might be explained by how efficiency is perceived. It is not always the case that efficiency from a transport buyers' perspective is the same as efficiency from a transport operator's perspective, since efficiency gains from a transport buyer is also about production, inventory, and marketing strategies that are experienced by the provider as being restrictive in their effort of making a more efficient transport system.

It was apparent from the workshops that actors today experience hierarchies in relation to each other, where both the transport operators and transport buyers were aware of the unbalance in the purchasing dialogue. For the operator, the challenge is to meet the demands from the transport buyer, turn these demands into a more sustainable offering, and getting paid for it. The operators would like to have a greater impact on the transport purchasing process, instead of just reacting to demands from the buyers. In terms of service and offers, the transport operators were asking for more openness and flexibility from the transport buyers in the discussion concerning new business solutions. Both actors identified following up with environmental goals as an important factor. However, the problem was discussed mainly among the transport buyers. In relation to this, Forslund and Jonsson (2009)—who study process integration where two companies agree on activities in the chain that could be related to the transportation purchasing process—conclude that a lack of supplier relationship and, to a lesser extent, the operational tools that could be converted to follow up environmental goals are the most important factors affecting this process.

This thesis is a hybrid between a monograph and a collection of papers in the sense that it also suggests an embryo of a dialectic contribution to conversation in our research community, as Huff (1999) suggests, or an attempt at prescience as Corley and Gioia (2011) put it, as well as an empirical contribution from the articles presented in the Results section. These two are linked in that they both constitute two important parts of the analysis of the research area—operational freight transport efficiency. What is not provided in the contribution to conversation is the last step of the scientific method, a validation of the hypothesis by testing the predictions against evidence. That is why this section elaborates on the implications.

Efficiency is typically connected with progress and development, the economic part of sustainability, but perhaps there is a flip side to the coin, especially in urban areas and in a freight distribution context. If efficiency might lead to an increase in production under certain circumstances with more utilisation of resources (however used more efficiently) and a potential relative increase of emissions as a consequence, it seems important to find a way to embrace efficiency and to curb a potential output growth of emissions from the transportation system. Perhaps it is time to critically scrutinise the concept as "a free lunch". Nevertheless, it is important to keep in mind that efficiency and cost effectiveness are an important part of the economic part of sustainability, as e.g. Behrends et al. (2009) conclude. However, the economic part of sustainability is only one part and to paramount any of the three pillars—profit, people, and planet—might lead to erroneous conclusions. Public transportation, for example, is financially unsustainable[8], but should we avoid it? How should the three parts of sustainability be weighed in relation to each other? Transport growth in itself is not bad, but in order to facilitate the environmental part of sustainability, it could be argued that it is worth lowering the rate at which these emissions are growing. McKinnon (2010b) proposes a disclaimer to this reasoning—that an increase in emissions from transportation might be

[8] http://people.hofstra.edu/geotrans/eng/ch6en/conc6en/revenueustransit.html.

necessary to accommodate the demand from climate change to "realign vulnerable infrastructure, strengthen flood protection, expand renewal energy and nuclear power systems and relocate population" (p 9). In this sense, the relationship between economic sustainability (with transport growth as good) and environmental sustainability (not transport growth because of emissions, at least with the current carbon intense transport system) is paradoxical.

The aim of the theoretical research's contribution to conversation has been to nuance the discussion and to show that the concept of operational freight transport efficiency is more complex than at a first glance, and probably not the panacea that we would like it to be with an inherently conflicting relationship to energy use. To paraphrase Zehner (2012), the point of this thesis has not been to label competing claims about transport efficiency as simply true or false, but to determine if these claims have manifested themselves in ways and to degrees that validate conventional transport efficiency in isolation, as an appropriate means of achieving our sustainability goals. Throughout this thesis, I have aimed to initiate a conversation, a reframing of certain narratives that are often taken for granted. *Most operational freight transport efficiency measures are likely to reduce emissions, but it is probable that the cost-reducing improvements will not lead to the desired and calculated total emission-reducing effect in the long-term.* Cost-reducing transport efficiency is an important driver to greater economic welfare, but it might have a limited impact on transport-related emission. In other words, there might be an over-estimation of the actual reducing effects these measures have. Perhaps it is time for a more balanced approach, recognising the benefits and potential costs of operational freight transport efficiency. Realistically speaking, do the managers of transport operators have the tools necessary to make these decisions? Can transport operators change? Taking a look around, on the one hand, structural constraints seem to prevent the managers from actively searching for environmentally friendlier alternatives, according to Preuss (2005), analysing the greening activities of supply chain managers. On the other hand, for a transport buying context, Lammgård (2007, p. 161) shows that from a strategic point of view, logistics managers at transport buying companies experienced more internal pressure than external pressure from customers in the purchasing process of intermodal transport, even though this solution was one of the measures that was least likely to be implemented (ibid, p. 163) compared to a range of measures.

In terms of implications, I have elaborated on three different discussions/debates; the first debate is induced or derived demand and the second is the relationship (or lack thereof) between operational freight transport efficiency and operational freight transport productivity, or the "saving qualities" of efficiency. The third debate is rebound and elasticities. This is an attempt to add to the scientific conversation in the area of sustainable logistics, a contribution that could help other conversations presented in the introduction, such as Weizsäcker et al. (1998, p. 38), rather than to rival them. It is an attempt to theoretically strengthen, rather than to weaken. However, this contribution warrants closer examination. Figure 13 presents relationships between the economic and environmental measures of some of the feedback mechanisms that play a part in a potential outcome process of more environmental impacts.

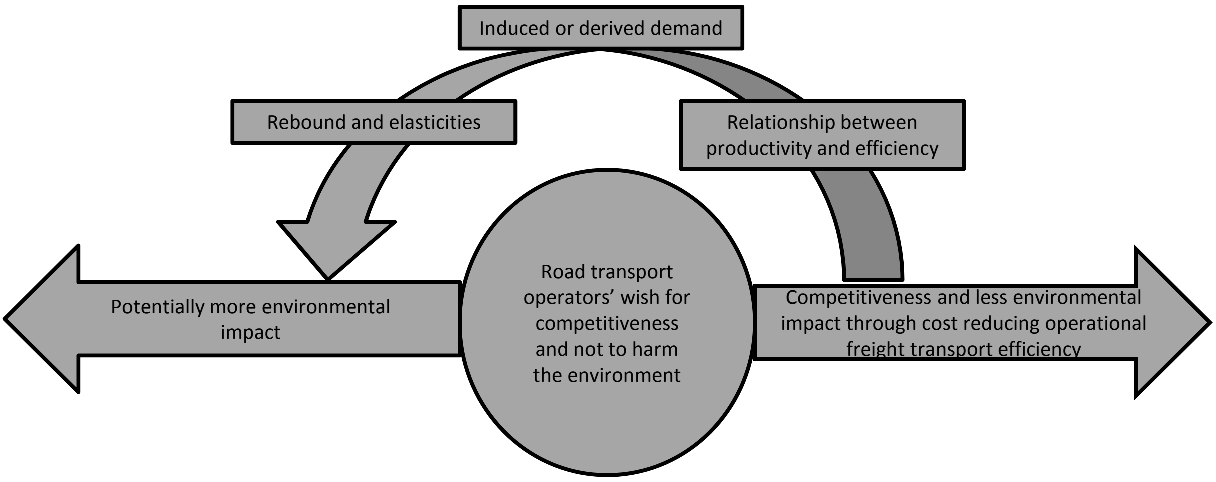


**Figure 13 A selection of different feedback mechanisms/implications.**

## 5.2 Future research

One possible future research is to compare private and freight transport by relating it to the rebound debate. It is relevant to mention the link between speed and transport volumes. According to Skinner et al. (2010), a number of studies show that the average person travels for 60-70 minutes each day. The same effect has been noted in a number of countries, has been constant over time, and seems to be unchanged by an increasing number of transport possibilities. One implication of this is that with the development of faster transport modes, demand for travel increases, measured in distance; people will be able to cover longer distances in a shorter period of time. In France, the distance travelled in the 1800s was a few kilometres, compared to 40 kilometres today. What is particularly interesting with most of these analyses are that they all are based on private transportation—the end-consumer perspective. It is reasonable to argue that some of the results of a direct rebound of 10-30 per cent could be related to the diminishing return of excessive private transport for an individual. People do not want to drive a car for more than one hour a day; therefore, to some extent the total price of transport might be of lesser significance than freight transport (for the developed world), it is argued. This reasoning would perhaps also be a qualitative argument/hypothesis for a higher total price elasticity of demand (tonkm), in absolute terms, for freight transport than for personal transport. This is also acknowledged in a paper by the European Union (Hill et al., 2012, p 19) where, in an analysis for fiscal instruments, they state that the knock-on consequences (rebounds) might be larger for the road transport sector in comparison with the private car sector. Nevertheless, this needs to be studied further. In freight transport the time preference is exchanged for a labour wage for the driver.

Possible questions for future research emanating from Paper 4 could be to explore how the business model relationship looks like between the operator, forwarder and transport buyer. Who is responsible for the improvement of load rate? Does the fuel surcharge setup protect the operators and forwarders from price fluctuations or affect the willingness to work with efficiency improvements? Exactly how prevalent is the milk-run load paradox?

Further investigation of the relationship between transport efficiency and productivity from a sustainability perspective are possible. Also, use of ratios in relations to transport efficiency could be explored. What are the problems/benefits of this approach? Which measures are, in monetary terms, cost-reducing, neutral and costly for the operators? Exploring each of the following five measures—utilisation measures of time, space, vehicle, fuel and driver—in the movement of goods and finding suitable additions to existing indicators would be potentially worthwhile. How can the operators include the social dimension of sustainability in transportation? Investigating CSR, CSI, Pareto, game theory, corporate environmental policy, environmental management systems, and eco-efficiency, etc., would consequently be of importance.

Forecast the future of energy efficiency and GHG emissions in Finnish, Swedish, Norwegian, and Danish road freight transport until 2016 and 2030 in the light of current trends, and recommend measures to achieve the energy efficiency and $CO_2$ emission targets is possible. A research proposal was submitted in collaboration with Tampere University of Technology's Transport Research Centre Verne, the Institute of Transport Economics in Norway and the Technical University of Denmark in September 2011. Funding was received from Norden Energy & Transport for 2012-1013[9] in a project called *Norfren*. Funding has also been received from Norden Energy & Transport for a network project called *NoSlone*[10].

European Commission funding in the form of a Marie Curie IAPP project was obtained together with Aston University and Insero E-mobility from 2013-2016. The scope is to research various business models for electric vehicles in a living lab setting.

[9] http://www.tut.fi/verne/norfren/

[10] http://www.noslone.com/

*"It's not as important to know where the puck is now as to know where it will be." Wayne Gretzky*

*"What then is truth? A mobile army of metaphors, metonyms, and anthropomorphisms -- in short, a sum of human relations, which have been enhanced, transposed, and embellished poetically and rhetorically, and which after long use seem firm, canonical, and obligatory to a people." Nietzsche*

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*"The battle for sustainable development will be won or lost in the urban environment".*

*Klaus Toepfer, Opening Statement to UN Habitat Governing Council, April 2005*

# Appendix A – profit function with increased output or reduced input

Consider a firm on a market with perfect competition, which transforms resources β (energy, labor, raw material etc.) into output α. Each resource has a unit cost c, and each output can be sold on the market at a price p. We assume p>c. The firm is risk neutral with profit function

$$\pi = p\alpha - c\beta.$$

We now consider two subsequent time periods. In the first period, the firm has efficiency $\alpha_0/\beta_0$. Now, due to process improvements, the firm has the possibility to realize efficiency improvements in the next period:

$$\frac{\alpha_1}{\beta_1} > \frac{\alpha_0}{\beta_0}.$$

The firm can then choose to realize the efficiency improvement through reduced resource usage, $\beta_1 = \epsilon\beta_0$, or by increased plant output, $\alpha_1 = (1/\epsilon)\,\alpha_0$, where the efficiency improvement $\epsilon$ is in the range of $0<\epsilon<1$. Since both options yield the same efficiency, we have:

$$\frac{\alpha_1}{\beta_1} = \frac{\alpha_0}{\epsilon\beta_0} > \frac{\alpha_0}{\beta_0}$$

Or

$$\frac{\alpha_1}{\beta_1} = \frac{(1/\epsilon)\alpha_0}{\beta_0} > \frac{\alpha_0}{\beta_0}$$

Let us assume a $\alpha = \beta$ relationship. The profit function then yields:

$$\pi_{output} = \frac{p\alpha_0}{\epsilon} - c\alpha_0$$

Or

$$\pi_{reduction} = p\alpha_0 - \epsilon c\alpha_0$$

We then differentiate $\pi$ with respect to $\alpha_0$:

$$\pi_o'(\alpha_0) := \frac{p}{\epsilon} - c$$

$$\pi_r'(\alpha_0) = p - \epsilon c$$

Let us assume p≥c and compare the two functions and see if the hypothesis holds:

$$p(\frac{1}{\epsilon} - 1) > p(1 - \epsilon)$$

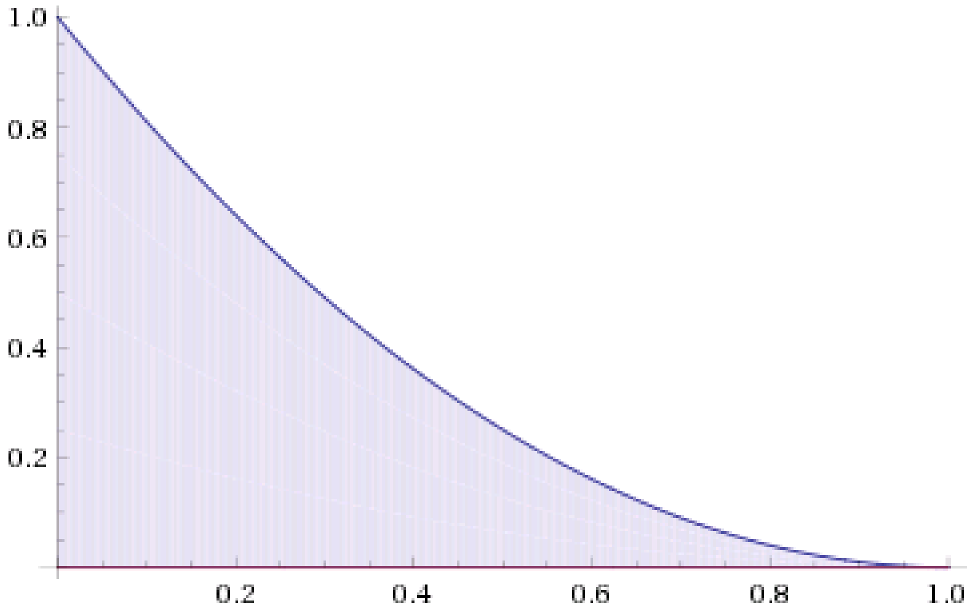
Simplifying:

$$(\frac{1}{\epsilon} - 1) > (1 - \epsilon)$$

$$\epsilon + \frac{1}{\epsilon} > 2$$

$$(\epsilon - 1)^2 > 0$$

Plotting $(\epsilon - 1)^2 > 0$, $0 < \epsilon < 1$:




Ergo:

$$\pi'_o > \pi'_r$$

$$\pi_o > \pi_r \, .$$

From a profit function perspective, increased output is better than reducing input from an efficiency improvement. It could be of importance to consider whether economic agents really would limit output growth for irrational reasons?

**Equation 1 Profit function with increased output or reduced input**

*”A traffic jam with no emissions is still a traffic jam” Bill Ford (related to Henry Ford)*

*“Probable impossibilities are to be preferred to improbable possibilities”. Aristotle also in Zehner (2012)*

# Appendix B

## Intervjumall – hållbar logistik

Denna studie syftar till att utforska transportörernas syn på hållbarhetsinriktade logistikåtgärder; åtgärder som syftar till att minska miljöpåverkan från godstransporter; antingen genom minskat behov av transporter, överflyttning till annat transportslag eller minskad miljöpåverkan från det transportslag som används idag.

Intervjuerna bidrar till att få mer kunskap om aktörernas syn på hållbar logistik i deras verksamhet och i förhållande till samhället. Det huvudsakliga syftet är att få en bild över transportörernas syn på vilka åtgärder som är mest intressanta idag och i framtiden. Vilka åtgärder har genomförts, vilka åtgärder är aktuella idag samt vilka åtgärder är mest intressanta på både kort och längre sikt? Det gäller både aktörens syn på åtgärder som aktören själv har möjlighet att genomföra samt åtgärder som anses ha potential till förbättring i samhället i stort. Närliggande frågor som också kommer att diskuteras i intervjuerna är huruvida godstransportfrågan är prioriterad i företagen, drivkrafter/hinder för att genomföra åtgärder samt vilka effekter som uppmätts av redan genomförda åtgärder. Hur aktörerna ser på framtida utvecklingen är också ett en fråga för diskussion.

Intervjuerna genererar underlag dels till en framtida enkätundersökning samt input till vilka åtgärder som anses vara intressanta att djupare analysera.

## Målgrupp

Målgruppen är transportörer.

## Genomförande

Intervjuerna kommer att genomföras av Niklas Arvidsson, Handelshögskolan, i formatet ”semi-strukturerade” intervjuer. 4-6 st intervjuer planeras (2-3 intervjuer per aktör).

Utifrån litteraturen så sammanställs en ”brutto”-åtgärdslista med effektivitetsrelation som skall ligga till grund för att strukturera åtgärderna. Utifrån denna åtgärdslista ombeds transportörerna att identifiera genomförda, aktuella och framigenom intressanta åtgärder. Åtgärdslistan innefattar strategiska, taktiska och operativa åtgärder. Därutöver innefattas även tekniska, administrativa, samverkande och politiska åtgärder. Totalt sett är de åtgärder som är förknippade med och påverkar transporttrenderna i samhället inkluderade, utifrån vad som beskrivs i litteraturen.

## Intervjufrågor

**Bakgrund**

| | |
|---|---|
| *Information om aktören* | • Vilken typ av aktör? Typ av verksamhet? |
| | • Storlek på företaget; antal anställda? Omsättning? |
| *Dagens logistik; (ej för myndigheter)* | • Var ligger era produktionsanläggningar/terminaler I GÖTEBORG? |
| | • Hur mycket transporter genererar företaget? Finns mätetal? |

**Åtgärder**

Vi har funderat kring detta med transporteffektivitet för att att minska miljöbelastningen av ett företags transporter. Det finns ett antal parametrar som vi tror är viktiga. Jag kommer nu att fråga om ni jobbar med dessa.  Antagligen finns det flera sätt än dessa som ni jobbar med som du gärna får berätta om sen.

-Har ni arbetat -eller kommer att arbeta- med eco-driving? Hur? Varför? Effekt? Hur jobba med framåt?

-Har ni arbetat -eller kommer att arbeta- med fordonens bränsleeffektivitet eller fordonsförbättringar? Hur?

Etc

Gå igenom nedan och försök ta reda på vad dessa åtgärder har för status hos operatörerna.

| |
|---|
| Ecokörning |
| Fordonsförbättringar |
| ITS ruttplanering |
| Fyllnadsgrad & backhaul |
| Förpackningseffektivitet |
| Ordereffektivitet |
| Modalmöjligheter |
| Regleringar och incitament |
| Samarbete i distribution |

Har ni jobbat med andra åtgärder som jag inte har nämnt här? Vilka? Etc (samma frågor som ovan)

• Finns det åtgärder som företaget/organisationen valt bort?

• Vad var anledningen till det?

**Framtid**

Vilka åtgärder anser du vara viktiga för utvecklingen av ett hållbart transport och logistiksystem för samhället i stort?

Vilken aktör tror du har störst chans att påverka utvecklingen i rätt riktning? Transportör, speditör, transportköpare och/eller myndigheter?

**Att tänka på under diskussionen om effektivitetsåtgärderna:**

- Har ni genomfört åtgärder historiskt? När?
- Vad var drivkraften för att genomföra dessa åtgärder?
- Vilka effekter har ni sett av den genomförda åtgärden? (Både kvantitativa och kvalitativa.)

---

- Har ni planerat att genomföra åtgärder idag eller inom de närmaste 1-2 åren?
- Vad är drivkraften för att genomföra åtgärden?
- Vilka effekter tror ni att ni kommer att få av den genomföra åtgärden? (Både kvantitativa och kvalitativa.)

---

- Finns det åtgärder som företaget/organisationen valt bort? (se ovan)
- Vad var anledningen till det? (se ovan)
- Vilka åtgärder är aktuella att genomföra på längre sikt?

*-Transportation is really not a sexy topic, is it?*
*-Unless you like it quick and dirty?*

*"There is more to life than increasing its speed" (Mahatma Gandhi)*

## Appended papers

**Paper 1: Arvidsson, N., Woxenius, J., Lammgård, C. (2013) Review of Road Hauliers' Measures for Increasing Transport Efficiency and Sustainability in Urban Freight Distribution Transport Reviews: A Transnational Transdisciplinary Journal, 33:1, 107-127**

**Paper 2: Arvidsson, N. and Browne, M. (2013) A review of the success and failure of tram systems to carry urban freight: the implications for a low emission intermodal solution using electric vehicles on trams, European Transport \ Trasporti Europei, Issue 54, Paper n° 5, ISSN 1825-3997**

**Paper 3: Santén, V. and Arvidsson, N. (2011) Road freight transport efficiency and less environmental impact – the perspectives of transport buyers and operators, Published in the proceedings and presented at Nofoma, Harstad, Norway, June 9-10, 2011.**

**Paper 4: Arvidsson, N. (2013) The milk run revisited: A load factor paradox with economic and environmental implications for urban freight transport, Transportation Research Part A, 51, 56–62**

**Paper 5: Liimatainen, H., Arvidsson, N., Beate Hovi, I., Christian Jensen, T., Nykänen , L., Kallionpää, E., (2013) Road freight energy efficiency and CO2 emissions in the Nordic countries, accepted for presentation at WCTR, 2013, July 15-18**


Transport Reviews: A Transnational Transdisciplinary Journal
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/ttrv20

# Review of Road Hauliers' Measures for Increasing Transport Efficiency and Sustainability in Urban Freight Distribution

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Version of record first published: 23 Jan 2013.

*Transport Reviews*, 2013
Vol. 33, No. 1, 107–127, http://dx.doi.org/10.1080/01441647.2013.763866

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(*Received 2 January 2013; accepted 3 January 2013*)

ABSTRACT *This paper analyses a set of measures for transport efficiency improvements from the perspective of the road haulier, particularly regarding improvements suitable for urban distribution and their effects. The first part of the paper addresses literature within the area of transport efficiency. The second part reviews potential transport efficiency improvements with respect to environmental impact and the number of actors involved in the decision. The third part presents results from interviews with the CEOs of two road hauliers regarding their opinions of the transport efficiency measures. Finally, the conclusions about transport efficiency measures are summarized in a matrix, taking into account whether these measures can be considered as costs or benefits for the actors involved. The results show ambiguous and often intricate relations with regard to costs and benefits for the actors in the system. They also explain part of the inertia to change within the freight industry. However, an increasing number of transport operators are now offering more sustainable transport solutions and this service might gain them a competitive advantage in the future.*

**Keywords:** transport efficiency; sustainability; urban freight distribution

## 1. Introduction

Freight transport is important in today's society, creating economic and social benefits. Ships, aircraft, trains and lorries support globalization and distribute commodities to locations near us. We cannot do without these services, but we pay a cost in the negative side effects in terms of emissions, accidents, visual and audio nuisance, barrier effects and not the least, time loss because of congestion. With the recent downturn in the global economy, there is growing concern that environmental issues are being neglected in favour of economic aspects. However, it could be argued that there are no alternatives to the redirection of transport systems towards economic, social and environmental sustainability.

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Urban freight distribution is often provided in inefficient ways, and the industry is particularly resistant to change (see, e.g. Behrends, Lindholm, & Woxenius, 2008). A French study (discussed in Small & van Dender, 2007) finds that the marginal external congestion costs of urban traffic are 10 times higher than inter-urban traffic. Moreover, there is no lack of ideas for improvements and development projects, but rather a lack of persistence in continuing tests into a steady state and learning from earlier pilot tests. A wide range of trials and pilot projects have been carried out by commercial actors themselves or as projects with public funding at the local, national and European Union (EU) levels. Many projects have been successful, but the mechanisms of analysis, learning and implementation are not functioning to satisfaction (Lindholm, 2013). As Uherek et al. (2010) put it, "Although transport problems are well identified and [some of] their solutions are also known and accepted, there is a lack of action on implementation" (p. 4798). Access to and understanding of these measures and their effects is particularly important for Europe's hundreds of thousands of small and medium road hauliers lacking their own budget and departments for R&D, negotiation power and, at times, the vision of how to operate in a better way.

The purpose of this paper is to review improvement and efficiency measures suitable for urban distribution and comment on their effects. This is examined from the perspective of road hauliers and illustrated in a case study of the two dominant pick-up and delivery hauliers in Gothenburg. The analysis of potential measures is structured along the actor categories that need to be involved, starting with the measures road hauliers can implement themselves followed by measures involving shippers, forwarders, other transport operators and policy makers.

The paper is divided into four parts. The first part of the paper is a literature review in the field of operational transport efficiency, which is not exhaustive. The second part reviews potential transport efficiency measures with implications for the environmental performance of road haulage. The third part is a case study presenting empirical findings from structured interviews with two CEOs of pick-up and delivery hauliers in the parcel and general cargo segment. The fourth part summarizes the transport efficiency measures in a matrix, taking into account whether they are mainly costs or benefits for the involved actors.

After the initial literature review, the identification and selection of transport efficiency measures relevant for road hauliers operating in an urban context relied on a series of 12 semi-structured interviews with experts representing transport providers, forwarders, shippers and authorities. The transport providers included medium-sized road hauliers offering services on a regional market and rail operators. In the forwarder segment, the interviewed experts represent global players with a truly extensive market offer regarding spatial coverage, consignment sizes and transport time. The shippers were large Swedish firms purchasing a substantial amount and a wide selection of transport services who were thus both very familiar with and powerful in the logistics market. They were selected from different industries including food, pulp, agriculture, construction, vehicle production, clothing and personal care products. The public sector was represented at the municipality level by the Traffic and Public Transport Authority of Gothenburg and at the national level by the Swedish Road Administration, now merged with its rail counterpart to become the Transport Administration. The final selection included a portion of logical deduction based on personal experience from transport research and advice to the industry and the public sector.

Sweden is a large and sparsely populated country, which has led to an oligopoly in the general cargo market where the two dominant players typically have controlled 80% of the flows. The forwarders are now part of German groups DB Schenker and DHL, respectively, and maintain a strong grip on the consolidation market, with some challenge by the logistics arm of PostNord, which is the merger of the Swedish and Danish post offices. The empirical basis for the case study in part three was structured personal interviews with CEOs of the pick-up and delivery hauliers who act as subcontractors to DB Schenker and DHL in Gothenburg. They were selected as case study companies based upon their sizes and dominant positions in the local pick-up and distribution market. They are considered as representatives for the segment and choosing two similar road hauliers facilitates comparison since the same questions were asked to both CEOs. Both CEOs used the opportunity to comment on the interview transcripts in order to avoid misinterpretation and to increase reliability. The road hauliers were interviewed in their Swedish context, although the aspects covered should be rather universally relevant to city distribution.

## 2. Transport Efficiency and the Environment

The past decades have shown a growing awareness of environmental problems. In the 1980s and 1990s acid rain and the diminishing ozone layer were of public interest, followed by an increasing awareness of climate change and some successful measures to counteract these effects. In relation to transport efficiency and the numerous measures that can be used to promote more environmentally sustainable distribution, those which yield both economic and environmental benefits command the greatest support and are the easiest to implement (McKinnon, 2003).

On an EU level, congestion is the external transport effect that costs the most for society. Road congestion costs approximately 1% of the GNP in the EU (European Commission, 2001). This corresponds to 123 billion euros in 2007, approximately the same size as the total EU budget (European Commission, 2009). Road hauliers both contribute to and suffer from this problem. From a more national perspective, fuel economy standards, vehicle emission standards and fuel quality standards have been the main regulatory measures taken by governments (Timilsina & Dulal, 2009).

One interpretation of transport efficiency is producing a service with less resource consumption without reducing the logistics performance in terms of costs and delivery service (Aronsson & Huge Brodin, 2006). Costs and the environmental impact often point in the same direction, i.e. a solution for lower cost for transport also reduces pollution. This paper explores some of the reasons why this might not always be the case, (e.g. optimizing transport efficiency might be at the expense of overall logistics costs).

The impact of transport efficiency on the environment can be analysed in a bottom-up vehicle approach (Léonardi et al., 2008) where the focus is the vehicle and its driver (e.g. reducing mileage, decreasing the energy and $CO_2$ intensity per transport unit and changing driver behaviour). A variety of mainly vehicle-related performance measures, or key performance indicators (KPIs), try to link the amount of goods produced or consumed to freight transport. The handling factor ratio converts the weight of goods produced in a system to freight tonnes lifted and can thus be used as a measure of the number of links in a supply chain. The average distance of haul multiplied by the number of links (≈handling factor), the transport work, can be determined by transferring the tonnes lifted into tonne-kilometres. The modal split specifies the amount of tonnes carried or tonne-kilometres carried out by different traffic modes. For road transport, the most common traffic mode within the EU, two more measures could be identified—the average load factor on trips and the proportion of kilometres run empty, partly explained by the back-haul effect. All these measures combined with fuel efficiency result in an analytical tool to improve transport efficiency by improving the ratios above (e.g. McKinnon, 1996, 2003; McKinnon & Piecyk, 2009).

Adding a time and fuel dimension, some of these ratios can be translated into vehicle loading, empty running, fuel efficiency, vehicle time utilization and deviations from schedule (McKinnon & Ge, 2004). A similar presentation for city distribution with an extended focus on time-related performance indicators such as speed per delivery round is presented in Allen et al. (2003). All these measures have different dimensions of output such as tonnes, vehicle kilometres and tonne-kilometres (e.g. De Jong, Schroten, van Essen, Otten, & Bucci, 2010).

Using measures of traffic work measured in vehicle kilometres in relation to transport work measured in tonne-kilometres requires care due to the strong effect of vehicle sizes. KPIs such as load factor and directness can easily be manipulated by using smaller vehicles or dispatch vehicles first when full but not necessarily fulfilling the shippers' demand in an efficient way as investigated by Woxenius (2012) and Kalantari (2012).

A review of the literature concerning freight vehicle activities in urban areas, with a focus on economic, social and environmental considerations of these activities and suitable transport efficiency measures is presented in Browne, Allen, Steele, Cherrett, and McLeod (2010b) and Whiteing, Browne, and Allen (2007). Sustainable urban distribution is addressed from a policy level by Danielis, Rotaris, and Marcucci (2010), Anderson, Allen, and Browne (2005), Muñuzuri, Larrañeta, Onieva, and Cortés (2005) and Allen et al. (2003). Other studies focus on particular parts or measures such as light goods vehicles (Browne, Allen, Nemoto, & Visser, 2010a; Browne, Allen, Woodburn, & Piotrowska, 2007), low emission zones, etc. (Allen et al., 2003; Browne, Allen, & Anderson, 2005) or studying the survey techniques used in urban freight distribution (Browne et al., 2010b) and summarizing the UK research in urban freight over the past 30 years, comparing similarities and differences.

One perspective, other than that of the driver or vehicle, is to include not only operational measures but also policy/regulations and organizational measures; they could be examples of a macro perspective complementing the traditional micro perspective (e.g. Santén & Blinge, 2010). A division along the lines of operational, tactical and strategic levels is yet another way of approaching the concept. Aronsson and Huge Brodin (2006) consider how transport efficiency is analysed with respect to micro and macro measures, presented in a matrix separated by changes in technology and structural domains. The decision hierarchy is divided into operational, tactical and strategic levels to illustrate environmental impact at different levels of the supply chain. The study proposes a holistic logistics perspective on structural changes but does not consider the different actors in the supply chain, only the shipper. They conclude that nearly all measures lead to both reduced logistics costs and environmental impact.

The forwarders depend on how their customers value environmental aspects, which varies among shippers. This was shown by a large survey in 2003, including answers from 567 transport buying firms in Sweden, where environmental aspects had a higher priority in large-sized companies as well as in manufacturing companies rather than in wholesale companies (Lammgård, 2007). This means that the environmental performance of a transport is an added-value service to some segments of shippers, and some of the largest logistics service providers (LSPs) now offer services with better environmental performance.

A somewhat critical perspective, represented by Rodrigue, Slack, and Comtois (2001), focuses more on the conflicting relations of green logistics, costs (environmental costs are often externalized), time/flexibility (extended production, distribution and retailing structures consuming more space, energy and emissions), network (concentration of environmental impact around major hubs and along corridors), reliability (modes used are the least environmentally efficient—lorries and air), and warehousing (inventory shifted in part to roads, contributing to congestion and space consumption) with the argument that reducing logistics costs does not necessarily reduce the environmental impact. Others suggest a more long-term perspective in the use of logistics performance measures (McIntyre, Smith, Henham, & Pretlove, 1998).

## 3. Review of Measures for Increasing Transport Efficiency

The focus of this paper is on the road hauliers together with the actors affecting the hauliers' process of increasing energy efficiency in transport. Therefore, it is necessary to consider not only operational measures—day-to-day activities—but also those macro or strategic measures that affect the road haulier directly or indirectly in an urban setting.

The road haulier, more generically called a transport operator, is the actor physically moving the goods. There is often a middleman between the road haulier and the shipper, typically called a freight forwarder or LSP, often providing additional logistics services such as consolidation in terminals, information processing and warehousing. In the remainder of the paper this organization will be referred to as a forwarder.

As indicated above, most transport efficiency decisions depend on or are affected by other stakeholders than the road haulier. In order for these measures to be implemented properly and to reap the benefits of energy efficiency and cost reduction, co-operation between the actors within and outside the supply chain is in focus. Therefore, the transport efficiency measures are divided into three main groups. These are internal transport efficiency measures (to the haulier), joint transport efficiency measures with the customers (the forwarder or the shippers) and joint transport efficiency measures with the public sector. These measures are neither mutually exclusive nor collectively exhaustive, but are instead an attempt to encompass some of the literature within transport efficiency and logistics areas where the effects on transport efficiency may be increased or decreased. These three groups of transport efficiency measures are discussed below.

### 3.1 *Internal Transport Efficiency Measures*

This section outlines two measures that the road hauliers can implement on their own or in cooperation with suppliers of vehicles and energy carriers. The reason for not using joint efforts with suppliers as its own category is that each of the 600,000 road hauliers in EU-27 (European Union, 2012, p. 25) has an insignificant influence on the supply of vehicles and fuels, although some are involved as commercial test beds for vehicle and fuel manufacturers. In practice, road hauliers select vehicles and fuels offered in the open marketplace rather than developed in close collaboration with manufacturers.

3.1.1 *Driver efficiency.* Providing eco-driving training can improve fuel economy and reduce the environmental impact per vehicle and driver significantly, where the reduction of fuel consumption can be up to 25–30% (Blinge & Svensson, 2006), even though the long-term savings are closer to 3–6% (Swedish Road Administration, 2004). Nevertheless, eco-driving seems to be more effective if combined with additional driver incentives, saving 2–12% (Hedenus, 2008). Today, many lorry drivers go through some kind of driver efficiency training. Maintaining the vehicle's technical standard, using the right tyre pressure, travelling at a suitable speed and minimizing vehicle idling contributes to fuel economy. In urban freight distribution, idling situations occur regularly and are not always driver related. According to McKinnon (2007) the increase of traffic congestion, in combination with stricter working time regulations for lorry drivers, could have a negative impact on delivery flexibility that is required to locate, collect and deliver suitable backloads. The stricter working time regulations' adverse effect is later shown to have little overall effect (McKinnon, Cullinane, Browne, & Whiteing, 2010, p. 209). Implementing these measures leads to a cost reduction for the road haulier and consequently lower transport costs for all actors under perfect market competition conditions.

3.1.2 *Vehicle efficiency.* A rule of thumb is that the vehicle, the driver and the fuel each account for a third of a Western European long-distance road haulier's costs. This is in line with Freight Best Practice (2009), which claims that fuel accounts for approximately 30% of a road haulier's operational expenses and fuel consumption obviously attracts attention as a major cost that can be affected. In a series of case studies presented by Freight Best Practice, the road hauliers used monitoring systems to observe fuel consumption with positive results and vehicle manufacturers have long prioritized improving fuel economy. Between 1980 and 2006, fuel consumption has been reduced by almost 40% (Mårtensson, 2006) for the same type and size of vehicle. According to Hedenus (2008), Volvo Truck estimates that lorries will be 15% more efficient in 2020, although Hedenus also argues that the greatest improvements have already been achieved with more or less stagnated improvements since the early 1990s. A contributing factor is vehicle emission standards, where a decrease in $NO_x$ increases fuel consumption (McKinnon, 2010). Hybrids and electrical vehicles would make a significant contribution to energy efficiency (Åkerman & Höjer, 2006) and are best suited for short urban freight services. Aerodynamic improvements and alternative fuels are also important factors for improved efficiency.

In the UK, light goods vehicles with less than 3.5 tonnes of gross weight have grown in both vehicle numbers and activity levels, and much of this growth is obviously found in urban areas (Browne et al., 2010a). This trend is also identified in Sweden by SIKA (2009) and Trafa (2012). The last rows in the tables show the calculated change between the years. Note the increased use of alternatives to petrol such as ethanol, diesel and gas. A decrease in the use of electric vehicles up to 2008 is significant, even though the numbers are relatively small Tables 1 and 2.

**Table 1.** Million kilometres driven by light lorries in Sweden, by fuel, 1999 and 2008, SIKA (2009)

| At the end of | Petrol | Diesel | Electricity | Ethanol-hybrid/E85 | Other hybrids | Natural gas/bio gas | Other | Total |
|---|---|---|---|---|---|---|---|---|
| 1999 | 2441 | 1844 | 1.7 | 0 | 3.7 | 0 | 0.2 | 4290 |
| 2008 | 1154 | 6368 | 0.8 | 7.3 | 0.9 | 37 | 0.1 | 7569 |
| Change | −53% | +245% | −53% | + | −76% | + | +25% | +76% |

**Table 2.** Number of light lorries (<3.5 tonnes) in use by type of fuel and permissible maximum weight, 7 by year 2002 and 2011 (Trafa, 2012)

| At the end of | Petrol | Diesel | Other (gas, ethanol, hybrid, electricity) | Total |
|---|---|---|---|---|
| 2002 | [166 249] | [165 735] | 793 | [332 777] |
| 2011 | [81 687] | [378 520] | 7326 | [467 533] |
| Change | −49% | +228% | +924% | +41% |

Improvements in fuel efficiency or vehicle efficiency would lead to improved economic efficiency for the road haulier unless the gains are offset by the higher investment cost of a lorry adapted to alternative fuels and the difference in fuel price. It should be noted, though, that compared with long-distance road haulage, the fuel's share of total costs is far less for urban distribution with comparatively short annual driving distances. Instead, labour costs constitute the bulk of costs since the vehicle costs are also comparatively low with small, standardized and mass-produced vehicles. The load factor and the back-haul problem could also be seen as a time- or sales-related problem, and, therefore, partly an internal measure.

### 3.2 *Joint Transport Efficiency Measures with the Customers*

This section presents six transport efficiency measures that the hauliers can take first after consulting with the customers in terms of shippers and forwarders.

3.2.1 *Intelligent transport systems and route efficiency.* An effective way to reduce environmental impact is route planning; the use of information and communication technology (ICT) is an often-mentioned measure for facilitating better planning and control of transport activities. ICT adapted to the transport sector are often referred to as intelligent transport systems (ITS). Today ITS offer real-time information and they are readily available at affordable prices and its efficient use could result in significant cost reductions for road hauliers.

From the road haulier's perspective, a significant pressure from vehicle suppliers, the government, forwarders and shippers to incorporate these new applications into their operations has put additional strain on their already tight profit margins. They often cannot develop their own technical competence. Consequently, they risk being forced to invest in several costly systems with overlapping functionality in order to fulfil certain needs of their strong counterparts (Stefansson & Woxenius, 2007). In that case, this could incur a cost for the road haulier, which are not offset by additional revenues. The European Commission and project partners have spent significant resources in development and standardization of ICT and ITS for freight transport (e.g. in the projects EASYWAY, SMARTFREIGHT, FREIGHTWISE, e-Freight, EURIDICE and iCargo). The ITS Action Plan adopted (European Parliament and the Council, 2010) also aims at reducing this risk. The ITS and route efficiency measure brings benefits to all actors, but the outcome is somewhat more uncertain for the road haulier because of the risk of investing in ITS without being able to implement and use them efficiently.

3.2.2 *Utilization efficiency—the back-haul effect*. One third of the road transport distance is run empty, according to a study by McKinnon (1996). This phenomenon is known as the back-haul effect, empty running or unbalanced flows. The problem occurs when the demand is asymmetric in volume at a certain time. The problem is universal. For example, oil tankers to Kuwait are emptier than those from Kuwait, and commuter traffic is denser in the morning into cities than away from cities. It is a common argument from politicians that investments in new roads are not needed because the hauliers must first utilize the slack capacity in the non-filled lorries. The market pressure to work on lessening the back-haul effect is very strong, since the availability of backloads is an important factor for determining the profitability of a transport operator. A common measure is to apply different pricing measures to attract goods to create a balance.

McKinnon (2007) argues that research shows a decline in empty back-haul mainly as a result of lengthening of freight journeys, growth of reverse logistics, increase in number of load matching agencies and Internet freight exchanges and various corporate initiatives to counter the back-haul effect. Vierth and Mellin (2008) exemplify this with the Swedish supermarket chain ICA, which has decreased the number of empty backloads by vertically integrating transport with an increase in consolidation in ICA's warehouses and collecting inbound supplies with returning delivery vehicles. On the other hand, when ICA takes control of its flow of soft drinks, the efficiency for Coca Cola might go down. Nevertheless, some measures to eliminate the back-haul effect which would potentially benefit all actors might lower the frequency and increase the lead time for shippers.

3.2.3 *Utilization efficiency—load factor*. The load factor is a measurement of vehicle utilization that obviously has attracted the attention of researchers and the industry for many years. The European Environment Agency (2006) concludes that the average load factor has declined for heavy goods vehicles between the years 1990 and 2004. The results of studies of the load factors in Sweden vary between 30% and 70% (Blinge & Svensson, 2006). In theory, this implies that the environmental impact of road transport could roughly be cut to half if more loads were consolidated. In reality, however, this is a very difficult task. For instance, the load factor is typically measured in weight but many vehicles are full in terms of their volume capacity before they reach their maximum weight. Another example is route imbalances where a distribution vehicle is successively emptied during the delivery route.

Furthermore, from a societal perspective, an increase in load factor is almost always something to strive for, and examples of projects aiming at increasing the load factor are plentiful. In one such project, the Swedish Exhibition & Congress Centre situated in the Gothenburg city centre has saved more than one-third of the deliveries by the use of a c/o address to a forwarder's terminal on the city rim from where the flow to exhibitions is coordinated (The Swedish Exhibition & Congress Centre, 2008).

The load factor in city distribution is very dependent on delivery time restrictions, the number of stops along the route and the time available for loading the vehicle carefully. A high load factor would be positive for society since more service can be produced with less traffic. For the road hauliers, however, an increase in load factor could mean a decrease of delivery trips and thus a potential loss in sales.

3.2.4 *Packaging efficiency.* The volume and weight of goods transported are a result of the design of transport and product packaging material and, ultimately, the product itself; therefore packaging efficiency is considered an important factor. Significant improvements can be achieved in packaging (Samuelsson & Tilanus, 1997). The home furnishing company IKEA is often used as an example of a company that successfully works with packaging optimization; smaller companies do not have the same capacity to enforce these measures. On the one hand, there is no real incentive for the operator to present packaging efficiency improvements to their customers, given that this would mean a potential loss in sales from a short-term perspective since the actual revenue generating tonne-kilometres would go down. However, from a more realistic long-term perspective, the operators might feel pressure to come up with these improvements in order to avoid losing the customer to a competitor who might offer the same improvement. Packaging efficiency has a positive effect on the tonne-kilometre and could also result in a decrease in the number of shipments for the road haulier and a potential loss in sales from a short-term perspective.

3.2.5 *Delivery efficiency.* The design of ordering systems obviously affects transport efficiency. The diffusion of the use of just-in-time (JIT) strategies might increase emissions from transport (Halldórsson, Kotzab, & Skjøtt-Larsen, 2009; McKinnon, 2007; McKinnon & Piecyk, 2009; Rodrigue et al., 2001). This is also true when combined with geographical changes in supply chains (Hesse & Rodrigue, 2004).

The arguments behind JIT strategies often relate to benefits associated with lower inventory levels, but the price to pay is smaller order quantities and an increase in traffic work. The studies that support this theory are mainly qualitative (Schonberger, 2007; Yang, Yang, & Wijngaard, 2005). More quantitative studies such as Nathan's (2007) are needed on the effects of sub-optimization, pushing the activities up the supply chain and adding extra nodes and links to the chain. Her study also uses a more holistic approach, taking into account both production and transport aspects of JIT. Another way to lessen the impact of the order is by using the "nominated day delivery" system (McKinnon, 2007). Road hauliers could achieve higher levels of efficiency by encouraging shippers to adhere to a certain delivery timetable. For city distribution, however, this is not always an easy task. Higher frequency of shipments is a trend that is in large part due to less storage capacity in city stores brought about by high costs of rent and a priority for using the space for sales. The retailers also demand reliable and frequent deliveries to utilize their staff and loading dock efficiently. A use of JIT strategies and small inventory in a city environment could make the supply chains more vulnerable to congestion (Danielis et al., 2010).

One solution to these inefficiencies includes wider time windows for road hauliers (Boyer, Prud'homme, & Chung, 2009) and an increased acceptance of waiting for consolidation or return loads. By offering lower environmental impact as a value-added service, forwarders could counteract these environmental inefficiencies. One example of this is the Danish forwarder DSV, which has re-branded the classic economy cargo with longer lead time as a sustainability service to its Swedish customers, which are used to expecting overnight deliveries except for transport to and from the far north. Shippers' willingness to use the service is thus uncertain, and transport researchers have not contributed with an abundance of freight value of time studies, as investigated by Feo-Valero, García-Menéndez, and Garrido-Hidalgo (2011) and Zamparini and Reggiani (2007).

For urban freight distribution, there are signs that time windows are getting stricter rather than being more relaxed. The reason is that more cities implement stricter time regulations for city distribution, mainly in order to reduce traffic congestion during peak traffic hours (Deflorio, Gonzalez-Feliu, Perboli, & Tadei, 2012). These time-window trends call for careful analysis, since the driving forces and effects are different. An extensive review is available in Quak (2008), who concludes that although time-window restrictions contribute to social sustainability by improving liveability, safety, access to the city centre for customers, and noise reduction, this comes at a cost of financial and environmental sustainability. More research on the correlation between transport efficiency measures, other logistics costs and transport price is needed; for example, hauliers have identified problems of recovering costs for waiting from shippers.

Measures that increase order efficiency benefit society and shippers, but they will reduce benefits to road hauliers and forwarders, since this will ultimately lead to a decrease in frequency and speed in the system, therefore increasing utilization and perhaps decreasing the number of transport movements and therefore transport revenues.

3.2.6 *Mode efficiency*. Mode efficiency relates to means by which traffic modes freight is transported. European transport statistics reveal that transport by rail and inland waterways has decreased in favour of more "reliable" and time-efficient transport such as road and air. In terms of transport and energy efficiency, a modal change towards an increased use of rail and sea is often preferable, but the sustainability of fast, short sea shipping services can be challenged as done by Hjelle (2010).

Goods transported over longer distances are more likely to undergo a modal shift than short-haul urban freight distribution. Worth noting is that some cities in Europe—Amsterdam, Dresden, Zurich, and Vienna—have implemented city distribution by using the existing tram system; however, this has been with mixed success (Arvidsson, 2010). The use of bicycles in the last leg of distribution from an urban consolidation centre was also investigated by Browne, Allen, and Leonardi (2011). From the road haulier's perspective, a move from lorry to tram or bicycle is considered a cost or a loss in sales, unless it is part of a multimodal service.

### 3.3 *Joint Transport Efficiency Measures with the Public Sector*

While this paper addresses efficiency measures from a road haulier's perspective, it is also important to mention that in cases of conflicting corporate interests, local authorities can act as brokers using regulations and incentives. This was tested in the EU-project START (2009), in which the cities of Gothenburg, Bristol, Ravenna, Riga and Ljubljana worked together to develop efficient access restrictions, consolidation of deliveries and incentives to change the distribution of goods into more environmentally efficient ways. The public sector has a particular interest in achieving efficiency in urban freight transport, and, therefore, it is common that regulatory measures are implemented. However, the effects of these measures are not always evident as investigated by Quak (2008).

3.3.1 *Regulatory and incentive-based measures*. Policies in urban freight transport are frequently implemented by local authorities. Studies show the complex effects on supply chains (Danielis et al., 2010; Muñuzuri et al., 2005) since the effects on stakeholders and environmental outcomes vary. For instance, the access-time restrictions might result in the use of more vehicles and drivers, and the vehicle-type restrictions (in terms of dimension, weight, engine or fuel type) might increase fleet size and increase renewal rate. Traffic regulations concerning access to loading places and fiscal policies might increase transport costs and decrease load factors. Urban consolidation centres might increase consignment costs but increase consolidation and pave the way for the use of more environmentally efficient vehicles (Danielis et al., 2010).

A number of different regulatory- and incentive-based measures have been implemented in European cities. The trend is towards more consolidation, coordination and regulations paired with incentives. A number of European cities have introduced environmental zones (OECD, 2003) and low emission zones that help one to accelerate the introduction of cleaner vehicles (Browne et al., 2005).

Regulation can also be designed with incentives. Copenhagen introduced a licensing system where road hauliers fulfilling the required 60% load factor were given access to preferred loading and unloading points. The road hauliers were generally satisfied with the system and one out of five participating transport companies changed their planning behaviour (OECD, 2003). The City of Gothenburg tried a similar system in which a load factor of 60% or deliveries to more than 50 consignees gave access to special loading zones and dedicated bus lanes. The test gave mixed results and it was terminated in 2007 (Olsson & Woxenius, 2012). In 2008, strictly enforced time windows were implemented in a smaller area in Gothenburg's city centre. Close collaboration between the Traffic and Public Transport Authority, the Police and road hauliers were used to implement and enforce the regulations, resulting in a 55% decrease in heavy-duty vehicles in less than a year. However, a negative impact was that the drivers had to circulate more to conform to the time-window restrictions. Furthermore, access restrictions in time or space could limit some market activities, while promoting others by giving way to pedestrians. Researchers warn against potential suboptimal situations by enforcing too strict time restrictions (Browne et al., 2005; Danielis et al., 2010; Deflorio et al., 2012; Quak, 2008). Another incentive-based measure is to allocate road slots to individual vehicles or road space rationing, which is currently realistic only for selective bottlenecks such as bridges, tunnels and bus lanes. ICT solutions can support the prioritization of which lorries could use the scarce capacity, as was developed and tested in the EU-project SMARTFREIGHT.

Collaboration with local stakeholders and local authorities in a city is another initiative and the City of Gothenburg is one example. A few years ago, the "Freight Group" started as a local collective effort with the Traffic and Public Transport Authority and the Swedish Road Haulage Association. The aim of this network is to discuss various future regulations and incentive measures with stakeholders such as hauliers, real estate owners, retailers and their local interest organization and lorry manufacturers (START, 2009). A similar initiative in the UK is the Freight Quality Partnership (Allen, Browne, Piotrowska, & Woodburn, 2010).

Local traffic regulations should not always be considered as a fixed variable in the long run. Local authorities have demonstrated interest in co-operation with the transport sector and other stakeholders in the issues of city distribution. Local authorities, and thus the society, might gain from regulatory and incentive efficiency measures, but the outcomes are more uncertain for the other three groups of actors (road hauliers, forwarders and shippers).

3.3.2 *Coordinated distribution*. In theory, efficiency can gain considerably from consolidating different types of consignments and increasing cooperation between competitors, referred to as "collaborative transportation" by Gonzales and Salanova (2012), but this practice is controversial since it risks violating competition laws. It is often advocated and used in very scarcely populated areas and for deliveries in historic city centres where coordinated transport might offset the risks of eliminating free market forces. Still, road hauliers and forwarders often show signs of resistance to cooperating with competitors. According to Blinge and Svensson (2006), smaller road hauliers do not easily collaborate in the ways required and coordinated distribution projects are often discontinued. Furthermore, some shippers do not allow forwarders to consolidate with goods for their direct competitors. Own-account transport is much less efficient compared to third party or road hauliers, if measuring utilization per unit of vehicle used (Danielis et al., 2010). The effect of coordinated distribution would have a positive impact, especially on the urban freight load factor, addressing the "last mile" or "final leg" problem. On the other hand, it would also decrease the total number of trips for the road haulier—society benefits, but the competitive laws may need to be revised.

## 4. The View of Two Swedish Road Hauliers

Gothenburg is the second largest city in Sweden with some 900,000 inhabitants, of which 500,000 live in the inner city area. As subcontractors to the forwarders dominating Sweden's oligopolistic transport market for consolidated goods, the road hauliers GB Framåt and TGM dominate the distribution of general cargo and parcels in Gothenburg. According to the CEO of TGM, "[TGM] and GB Framåt are by far the largest hauliers" in the Gothenburg area. TGM is DB Schenker's dedicated subcontractor for pick-up and delivery in the Gothenburg area using a fleet of 190 vehicles. GB Framåt performs most of the distribution for DHL in Gothenburg and has a fleet of more than 110 vehicles. As the forwarders are responsible for the consolidation terminals, most of the transport planning, as well as marketing and sales, the road hauliers strictly focus on pick-up and distribution activities. Consequently, the number of employees approximately equals the number of vehicles in both companies. The CEOs of TGM and GB Framåt are referred to as CEOTGM and CEOGBF, respectively, in the following section.

The starting point in the interviews was transport efficiency and its potential effects. Transport efficiency was described by CEOTGM as less emissions and better economy, both for the operator and the customer. CEOGBF also highlighted better economy, but also included speedy deliveries and an optimization of loading the cargo in the vehicles. Below, the interview results are categorized and presented along the lines of the main headings of the previous sections.

### 4.1 *Driver Efficiency*

Both CEOTGM and CEOGBF find eco-driving effective, especially on longer hauls. The time lost by driving more carefully is small compared to the fuel saved, which results in less emissions and better economy for the road haulier. On shorter hauls, as in urban distribution, this measure is effective and is considered a positive measure in all respects by the CEOs. The elimination of engine idling was given as one example in an urban context.

### 4.2 *Vehicle Efficiency*

Larger vehicles are better on long distances in order to increase volumes transported, but there is no real benefit of using them in city distribution, according to CEOTGM and CEOGBF. Instead, the vehicles are both shorter and smaller than the maximum allowed in order to make deliveries on time and to gain accessibility in the streets and loading docks. CEOGBF points out that normally economy and the environmental impacts go hand-in-hand, but not always. He exemplifies this with the investment cost for a gas- and petrol-fuelled lorry being higher than an ordinary lorry. Also, the initial calculations for such a lorry show an increase in costs in operation. One reason for this might be that the drivers keep driving on petrol when the gas tank is empty. As a means to minimize the use of petrol, the drivers of gas vehicles, accounting for nearly 10% of the GBF fleet, now have to collect petrol vouchers from the main office. CEOGBF points out the environmental benefits if the lorries are bought and replaced more frequently than today, but the hauliers' tight profit margins do not allow this.

### 4.3 *Intelligent Transport Systems and Route Efficiency*

CEOTGM argued that it is very difficult to recover the costs of a specific route planning system because of the initial investment and implementation costs and viewed these systems as a supplementary aid only. Since the distances are quite short, many drivers have good local spatial knowledge because they often drive the same route every day. CEOTGM says that each city distribution vehicle only drives approximately 10,000 kilometres per year. Also the availability of GPS in smart phones makes complex route planning systems somewhat redundant. Furthermore, route planning system facilitates increased competition from drivers from low-wage countries, since local geographical knowledge is no longer required to drive a lorry, CEOTGM concludes. However, a low line-haul price is the competitive advantage, but it is not as severe in city distribution as in long haul because proficiency in Swedish is important and may be an absolute requirement. CEOGBF was slightly more positive about route planning and stressed the importance of proper freight planning before loading and having systems helping the loading process by sorting by postal codes. This is especially useful for new drivers. CEOGBF says that a parcel delivery vehicle has 60–85 stops in the city centre during a day with up to 120 deliveries, having to exceed 25 kilometres in order for the cost and time used with a GPS to be offset by reduced diesel consumption. Both CEOs identified delivery time restrictions from customers as an important limitation for route efficiency.

### 4.4 *Utilization Efficiency—the Back-haul Effect*

The distribution in greater Gothenburg has rather balanced flows in terms of volume, according to both CEOs, much due to Gothenburg's character as a manufacturing city. This is in contrast to most cities with more goods to deliver than to pick up, not the least of which is Sweden's capital, Stockholm, which is dominated by the administration and service industry. However, the same unbalance applies to Gothenburg's city centre. CEOGBF points out that it is more work to get the goods out of the city due to large pick-ups. CEOGBF also highlights a balancing problem with respect to time: customers want to have goods picked up as late in the day as possible and this might force the road haulier to use more lorries for pick-ups even though the volume and number of stops might be less than delivery operations. CEOTGM stresses the importance of different pricing systems and it is better when the operator is getting paid from A to B, rather than in an A–B–A situation as the operator might lack incentives to find a back-haul.

### 4.5 *Utilization Efficiency—Load Factor*

Higher load factors are possible when deliveries are coordinated in a network, which both companies have as a strategic advantage. CEOTGM refers to the term "public transport for freight," which their customer DB Schenker promotes in its market communication. "If we knew what we will deliver tomorrow, we would be even more efficient," said CEOTGM. Planned deliveries imply less transport and less emission. For short-haul transport, the lorries are usually filled in the morning for delivery throughout the day. Ability to increase the load factor can be limiting at times in city distribution, according to both CEOs. "In urban distribution the load factor is not the main focus—time is," says CEOTGM, a view shared with CEOGBF: "The deciding factor is time." Situations occur when the lorry is not fully loaded due to time restrictions of at least three types. The first type is generated from consignees in the city who want goods delivered before a certain time, often in the morning. The second type is regulated time windows imposed by the municipality. The third type is internal and comes from the drivers themselves; at times, the large number of stops during the day may limit the loading factor, especially for parcel deliveries. A large number of stops also usually means a shorter available loading time. CEOGBF also identifies seasonal variations as a problem for the load factor. CEOGBF says, "In the summer, we might deliver 200 kg of parcel deliveries, where we normally deliver a tonne on the same run." In general, improving the load factor is considered a good measure.

### 4.6 *Packaging Efficiency*

Packaging efficiency improvements are often prompted by shippers, with the ambition to minimize transport. When the CEOs were asked whether there was a lack of incentives from the operator's point of view to come up with similar improvements, CEOTGM thought that competition is the incentive for packaging efficiency improvements. Therefore, "to get paid too much is no good" if they want to keep the customers. CEOGBF recognized that his company would like to transport as much as possible since it improves the revenue, but "competition plays its part as well. Poorly packaged consignments increase the risk for damages and lowers packaging efficiency." In sum, both CEOs considered packaging efficiency a good measure for improvements, which are needed to be competitive.

### 4.7 *Delivery Efficiency*

On the question of whether the shippers are moving towards more JIT, CEOTGM agreed and has witnessed how it has resulted in smaller shipments. CEOGBF was unsure, but thought that the development would probably move towards smaller and more frequent shipments and backed it up with examples of how his company might benefit from this trend. Both CEOs identify this as an opportunity since they can coordinate shipments, use a consolidation terminal and, according to CEOGBF, "get paid not just by volume but also per shipment." CEOTGM sees possibilities in a transport network by making the milk runs shorter or longer depending on the supply of goods. They can still be effective even if some customers are lost. This may not be possible for a lorry operated on its own account where the loops are more static and homogenous in size. Another point discussed was whether the profit margin is different on small and big shipments. CEOTGM does not identify a significant difference while CEOGBF said he intuitively thought that the profit margin is bigger on smaller shipments, "since we get paid by the stop. The more stops on a milk run, the more revenue." CEOTGM points out that the smaller shipments require more handling. This means higher costs that are reflected in their price list, since more frequent deliveries are more expensive per shipment than one main delivery once a month, for instance. One problem is that the consignor pays the delivery, not the consignee, which makes coordination of deliveries to a specific consignee more difficult.

### 4.8 *Mode Efficiency*

This question was not included in the interview since neither of the companies runs a multimodal service. However, they often perform pre- and post-haulage in intermodal transport chains arranged by the forwarders.

### 4.9 *Regulatory and Incentive-based Measures*

CEOTGM identifies sticks and carrots (and the interaction between the two) as an important strategy. CEOGBF would like to see more firm and clear rules, or more sticks than carrots. "The environment can only be steered through laws and regulations. What if we did not have environmental zones today [through regulation], how would it have looked like then?" Gothenburg has had environmental zones since 1996 in order to exclude old lorries from the city. CEOGBF also points to the significance of cooperation between operators and municipality. "It is also important to stress for 'the public' that the lorries are not in the city for the sake of having fun or to pollute, but for delivering goods to the shops." Time restrictions from the municipality sometimes limit the load factor efficiency according to CEOGBF.

### 4.10 *Coordinated Distribution*

Examples of coordinated distribution are given by both CEOs. In fact, the forwarders, for which TGM and GBF work—DB Schenker and DHL—have historically cooperated in line-haul since their Swedish terminal networks are more or less mirrored. In pick-up and distribution, the cooperation has been focused on scarcely populated areas, primarily in the far north. A closer example of cooperation is deliveries to an island north of the city called Marstrand, but it has been terminated. The same happened with a similar project in Stockholm. "All these projects tend to end in Sweden," says CEOTGM, who raises problematic issues (e.g. who pays for damaged goods or the last delivery on a route). The forwarders' cooperation in distribution might also violate European competition laws, particularly considering their joint dominance of the Swedish market, and the shippers often turn suspicious when strong players cooperate.

The freight transport market they are part of has tight margins according to the CEOs. If the distribution is further coordinated, then CEOGBF fears a problem with pricing the services. He also thinks it could be "messy" since the goods might have to go through too many consolidation terminals. Both CEOs think that shippers enjoy too low transport prices considering current operating costs.

## 5. Discussion

*Driver efficiency* was regarded satisfactorily, especially on longer hauls but somewhat less so in urban distribution. This is surprising since the potential benefit of a skilled driver in an urban setting with frequent changes in speed and direction could be argued to be higher than for a driver operating the vehicle at constant speed along the highway. Regarding *vehicle efficiency*, there is no real benefit of using larger lorries in city distribution, according to the CEOs, but instead adapts the lorries to an urban environment. *Route efficiency* was hindered by time restrictions from customers, according to the CEOs. Route planning system in cities was of limited use and has allowed competition from low-cost countries on the market (CEOTGM). The *back-haul effect* was of limited importance as the distribution in greater Gothenburg has rather balanced flows in terms of volume according to the interviewees. Also, if the back-haul is included in the payment to the operator, then the incentive to find a back-haul is limited. However, a limiting effect for back-haul was time. Time constraints, along with seasonal variations, might offset the *load factor efficiency*. A potential for improvements is better planning of the deliveries facilitated by more and earlier information from the customers. The road hauliers viewed work with *packaging efficiency* as a means to be competitive towards shippers. The CEOs interviewed believed in the trend towards smaller and more frequent shipments, which is the opposite of *delivery efficiency* as it is defined here. *Mode efficiency* was not relevant for the interviewed CEOs. The transport companies recognize both sticks and carrots within *regulatory and incentive efficiency*. Interestingly, one CEO believed more in firm and clear rules (sticks) than voluntary incentives

**Table 3.** Transport efficiency measures in distribution and the effect on actors in the system

| Efficiency measure\actors | Decision maker | Road hauliers | Forwarders | Shippers | Society/city |
|---|---|---|---|---|---|
| Driver efficiency | RH | + | + | + | + |
| Vehicle efficiency | RH/VM | + | + | + | + |
| ITS and route efficiency | RH/F | ± | + | + | + |
| Utilization efficiency—back-haul effect | RH/F/So | + | + | + | + |
| Utilization efficiency—load factor | RH/F/Sh/So | ± | ± | + | + |
| Packaging efficiency | RH/F/Sh | ± | ± | + | + |
| Delivery efficiency | RH/F/Sh/So | − | − | ± | + |
| Mode efficiency | RH/F/Sh/S | − | ± | ± | + |
| Regulatory and incentive-based measures | RH/F/Sh/So | ± | ± | ± | + |
| Coordinated distribution | F/Sh/So | ± | ± | + | + |

Notes: (−) cost, (+) benefit. F, forwarder; RH, road haulier; Sh, shipper, So, society/city, VM, vehicle manufacturer.

(carrots). *Coordinated distribution* was viewed as both positive and negative with arguments supporting both views. However, impediments for implementing this measure are the distribution between collaborators of costs for damaged goods, dividing costs and profits in the last leg and laws of competition.

Table 3 summarizes the rendering on the efficiency measures. It departs from a set of measures generally viewed as positive from different stakeholder perspectives. The measures were identified and selected based upon the literature review, 12 expert interviews and personal experience from transport research. A measure triggers a minus in a specific stakeholder column if the result of implementation logically results in a cost or a loss of sales for the stakeholder. If the cost or benefit outcome is uncertain, a plus and a minus were inserted and, lastly, a plus was rewarded to the measures that would benefit the stakeholder. Information was derived from the literature review, the interviews with experts and the more specific ones with the road haulier CEOs and processed with a portion of logical deduction.

Several urban freight researchers have pointed out the conflicting objectives and interests among stakeholders (Anand, Quak, van Duin, & Tavasszy, 2012; Danielis et al., 2010; Macharis & Melo, 2011; Muñuzuri et al., 2005; Taniguchi, Thompson, Yamada, & van Duin, 2001; Quak, 2012). It is important to recognize the concerns of different stakeholders (Puckett, Hensher, Rose, & Collins, 2007); the preferred solution for an operator does not always correspond to the best solution for the system (Gonzalez-Feliu, & Salanova, 2012). If the interaction and the various stakeholder perspectives are not taken into account the introduction of new policies might be unsuccessful. Not surprisingly, low-cost policies generate the most support (Stathopoulos, Valeri, & Marcucci, 2012).

According to Table 3, the stakeholders who would find the measures the least beneficial are the hauliers followed by the forwarders and shippers. A similar result can be found in Stathopoulos et al. (2012, p. 37), where the stakeholders scored a series of policy measures. Exceptions to this order are also found in their study; hauliers score higher than the other actors on “real time information on state of traffic" and "variations of time windows." The study found no measures that completely shared the support of all actors. A qualitative and perhaps overly simplified argument could be the importance of the transport service for the different actors. Transport obviously accounts for most of a transport operator's turnover, while a forwarder usually also relies on complementary services such as warehousing and information processing. For a typical shipper, freight transport is approximately 5% of total costs, and the city regards transport as not only a means to an end, but also a nuisance creating congestion, noise, accidents and pollution.

## 6. Conclusion

Many of the environmentally beneficial transport efficiency measures categorized as beneficial for the society in Table 3, result in less kilometres to drive for the road haulier. Therefore, implementing these measures would not intuitively foster more business for the road haulier, at least not in the short term. This could partly explain the inertia to change within the freight industry. Nevertheless, the reluctance might alternatively be explained by the fact that the road hauliers are hardened after many years of improvements without being able to keep, from their perspective, a fair share of the efficiency gains. Most cost reductions have been fully passed onto the forwarder and much of that further to the shipper. The results are thus in line with McKinnon's (2003) statement: "Those measures which yield economic as well as environmental benefits generally command the greatest support and are the easiest to implement."

The empirical part of the article also revealed that fuel saving was not of top priority for the interviewed CEOs. This is not interpreted as a negligence of society challenges, but a consequence of the fact that a distribution lorry travels about 10,000 kilometres per year, which is actually far less than the average private car does in Sweden. This intuitively leads to the conclusion that technical improvements of distribution vehicles might better focus on emissions with a local effect and let long-distance road transport lead the challenge of decreasing $CO_2$ emissions with a global impact. Against this conclusion stands the large and strongly increasing amount of distribution lorries.

Time is a much more important driving force, including working time for drivers, delivery time windows, lead times for customers and time available for planning and efficient loading. In addition, time restrictions in city traffic and street accessibility have significant effect on transport efficiency.

Nevertheless, road hauliers could become the principal actors in making transport efficiency and sustainability a trademark and positioning environmentally better transport as a strategic issue. Road hauliers and forwarders increasingly identify this as a business opportunity, and several are already moving in this direction, which is likely to offer them a competitive advantage in the future. From a policy point of view, identifying the stakeholders that risk being affected negatively by a certain measure could improve incentive actions and avoid the high discontinuation frequency of future collaborative urban freight projects.

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# A review of the success and failure of tram systems to carry urban freight: the implications for a low emission intermodal solution using electric vehicles on trams

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**ABSTRACT**
This paper considers the potential use of trams and Electric Distribution Vehicles (EDVs) as cargo carriers in intermodal urban freight distribution. Distribution activities are vital for society but are also the cause of environmental and social problems. Transporting goods in urban areas, where most logistics chains start or end, is an activity that increasingly generates severe problems for all stakeholders, for instance, local authorities, the logistic industry, customers and society in general. New transport solutions are necessary in order to decrease traffic congestion, noise and traffic pollution, e.g., emissions of greenhouse gases and other pollutants in urban areas. A possible solution to these problems is to transform the current freight distribution system within cities, for example by favouring the enhancement of intermodal transport alternatives, i.e. combining road and rail transport. Information has been collected through a literature review and interviews in Amsterdam and from these results a conceptual model is presented, as well as a low emission concept using electric vehicles on trams in Gothenburg. The concept utilizes techniques from the shipping industry, train industry, and the car industry.

**Keywords:** light rail, tram, electric distribution vehicles, EDV, transport efficiency, sustainability, urban freight distribution, intermodal city freight distribution, urban rail freight transport

# 1. Introduction

It has been argued that the configuration of freight distribution systems in urban areas is reaching unsustainable levels in terms of economic efficiency and the impact on quality of life - see for example Genta *et al.* (2006). The scientific evidence points to an increase risk of serious, irreversible impacts from climate change associated with business-as-usual paths for emissions (Stern, 2006). BAU is not a sufficient if the major problems are to be addressed. Therefore, the EU White paper for transport aims to achieve dramatic reductions in transport CO2 emissions (Com 144, 2011). The goal of the Commission is to cut the use of 'conventionally-fuelled' cars in urban transport in half by 2030, phase them out in urban areas by 2050, and "achieve essentially CO2-free city logistics in major urban centres by 2030" (p, 9). A Delphi study conducted by DHL (2009) provides some guidance on the implications for production, retail and logistics.. According to over 900 professionals and researchers interviewed many believe a proof of energy efficiency will be necessary to ensure a product's acceptance and marketability. Nevertheless, there are differing opinions regarding the extent to which "global warming" represents a genuine business opportunity, but the interviewees in the study also believe that "An enormous amount of money can be earned with the right answers to 'global warming.'" (DHL, 2009 page 25).

The report focuses on answers not the answer. As there is not yet a single renewable fuel that can replace oil, but many, as well as no one logistic solution that can replace current practice. In this paper, one suggestion is presented for urban freight distribution that would potentially help to decrease emissions significantly[1] for parts of urban freight distribution, but also help the logistic companies to become more profitable.

Logistics companies that want to be green and stay in the 'green' race as well as to become or remain market leaders will need to constantly set new standards. It will not be enough to react; they will also need to adopt a proactive position. Only in this way will it be possible to operate profitably with their 'green' ideas – at least until these ideas become the legal standard. The timeframes during which it is possible to make a profit with sustainable efforts will become shorter, according to the DHL report. The report further states that logistics companies that offer the most intelligent low CO2 solutions will emerge as market leaders. However, it will only be able to maintain its market leadership if it constantly improves these solutions. Thus, logisticians need to continuously set new standards if they want to experience financial gains from the sustainability trend over the long term. It is presently truer than ever that merely reacting is not sufficient. Logistics companies must be actively involved in the formulation of standards and thus assume a leadership role in the economy.

An explicit definition of what is meant by light rail does not exist. In the literature many definitions are found. According to Priemus and Konings, (2001) a common feature seems to be that light rail is a rail associated transport system that can be positioned in the triangle between train, tram and metro.

To use the more general term light rail avoids incompatibilities in American and British English. The British English tram, could mean aerial tramway, trolley car or streetcar in American English, whereas aerial tramway is called cable car in British English (Merriam-Webster online dictionary, 2009-09-23). Cable car in North America usually refers to a trolley pulled along by subterranean

[1] provided that the electricity is produced from renewable sources.

cables. Trolley in American English typically refers to streetcar, while in British English this word means a (shopping) cart (Merriam-Webster online dictionary, 2009-09-23).

Trams and street cars are commonly classified as a subtype of light rail, but this is not always true. There is a significant amount of overlap between these technologies. Light rail is mostly separated from other traffic with dedicated lanes and rights-of-way, passengers get on and off at stations rather than in the street, and the speeds are faster than for trams (Smiler, 2001). In this paper, no distinction is made between trams and light rail for the sake of simplicity, variation and to facilitate keyword search.

According to Merriam-Webster online dictionary there is no significant difference between the use of cargo and freight anymore. Historically the use of cargo, from Spanish cargar used to refer to ships and later airplanes, but now also includes land-based vehicles. Freight, of mixed English, Dutch and German heritage, is somewhat more of a generic term, often attributive as in substituting transportation in transportation costs but also often referring to land based vehicles. The use of CarGoTram in Dresden is a pun, supplying car parts to the Volkswagen factory. In this paper, no distinction is made between cargo and freight for the sake of simplicity, as well as no distinction between transportation and distribution, for the same reasons as above.

The paper consists of five main parts. Firstly, the nomenclature of the terms appearing in the paper is discussed in the introduction. Secondly, a literature review was conducted on the previous projects using light rail in Europe followed by a literature review of the use of electric distribution vehicles in Europe. Thirdly, the four major projects using trams are presented. Information from Dresden, Vienna and Zurich is derived from a literature review and information from Amsterdam originates from empirical data from interviews. Fourthly, a discussion is held based on comparing differences and similarities between the cities. Lastly, barriers and recommendations are identified and an analysis of a possible future concept for the example city of Gothenburg is presented.

## 2. Cargo trams, Light rail and Underground freight

In this section some of the most recent research focusing on urban freight distribution in relation to rail is presented. The major projects in which this type of research has been evident are Bestufs (http://www.bestufs.net/), Civitas (http://www.civitas-initiative.org/index.php?id=69), Eltis (http://www.eltis.org/) and Sir-C (http://www.sir-c.se/web/page.aspx?sid=7126). Goods have been carried on rail vehicles through the streets since the 19th century and the use of rail in urban freight has been the focus of researchers and practitioners for the last century. Projects aimed at using rail in urban freight in Europe have emerged over the last decades, some with the aim to partly eliminate road freight transport, like in Amsterdam, whilst others are of more limited application. For example, the system in Dresden is a privately owned operation running between two points whereas Zurich and Vienna are non-commercial municipal services focusing on waste recycling and freight transport for the retail industry respectively.

According to Mortimer (2008), rail in urban freight has been on the decline in favour of better suited road transport, with regards to supply patterns, land use planning and regulations. Some of the known limitations of rail are the lack of door to door capability, difficulties in the integration of road and rail and the differences in economic mass. On the other hand, rail has a good weight/volume capacity, low energy and environmental impact, lower fatality risk in comparison to road traffic flows, a good network linkage between cities and in some cities – trams and undergrounds. Today the vast majority of urban freight service is performed by trucks and vans on road and to a lesser extent through intermodal services. Transportation is a vital part of our society but at the same time considered to be a major contributor of emissions and thus also a major impact on the environment. This has triggered planning authorities all over the world to impose a variety of restrictions and constraints on road transport, e.g. access times, weights, dwell times, noise limits and emissions etc. The light rail industry, much like rail and road, is considered to be conservative and the business model primarily focuses on passenger transport with generic constraints also with regards to coverage and access. Alessandrini et al. (2012) investigate the use of a MUDC (multi-modal urban distribution centre) in conjunction with shuttle trains and low polluting vehicles for delivery of fish in Rome the last leg. They also provide a good review of rail based schemes in Europe. Delaître and Barbeyrac (2012) study a rail freight transport system in Paris, the 'Monoprix', which reduces the pollution by almost half but costs more than conventional truck distribution due to extra handling, low volumes, and an uneven freight flow, according to the authors. Another reason to the higher costs is presented in GAO (2011). Marinov et al. (2011) study operational and tactical aspects of short haul rail freight services in the UK and try to demonstrate how it could be successful by calling for a different approach to asset management, planning, technology and resource allocation.

In the Italian TADIRAM project ("Advanced Technologies and Innovative Tools for Freight Distribution in the Sustainable City"), ending in 2006, research activities have been performed with the aim to identify new organizational and technological solutions for the optimization of freight distribution process, see Genta *et al.* (2006). One part of this project studied the cargo tram concept in a feasibility demonstration. The TADIRAM project partners demonstrated a new prototype designed for goods assembled onto load units. A new version of SIRIO Cargo Tram (light rail), the same type of tram ordered by Gothenburg municipality, has been studied. This type of tram is module-based and can also be coupled with passenger trams. Furthermore, the tram has a drop centre design, with a flatcar in the middle with 350 mm from the rail plane to the passenger floor.

The OLS-ASH project has generated knowhow on designing automated underground freight transportation systems that can be used for future underground freight transport projects (Pielage, 2001, Wiegmans *et al.*, 2010). The project stimulated academic research in e.g. innovative transport systems and logistics concepts, received support from local and regional governments and the public. Royal Mail have been operating its own automated underground transport system called Mail Rail, with the aim to move mail across London successfully since 1927 (Bliss, 2000). In Japan, Kikuta *et al.* (2012) propose and demonstrate an integration of the subway with freight operations from the suburbs to the city center. Ooishi and Taniguchi (1999) present a cost-benefit analysis as well as other aspects of underground freight transport.

## 3. Electric distribution vehicles in urban freight distribution

The electric vehicle is not a new concept; it actually precedes the internal combustion model. The deficient factors identified so far are: the same ability to accelerate and go fast, and to provide the same reach and ubiquity of the gasoline car. (Lesser, 2009; ELCIDIS, 2002). Henry Ford mentioned the electric car in his book "My life and World" in 1922:

> “Practically no one had the remotest notion of the future of the internal combustion engine, while we were just on the edge of the great electrical development. As with every comparatively new idea, electricity was expected to do much more than we even now have any indication that it can do. I did not see the use of experimenting with electricity for my purposes. A road car could not run on a trolley even if trolley wires had been less expensive; no storage battery was in sight of a weight that was practical. An electric car had of necessity to be limited in radius and to contain a large amount of motive machinery in proportion to the power exerted. That is not to say that I held or now hold electricity cheaply; we have not yet begun to use electricity. But it has its place, and the internal combustion engine has its place. Neither can substitute for the other--which is exceedingly fortunate.” (Ford, 1922)

The ELCIDIS (Electric vehicle city distribution systems) project succeeded in verifying the principal advantages of using electric distribution vehicles (EDVs), hybrid as well as electric, in urban delivery concepts. ELCIDIS has provided proof that there are no predominant objections to the use of hybrid and electric vehicles in urban distribution, neither from company managers nor from drivers, and certainly not from local authorities (ELCIDIS, 2002). However, they stress the need for further development of the next generation of electric vehicles and hybrids. Furthermore, the project states the necessity of ‘home-recharging’ equipment close to the city centre for battery-run electric vehicles.

A study was carried out in the Brussels capital region by Van Mierlo *et al.* (2003) and was also presented in Macharis *et al.* (2007) that investigated the environmental benefits of electric heavy duty vehicles in which the Ecoscore or environmental damage rating was calculated. The methodology was based on a well-to-wheel analysis of emissions by calculating the impacts related to global warming, health, buildings and noise. The electric vehicle in the analyzed example was an electric bus and it had more than three times lower environmental impact compared to a diesel truck and twice as low as a liquid petroleum gas (LPG) truck. The study does however not describe how these figures were calculated. It would be interesting to know if the electricity was produced by coal, renewables or a mix. The use of electric cycles and vans in the last leg of distribution in conjunction with an Urban Consolidation Center (UCC) was investigated by Browne *et al.* (2011) with positive results. Ehrler and Hebes (2012) study the implementation of electromobility in city logistics from a multi-actor perspective. A good selection of other studies of electric delivery trucks is available in Davis and Figliozzi (2013).

## 4. Light rail freight and cargo trams in Europe

Transportation companies in the EU and around the world are trying to combine economic sustainability with finding green solutions for transport. One way of doing this is to apply transport efficiency, a set of measures to utilise resources to move goods with the aim to minimize externalities. One resource efficient way to move goods is by using tram systems with or without electronically driven vehicles. This paper will investigate the issue from a European perspective. One could argue that this type of transport system could have a broad applicability in Europe, as carrying goods on rail (train) in Europe has its roots from the 19$^{th}$ century. The current known tram examples include Dresden which now has a regular Cargo tram service run by the world’s longest train sets, 59.4 meters. Cities of Vienna and Zürich are using cargo trams as freight transport and mobile depots for recycling used goods respectively. Amsterdam has developed this concept the furthest in the group, regarding the applicability of trams as freight movers, including a wide variety of consumer goods and the sheer economic size of the project is well exceeding the economic size of the other three projects combined. That is the main reason why Amsterdam was chosen as case in this study, even though it was never fully operational. Furthermore, the authors try an unconventional approach to gain insight into possible future success by analysing a failure. In the following sections a short description of three projects precedes the results from the analysis of the Amsterdam case. Strengths and weaknesses of the experiences from these cities will help in the development of a feasible concept and possibly a more sustainable implementation in the future.

### *4.1 Dresden – Volkswagen project*

Volkswagen opened an eye catching transparent factory in the city centre of Dresden in 2002. A prerequisite of the Dresden municipality, as the city centre is small and particularly sensitive to heavy trucks, was to seek another solution of the goods flow (P Hendriks, 2010). Volkswagen together with Transportation Services of Dresden came up with an idea to utilize cargo trams. At the new factory access to a local tram line was possible as well as for the distribution centre four km away, this made the cost for additional infrastructure low with only short connection tracks needed. The project with the Cargo Trams started in Dresden on 16 November 2000 and made its first test run in January, 2001.

The trains run every hour on a fixed route that is five km long (frequency can be increased to every 40 min). It takes approximately 15 min for each trip and the cargo is unloaded in 20 min by forklifts at the factory. The public transport provider in Dresden (DVB) system of operations is controlling all public trams and the Cargo trams take advantage of gaps in the regular schedule of the passenger trams. One trip of the ‘CarGoTram’ eliminates three truck rides through the city center. The project ‘CarGoTram’ is unique in Germany (Civitas, 2005). Every day the trams transport the equivalent of 60 trucks to the Volkswagen factory. The 60 m long tram can carry 214 m3 or 60 tons each (DVB, 2013). Over the year this is the same as 200 000 km by road, according to Volkswagen AG’s own calculations. The environmental impact is accordingly reduced drastically.

The CarGoTram have been successful since the start in 2000 but it is a purpose-built project with very specific conditions, the project facilitates one customer on one route only at this point. DVB is looking for further applications for their cargo trams; one is to serve a newly built city center shopping mall with over a hundred stores (PTUA, 2008).

### *4.2 Vienna – ‘GüterBim’ project.*

The project considered as a modern solution to urban logistics for transporting goods within the city using the existing rail network, ‘GüterBim’, examined the basic infrastructure required for operating a cargo tram in Vienna. The aim was to use the existing, well developed public transport network to switch goods traffic from the roads to rail (Fochler, 2005; Ehrlich, 2005). The project investigated potential applications, e.g. hospitals, shops and waste disposal, and a pilot operation on a selected route. In August 2004, the project started and was implemented in the context of a demonstration event in August 2005.

Moreover, in 2005, possible combination of rail and tram freight transport (container transshipment) was tested, in order to introduce a rail bound city logistics solution for densely populated areas. The municipal public transport operator of Vienna carried out freight transport for its own internal purposes. The ‘GüterBim’ transports spare parts between the main workshop and its satellites. These initial demonstrations across the city of Vienna in 2005 had the intention of exploring options for further traffic applications, and study the needs for designing a feasible telematics system under an open interoperable based platform for logistics, order, and operational control.

In 2004, representing the government, the Austrian Ministry of Transport, Innovation and Technology proposed a joint-venture called ‘GüterBim’, composed by key players, such as, the Wiener Linien, the railway undertaking Wiener Lokalbahnen (WLB) and the two consulting companies TINA Vienna Transport Strategies and Vienna Consult, to carry out the respective research, and subsequently led the project team to develop follow-up projects (Fochler, 2005). Tests have been performed within the supply chain of different retail companies, to find low-cost solutions for a reliable delivery of their stores and sales points in the City of Vienna, for instance, developing techniques for fast handling.

### *4.3 Zurich project*

The Cargo tram in Zurich is a project that took only a few months to be converted into a pilot after its conception. It was the CEO of “Entsorgung und Recycling Zürich” ERZ (municipal public waste disposal and recycling company Zurich), Mr. Gottfried Neuhold, who initiated the project in April 2003. Along with its future implementation on a daily operating basis, starting with four stops, and by 2004 extending them to eight. The initial approach was to collect bulky waste from households along the city´s outskirts, near the trams’ turn around points. Afterwards in 2005, the collection of disposal electronic home and industrial equipment followed. According to Neuhold (2005), the way Cargo tram started to operate was based upon the collection of waste in two standard refuse containers, but the normal containers turned out to have an insufficient capacity for bulky goods. Therefore, a new container was developed, incorporated with a press for bulky goods, which in turn were carried on flat wagons, pulled by a converted tram.

ERZ jointly with the tram company VBZ used the actual infrastructure and the surplus tram units. They started by investing 32.000 Euros, in order to convert old trams and wagons into a functional unit, by adding standard parts. Zurich has a broad tram network serving the majority of the city areas. There are also many sidings not used by regular services which could be suitable. An equivalent road vehicle would have been harder to purchase due to initial funding and environmental constraints (proaktiva.ch, 2005). By strictly following the pre-condition of the system, which is neither disturbing nor slowing down the public transport for passengers, the Cargo tram serves, nowadays, nine different tram stations in the city area of Zurich. Hence, the positioning of Cargo tram is at those stations where additional tracks already exist, mostly turning points at the end of a tram line, where residents can leave bulky items for free. It has been estimated that collecting the same amount of waste by road transport equals 5 020 kilometers covered by lorries (which need about three times longer to move across the heavily congested city during peak hours) which in turn equals 960 running-time hours, (Neuhold, 2005). According to these calculations, the solution of disposing waste by Cargo tram has achieved a reduction of 37 500 liters of diesel annually, thus, avoiding equivalent emissions of harmful substances. In short, Cargo tram not only makes a contribution towards reducing traffic congestion, traffic pollution and noise, it also provides a valuable service to Zurich’ residents, offering a low cost service, but faster, moving commodities of low or null intrinsic value that commonly is not time sensitive.

# 5. Amsterdam case study

### *5.1 Amsterdam – City Cargo project interviews*

The Amsterdam City cargo tram project is by far the biggest of the four investigated projects. The following Amsterdam section is based on a literature review as well as five interviews in Holland and two phone interviews. For the presentation of interviews we used the method suggested in Gonzalez-Feliu and Morana (2010) and Morana and Gonzalez-Feliu (2010), please see Table 1. All the interviewees were approach through LinkedIn, except Willy Nicklasson who was identified by reading the WSP (2008) report. A visit to Amsterdam and Utrecht was made in 2010 to conduct the interviews. The interviews were semi-structured, recorded and later transcribed.

| Name | Post | Entity | Type of interview |
|---|---|---|---|
| Willy Nicklasson (2009-06-12) | Technical Manager | Gothenburg Tram Company | Phone interview |
| Peter Hendriks (2010-01-15) | CEO | Cargo tram | Recorded semi-structured face to face over lunch |
| Michael Hendriks (2010-01-19) | Financial Manager | Cargo Tram | Recorded semi-structured face to face over breakfast |
| Jan Dijstelbloem (2010-01-18) | Municipality Project Manager | Amsterdam Municipality | Recorded semi-structures face to face |
| Jupijn Haffmans (2010-01-18) | Public affairs | Cargo Tram | Recorded semi-structured face to face over lunch |
| Stefan Saalmink (2010-01-18) | Former project leader MindsinMotion.net | Utrecht | Recorded semi-structured face to face over dinner |
| Annick Driessen (2010-05-05) | Writer, MindsinMotion.net | Gothenburg | Phone interview |

Table 1: Presentation of conducted interviews

### *5.2 Description of the city center*

As for many European cities the construction of the city centre with its narrow streets during the seventeenth century did not provide a favourable situation for the modern day vehicles. At the start of the twentieth century the city was adapted to the needs of motor vehicles by filling in many canals of the city. However during the process major canals still remained intact. All administrative officials in all cities in the Netherlands follow the same agenda in formulating development plans for a city; pollution and noise caused by the traffic ought to be reduced, traffic safety ought to increase and quality of space available for general public ought to be enhanced. This emphasizes the need to develop measures in order to reduce traffic congestions and reduce the effect of cargo transport on the environment.

### *5.3 Process*

Cargo trams in Amsterdam were expected to start their operations in 2008. The rationale of these trams was to shift the traffic load from trucks on the road to the trams for distribution of goods among the various stores and restaurants in the city. Also the restrictions on truck access would present an opportunity for an implementation of the cargo tram operations. The trams would provide service from the distribution centers to the central parts of Amsterdam to reduce traffic load on the roads and would help improve the environmental aspects of the city transport. The door to door service could be maintained by the carrying of goods the last mile through the use of EDVs. According to Valkering (2009), the project was met by opposition from some residents who lived on a square (Cornelis Troostplein) that was planned to become a reloading point; however, this information is from an unconfirmed source. In the month of March 2007 the test phase of this project included running of the cargo trams without loads from Osdrop to central Amsterdam. The trams used for this test phase belonged to GVB trams and after this test phase the trams were planned to be running with goods (Technisch Weekblad, 2007; P Hendriks interview, 2010).

Amsterdam's project regarding the Cargo trams became a reality with the accomplishment of the test phase as it was carried out in March 2007. During this test phase the trams ran without goods but from 19th March, they were supposed to run with cargoes from De Aker to the city. Cargoes included Heineken beer for pubs in the city and clothing for the Mexx store. During the last week of the phase waste paper was also carried in the opposite direction. (Cargotrams Yahoo group, 2007)

According to M Hendriks, the city council of Amsterdam allowed City Cargo to carry out trial operations whereas the full scale operations were expected to start in 2012. The trams were responsible for delivering goods to the city business companies. These cargo tram operations were restricted to the lines which have enough capacity to avoid problems with passenger trams. The operations were also limited within the time frame of 07:00-23:00 to avoid noise disturbances during the night. This project could result in the reduction of 2 500 lorry movements within the city per year and the particle pollution in the air by 15 percent according to calculations made by the company. The trams used for these initial trials belong to GVB trams whereas in the later stages of the project City Cargo would use its own designs (M Hendriks, 2010), also in interview by local newsfeed in 2006 (Nieuwsuitamsterdam.nl, 2006). The economics of the operations were calculated to save almost 15 percent compared to a conventional set up with trucks (Haffmans interview, 2010).

### *5.4 Operations*

According to a press release of Amsterdam tourist information dated 17 July, 2007, a joint venture of City Cargo BV with Amsterdam municipality, signing a 10 year contract to launch a cargo transport project employing freight trams running on the existing tram tracks used for public transport. According to P Hendriks (2010), ten cargo tram units were planned to start working by mid 2008. To ensure that the freight trams did not disrupt or alter the existing passenger tram schedule, a pilot was tested in March.

Jupijn Haffmans, City Cargo spokesman told the press after the test that this was the municipality's main concern and they demonstrated that by using 'follow mode' with the passenger trams, hindering the existing passenger tram schedule could be avoided. The 'follow mode' could easily be performed since the cargo trams did not have to stop to pick up passengers. The contract requires close collaboration between Amsterdam tram company GVB and City Cargo which uses GVB's schedule to establish when and where they can operate. As central Amsterdam is still reminiscent of its medieval times having only narrow streets and canals, the municipality allows heavy vehicles only between the hours of 7:00-11:00 hence stores and businesses are in need of a quicker and efficient supply system (M Hendricks interview, 2010). Haffmans (interview, 2010) also highlighted the future plans of expansion, City Cargo did aim to increase its number of trams from ten to fifty in the next four years. This was expected to half the daily truck load in the inner city.

The project would have employed a system of a number of strategically located distribution centers or cross docks situated in western suburbs near Schiphol airport. Therefore the inbound goods arriving at Schiphol airport could also be transported onboard the freight trams. At cross dock locations goods would be transferred from trucks to trams, after being sorted in the delivery area, and transported to inner city transhipment hubs.

Sophisticated networks of electric distribution vehicles were to deliver the goods to their final destination. Although the cargo trams took fifteen minutes extra compared to direct transport trucks, the City Cargo claimed that it cuts the cost by fifteen percent (P Hendriks interview, 2010) and accordingly being significantly more useful for small businesses like restaurants and boutiques.

Peter van der Sterre, policy consultant of EVO, a Dutch organization of companies dealing with cargo transport, as part of their core business acknowledged and appreciated City Cargo's initiative and its usefulness to small companies but at the same time pointed out the limitation of its use for larger companies like supermarkets. EVO, have lent only conditional support to City Cargo so as to make sure those companies are not forced into using the tram system and still have the freedom to choose between the two.

Meanwhile, Haffmans unfazed by Peter Van Der Sterre's cautious approach told the media that City Cargo has received encouraging feedback from around the world. Tokyo and San Francisco showed an interest in addition to many European states like the Netherlands and Germany, to mention a few. He also stressed the need of expanding the tram network to all the metropolitan areas of Amsterdam in order to be truly successful. While for smaller cities like Utrecht or Rotterdam a single company may be enough. He went on to quote the examples of some other European cities employing the cargo trams, like Dresden (Driessen, 2007; Haffmans interview, 2010).

After the successful trial, the company faced a problem with financial stability. The company board admitted they were not yet stable. As Peter Hendricks pointed out "almost no company is profitable from the start", similarly City Cargo would have needed at least three years to be profitable according to Hendricks. According to Driessen (2007) and Dijstelbloem (2010), the municipality gave the City Cargo a three weeks' notice to come up with a bank guarantee in November 2008. Having failed to meet the 1st December deadline, City Cargo was declared bankrupt.

## 6. Analysis of case study – reasons for failure

Quite a lot of research point to success stories of innovative transport solutions (van der Straten *et al.*, 2007; Wiegmans *et al.*, 2007) but few researchers focus on providing insight into possible future success by analyzing failures (Wiegmans *et al.*, 2010). With this in mind, the people at Cargo Tram identified two reasons for failure; inability to acquire adequate finance for investments and politics. Cargo Tram, through Peter and Michael Hendriks, focused on receiving finance from major banks. The timing with the financial crisis was, to put it mildly, not working in favour of the project. Furthermore, the banks would much rather invest in bigger projects according to Mr P Hendriks, thus one of the reasons for the project not starting out small scale and then scaling up. The business plan estimated the project costs to 70 million Euros, ten percent of this amount was Peter's private money (M Hendriks interview, 2010). The investment included trams, EDVs, new infrastructure, tracks and distribution center.

Others additionally identified a lack of understanding between Alderman Marijke Vos[2] and Peter Hendricks, two people at the opposite ends of the political spectrum. It was 'unfortunate' that Mr Hendriks went to the meetings with Mrs Vos in a big car with a personal driver, while Mrs Vos herself chose the bicycle.

The municipality, through Jan Dijstelbloem, identified finance as the main reason for failure, the lack of finance led up to the bankruptcy of this start up at the end of 2008. Up to the end of 2008 the municipality, through Aldermen, had helped Cargo tram by allocating a project group working with the company as well as fast tracking many of the necessary adjustments and changes in regulations, all in all, much more than normally provided for a new private company. City Cargo was amongst the projects the City embraced. One of the things the City did was extending the concession from the usual six years to ten years to give the company more time to become profitable. In addition, the municipality seriously considered the question of City Cargo to financially partake in the project. In the end the City made a proposal for City Cargo in what way the City would participate (financially) in the project. This proposition was never realised as City Cargo went bankrupt during these discussions (Dijstelbloem interview, 2010).

This was one of the reasons for the city refusing to contribute to the construction of extra tracks that were going to be needed. The city administration was interested in the project without including any additional subsidy. On the other hand, according to Mr Hendriks, City Cargo had already collected 69 million Euros from various companies like Nuon and Rabobank and had asked the city administration for a contribution of 6 million Euros for the construction of extra tracks (Dutchnews.nl and Railway Gazette, 2008).

The cargo trams use the passenger tram lines for transport and the no longer used tramways, called 'dead tracks', were used as parking lanes and loading and unloading bays. Being electrically run they have the added advantage of low carbon emissions and replacing the trucks on the roads and reducing the city congestion, especially at the motorways to and from the city. The City council also admits to this benefit, pursuing a policy of adopting measures to reduce air pollution (Dijstelbloem interview, 2010). Dijstelbloem stressed that the municipality took this project onboard and really supported the company with an extended concession mentioned above and the support of a project group to help City Cargo in all their affairs with the municipality.

The company director Peter Hendriks revealed that the municipal transport company GVB has objected to the use of dead tracks by City Cargo. The GVB claimed these tracks to be 'calamity tracks' and therefore could not be provided to City Cargo (P Hendriks interview, 2010). He continued by stating that this meant that City Cargo had to build its own parking track which is an expensive ordeal with a cost around one million Euros per kilometre, *ibid* (2010). The extra tracks were difficult to finance for City Cargo since, by law, all tracks being built were owned by the municipality and a privatization of the trams or its tracks was not on the agenda at this point.

[2] http://en.wikipedia.org/wiki/Marijke_Vos

## 7. Concluding discussion

We choose to summarize by presenting a table (see Table 2) with differences and similarities between the cities presented in the paper. From the table one could argue that an evident conclusion on a business model that works in all cases is quite hard to identify. Comparing the only two on-going projects at the moment one comes to the conclusion that starting small seems to be the only common denominator between the two projects. But the sample could be argued to be too small and the context, e.g. size of city and logistics character, is different from case to case making it difficult to compare the different cities. What can be derived from the cases however is a set of barriers for implementation and this will be the focus of the reminder of this conclusion.

| **City**<br>**Key factors** | **Amsterdam** | **Dresden** | **Wien** | **Zurich** |
|---|---|---|---|---|
| Project owner | Private (City cargo) | Private (VW) | Municipality/Private | Municipality |
| Funding | Banks/private | VW | Municipality | Municipality |
| Size of project | Large | Medium | Small demonstration | Small |
| Type of goods | Commercial, parcels etc | Automotive parts | Commercial, mainly retail | Electronic waste |
| Type of customers | Commercial | Private (VW) | Commercial/public | Public |
| Logistics character | Logistic service provider | Internal logistics | Commercial/recycling logistics | Recycling logistics |
| Infrastructure investments | Large | Small | Small | Small |
| Current status | On hold, bankrupt late 2008 | Ongoing | On hold | Ongoing |

Table 2 – Cargo tram projects in Europe

Barriers identified other than scale, are not to interfere with personal traffic (all), high initial investments (Amsterdam, Dresden), limitations in battery technology (Amsterdam), resistance to try something not tried before (initially all), number of actors cooperating (Amsterdam). It is important to repeat that the two identified reasons for failure of the Amsterdam project were: inability to acquire adequate finance for investments (supported from interviews by both Cargo Tram and the municipality) and, to a lesser extent, politics (supported only by Cargo Tram). The barriers is summarised in five categories in the following paragraphs.

Perhaps the most important feature of a concept that utilizes public transport for freight, as learnt from Amsterdam; is not to interfere too much with the daily city picture of urban space and life – **Barrier 1: not interfere with personal traffic**. According to Zunder (2004) trucks produce over 40 percent of pollution (congestion) and noise in cities although only accounting for 10 percent of operations in urban areas. It could be of interest to investigate what the reasons behind this congestion are and how much of the truck's contribution to congestion can be deduced from size? Furthermore, how would a decrease in size and increase in numbers of distribution vehicles effect congestion, if smaller vehicles were used the last mile?

Building add-ons, or sidings, to tracks for loading and unloading in the city center are very costly as learnt from Amsterdam, according to Peter Hendriks, one million Euros per kilometer. Partly, also one reason to why City Cargo started filing for bankruptcy in the end of 2008, see section on Amsterdam. The funding of the project was estimated at an impressive 70 million Euros, not a small scale endeavor – **Barrier 2: scale**. Cost calculations for any type of set up need to be conducted before any new projects are considered. The business model for the Amsterdam operations were calculated to save almost 15 percent on an operational basis compared to a conventional set up with trucks according to Haffmans interview, (2010). Unfortunately the authors of this paper did not get the opportunity to have a look at these numbers. The "15 percent" is thus secondary information. For future cost calculations it is important not to compare apples with oranges. Tram costs are normally higher than truck cost when one considers distance. Tram and truck costs are usually calculated in cost/km but for a city distribution scenario one of the advantages of an all day delivery tram is to partly avoid the busy hours in the morning and in the afternoon, which a delivery truck does not since it usually makes one round trip per day3. However, trials with night deliveries with trucks are becoming increasingly popular. It is therefore suggested that both cost for trucks and trams are calculated in hours rather than kilometers. Also, the cost for trams is divided on a set of 2-3 wagons and that some of the variable costs, if one tram is used for delivery, ought to be adjusted accordingly. Furthermore, if old trams are used this means that the total tram park can be utilized for a longer period of time and thus affecting the depreciation, which has to be accounted for.

"An electric car had of necessity to be limited in radius..." (Ford, 1922). Solutions to this 'range anxiety' that some users of electric vehicles feel is put forward by Kley et al. (2011) – **Barrier 3: radius of action.** An electric vehicle has more than three times lower environmental impact compared to a diesel truck and twice as low impact compared to an LPG truck according to Van Mierlo *et al.* (2003). But it is important to point out the importance of where the line is drawn in the analysis, whether a well-to-wheel or a tank-to-wheel analysis is used. For instance, the production process of an electric car and its battery is far more carbon intensive than the manufacturing of a combustion engine car, according to Zehner (2012).

From the interviews some agreement was received, but not from all, on a potential opposition from the other logistics competitors of the new, now bankrupt, company: City Cargo. The transportation industry is argued, for example, by Behrends *et al.* (2008), to be particularly resistant to change. In a report on Intermodal City Distribution from WSP (2008) a great concern was the lack of interest and motivation among the stakeholders. The Dutch UFT project also experienced the same reluctance from the freight transport industry (Wiegmans *et al.*, 2010). – **Barrier 4: conflicting objectives amongst stakeholders**.

The number of actors involved in the decision process is greater in light rail freight than traditional freight by truck set-up, thus making the implementation and cost-benefit division amongst the actors more complex. Unfortunately, excerpts from conducted interviews with the logistics industry in general do portray a similar picture. Phrases like "we were forced to cooperate" have been recorded – **Barrier 5: stakeholder involvement**.

To conclude the paper we present an outlook for a project that would refine and develop some of the interesting work already done concerning the use of light rail for urban freight movement (see Box 1 below). In the outlook we consider whether there may be an opportunity to test a novel concept to combine the use of small electric vehicles delivered to the city centre by means of a tram system. To

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[3] Interviews with Schenker and DHL

provide a clear spatial focus we consider the possibility to apply this trial in Gothenburg and draw on the results from Amsterdam due to its close realization of implementation, business orientation and because of these two cities many historical, geographical and political similarities is presented. The barriers and obstacles are manifold and the success of a cargo tram project is uncertain. However, the authors of this paper are optimistic about the scope to try a small scale test, for the simple reason that it has never been tried out commercially before. Potentially, the world leading truck manufacturers like Volvo and Scania would see the concept as a challenge and try similar approaches substituting the tram with a truck or trolleybus?

**Box 1 Outlook –A truly intermodal solution that might break down some barriers?**

Some do claim that one part of research is to investigate and compare projects and concepts and see if it is possible to learn from potential mistakes or change some of the parameters in order to acquire a different result? In the following outlook we will therefore try to do this in the case of Cargo Tram moved to a new setting. One might ask why Gothenburg is chosen as a possible arena for future implementation, apart from being the hometown of one of the authors. The city of Gothenburg is almost the same size as Amsterdam, according to Wikipedia, 530 thousand inhabitants versus 820 thousand. Gothenburg city is with its 450 km2 bigger than Amsterdam, 219 km2. A coincidental fact is that the city was heavily influenced by the Dutch. Dutch city planners had the necessary skills to build in the marshy areas around the city and were contracted to build the city to have canals, using Amsterdam as a blue print, according to Henriksson and Älveby (1994). The tram system in Gothenburg is extensive covering an area of 3 700 km2 (Amsterdam 1 800 km2) and dates back to 1879. One could argue that the tram is synonymous with Gothenburg but also with its culture. Many of the tram tracks in Gothenburg are integrated with the street at the same level as the tracks, unlike for instance train tracks. This would facilitate the RoRo technique presented in the next section.

Willy Nicklasson (2009), a technical manager at the Gothenburg tram company, revealed that a great number of old tram models but fully functional trams, known as M28 and M29, are available to a fraction of the price for a new tram. M28 and M29, are high floor trams, which makes it harder for older people to board than the newer drop center design. But on the other hand the floor is flat on the inside allowing for up to three electric distribution vehicles no wider than 2 600 mm to fit. And as identified from Amsterdam, the cost of the trams together with the cost of new infrastructure, tracks and a distribution center, are by far the most expensive investments in a cargo tram project. The low cost of trams would support a low cost and small-scale approach.

Using the lessons learnt from the failure of Amsterdam we arrive at a potential future transport system for Gothenburg that would be suitable for smaller shipments, like parcels. This transport system borrows techniques from three industries; the shipping industry, the train industry, and the car industry. RoRo, intermodality, and the assembly line technique, respectively:

**Barriers 1: not interfere with personal traffic.** In order to minimize the building of sidings and maximize the use of existing infrastructure the EDVs could catch a ride, ‘piggy-back’, on a rebuilt tram from the tram end point into the cities, rather than waiting in the city centre and thus avoiding the costly operation of re-loading from tram to EDVs. Allowing for these EDVs to drive onto the trams via a ramp in the back would also mean that they are not obstructing traffic on the motorways to and from the city and by using ‘follow mode’ (see the Amsterdam section) avoids the risk of obstructing the personal tram traffic. By using a rebuilt distribution wagon, type M28 or M29, in ‘follow mode’ the time for rolling off and rolling on (RoRo) the trams in the city centre and at the tram end stations would be the time between the existing trams in the system, varying between twelve to twenty minutes depending on route and time of day (Nicklasson. 2009). This would also mean no necessary investments in infrastructure. So, why did Amsterdam not consider this method? The trams in Amsterdam are quite narrow because of the narrow streets of the city. They are about thirty centimeters more narrow than in Gothenburg, and the design of the trams is not suited for a roll on and roll off setup. The old versions have a drop center design meaning that the middle wagon is lower than the other two and the new ones are built for accommodating disabled people with low entrance possibilities throughout the entire tram, requiring the wheels to be built in and sticking up in the compartment. Thus making it impractical to drive EDVs on and off without a complete rebuild of the tram. The floor of a M28/M29 on the other hand is flat from the back to the front and fifteen meters long but would need to be reinforced in between the wheel houses.

**Barrier 2: scale** is potentially the most important lesson from the failure of the Amsterdam case; to try this concept in a more small scale fashion, allowing for test and necessary changes before a possible scale up. Lessons learnt from Dresden and Zurich, the only ongoing projects at the moment, it seems sound to start small scale and gradually scale up. Furthermore, a test could be carried out for a limited time period with normal express diesel or renewable fuel vehicles commonly used today, like MB Sprinter, instead of EDVs. This could be an inexpensive way of trying out the concept in a real life situation before investing large amounts of money on EDVs.

The system could benefit from the use of the assembly line technique, separating the driver from the goods. The drivers of the EDVs could circulate in the city center delivering goods and adding value and let the tram transport the EDVs back and forth from the distribution center to the city center. The same idea of separating the driver from the goods has been used in intermodal transportation, where it is not always necessary for the truck driver to partake on e.g. the ship journey. The driver simply parks the truck on the ship, picks up a new one going the other way, and another driver assumes the transport at the ship destination. By keeping driverless EDVs on the tram into the city center facilitates the charging of batteries inside the tram on the way to the city center, thus resolving **Barrier 3: radius of action**. This could potentially lower the costs since an extra handling of the goods at the city center could be avoided. This is a cost issue, but also a social issue since there were indications that inhabitants around one of the squares in Amsterdam were against their square turning into a logistics center. It would also make the distribution a team effort rather than an individual endeavor.

Rather than creating a new competitor and in order to increase the chances of the recommendations to be implemented in Gothenburg by decreasing initial investments and to tackle **Barrier 4: conflicting objectives amongst stakeholders**, the recommendations ought to be presented to the already existing distribution companies, as well as the municipality and tram operator after a thorough cost-benefit analysis has been made. By doing this, additional competition in an already competitive industry as well as a, “not invented here” mentality is avoided. An “open source” mentality could be preferable until falsified.

Unfortunately, there might be no other way of resolving **Barrier 5: stakeholder involvement** other than to call for an increase in cooperation between the logistical actors, municipality and the Gothenburg tram company.

## 8. Acknowledgements

We would like to thank the students Fawad Awais, Patric Lindquist and Rafael Serrado for their valuable input in the creation of this paper, Mentors4research for their financial support, and finally the editors of this special issue and the two anonymous reviewers for the valuable comments and recommendations.

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# Road freight transport efficiency and less environmental impact – the perspectives of transport buyers and operators

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## Paper number: 47532

# Paper number: 47532


## ABSTRACT

**Purpose of this paper**

The purpose of this article is to describe and compare the transport buyers' and transport providers' views of challenges when improving transports efficiency and reducing environmental impact from freight transport. By investigating perspectives of the actor groups, an increased understanding of different viewpoints is made and factors that are of importance for improving transport efficiency and reducing environmental impact are identified. The role of the actors and especially what could be expected from each actor is discussed.

**Design/methodology/approach**

The empirical findings have been collected through semi-structured interviews and two focus groups. The target groups have been two main actors in the logistics system; transport providers and transport buyers in Sweden. Grounded theory has been used for analyzing the data. The focus is road transports and its interface to other transport modes. Both long distance transports and short distance distribution have been included.

**Findings**

Competence and resources, Knowledge and information, Demands, Service and offers, Follow up environmental goals and Priority of transport are identified as important factors. The transport buyers need to raise the focus of transport and environment in order to better understand the effects of transport in the system while the transport providers need to be innovative and proactive in order to find business models that steer towards both efficient and sustainable transports.

**What is original/value of paper**

The interface between transport buyer and transport provider has shown to be poorly studied before. This article provides input to a more holistic approach when improving the logistics system towards an efficient and environmentally preferable direction.



*Keywords: actors, environment, factors, perspectives, road freight transport efficiency*

# 1 INTRODUCTION

That transportation is an important sector for society is undisputed. According to the European commission the transport sector is the "the backbone of European economy" (EC, 2009a). However, there is an increased focus on social and environmental impacts from transportation in the political as well as the societal debate due to e.g., large amount of emitted greenhouse gas emissions from the sector, congestion problems and accidents. The trends are clear; there is an increased share of road transport in Europe as well as longer transport distances in a steadily growing international market. The transport sector alone is today the largest sector still increasing its share of greenhouse gas emissions in society (EC, 2009a). Looking into the societal goals, e.g., reducing greenhouse gas emissions by 20 % by 2020 (EC, 2009b), makes it obvious there is a large gap between societal goals and current trends.

Within logistics, transportation is the major function contributing to environmental impact (Wu and Dunn, 1995). There are a number of logistical actions suggested in literature in order to reduce environmental impact from freight transportation, such as more efficient technology, modal shift, better logistical planning, consolidation and changes in logistical structures, e.g. Skinner et al (2010), De Jong (2010) and Piecyk and McKinnon (2010). However, even if the vehicles in operation are becoming more and more efficient, the transport demand tend to increase along with the requirements on service level from the transport buyers which may limit the improvements (McKinnon, 2003). In addition, the interest for environmental issues in logistics are lacking in favor for traditional logistical performances such as cost and service (Vachon and Klassen, 2008), which may hinder implementation of environmentally preferable actions in the transport sector. From a transport providers perspective, Léonardi and Baumgartner (2004) show that to a large extent, the measures aimed at improving transport efficiency have been poorly implemented. Drewes Nielsen et al. (2003) argue in line with this statement, that "the transport buyer do not display a great interest in an environmentally based change of transport demand and the transport companies only seem willing to supply new transport concepts if demand exists.".

There are a number of actors in the logistics system that potentially could take action, alone or in co-operation with others, e.g. transport providers, freight forwarders, third party logistics providers and transport buyers. Today, most manufacturing companies outsource their transportation and/or logistical activities to a transport provider or a third party logistics provider, which makes the responsibility for improvements being more focused on the transport provider. Björklund (2011) investigates drivers and hinders when purchasing green transportation services from a transport buyer's perspective. Her study shows that transport buyers' view the transport providers as playing an important role in the greening of transportation services. Their knowledge, ambitions, equipment and the relationship between the transport buyer and transport provider has a great positive influence when purchasing green transportation services. Blinge (2005) explores the transport buyers view on transport related environmental issues. He describes some important future focus areas in the interface between the transport buyer and freight forwarders, such as lack of incentives from the forwarders and raises the question, who is actually responsible for the emissions produced from transport activities? However, both of these studies highlight the need for more knowledge about the improvement potentials, especially in the interface between transport buyer and provider. Also, both studies raise these statements from a transport buyer's perspective only.

Few studies exist where comparing several actors' perspectives on acting towards more efficient and environmentally preferable freight transport solutions. Wolf and Seuring (2010) is one such study however, examining how environmental issues is taken into account by transport buying companies, studying cases of both buyers and suppliers of logistical services. These cases shows that, in order to reduce $CO_2$ emissions, one of the main challenges is to change business practice along supply chains, e.g. improving cooperation, trust and information change in between actors. There is a need for a more holistic approach, widening the scope towards suppliers', customers' and competitors' environment in order to find the factors that are of importance for improving the logistics system further in an efficient and environmentally preferable way.

The purpose with this article is to describe and compare the transport buyers' and transport provider's perspectives when improving transports efficiency and reducing environmental impact from freight transport. By investigating the views of the two actor groups an increased understanding of the different perspectives could be made and factors that are of importance for improving transport efficiency and reducing environmental impact are identified. The following research questions are answered in this study:

RQ 1: What factors are of importance when improving transport efficiency and reducing environmental impact from freight transport from a transport buyer and operator's perspective respectively and how are they related?

RQ 2: What differences and similarities can be identified when comparing transport buyers' and transport providers' perspectives?

This paper is distributed as follows: first, the method is explained. Second, an introduction to the concept of freight transport efficiency and its correlation to less environmental impact is made. Third, a general overview of the actors' perspectives concerning what may obstruct transport efficiency and reduce environmental impact is described. Finally, a concluding discussion compares the factors identified as important for the actors and a discussion of the implications of the coinciding and differing views takes place.

# 2 RESEARCH METHOD AND DATA COLLECTION

Interviews and the results from two focus groups form the basis for the empirical data collection in this study. As introduced earlier, there is a lack of research that investigates more than one actor's view when analyzing ways to improve transport efficiency as well as reducing environmental impact from transport systems. How different actors, such as transport providers and transport buyers, view the system is fairly new and unexplored. Therefore the data collection has been performed in an explorative way, aiming at describing the system and forming hypotheses and suggestions for further research based on empirical data.

The two studied actor groups were transport providers and transport buyers. Transport providers included actors offering logistics and transport services and operations; third-party logistics service providers, freight forwarders and hauliers. Transport buyers included actors that have a large goods flow and purchase the transport service from a third part, i.e. they do not have their own vehicle fleet. The transport providers were both medium sized trucking terminals operating on a regional level, rail providers and third party logistics providers operating at a national and international level. The transport buyers were large international companies having a large goods flow. All of them originate from different branches including food, pulp, agriculture, construction, vehicle production, clothing and personal care. They all have their base in Sweden.

A combination of interviews and focus groups were complementing each other. Semi-structured interviews were conducted since it was important to understand the specific respondent's context, being able to include open questions as well as to include different follow up questions. In addition, semi-structured interviews allow you to be flexible about the order of questions as well as to be able to include questions of interest dependent on the specific respondent (Bryman and Bell, 2007). An interview guide was used as a base for all interviews. The respondents were included from both actor groups; transport providers and transport buyers. Interviews were performed with 5 transport providers and 3 transport buying companies. Two researchers conducted the interviews, lasting about 1 to 2 hours each. The interviews were recorded and later transcribed.

Since we wanted to both identify factors of importance and comparing the viewpoints between the two actor groups, focus groups were chosen as a method to collect data. The interviews contributed to forming subject areas that were discussed in two full day focus group seminars, one for each actor group respectively. Focus groups were chosen for its advantages of capturing the dynamics in viewpoints from several participants in the groups (Kvale and Brinkman, 2009). Also, focus groups are useful for e.g., orienting oneself in a new field, generating hypotheses based on informants' insights and evaluating different study populations (Morgan, 1988), which is in line with the aim of our study. The focus groups included 8 and 10 participants respectively. The researchers were moderating the focus group discussions with the aim to create informality in the discussions in order to get all members to speak openly while at the same time keeping the discussion within the different subject areas. During the focus groups notes were taken continuously by the authors of this article. The notes were thereafter summarized and sent out to the participants for their comments.

The analysis of data has been performed in line with grounded theory (as described in Bryman and Bell (2007)). The key process of coding has been performed; data were analyzed and compared from the interviews forming subject areas that were included in the discussions in the focus groups. Open coding has been carried out, which is "the process of braking down, examining, comparing, conceptualizing and categorizing data" (Strauss and Corbin, 1990). The outcome from the process was the identified common factors. Also relationships between these factors were explored, by presenting a model in which the factors are connected to each perspectives and its influence on the actors.

# 3 FREIGHT TRANSPORT EFFICIENCY AND ENVIRONMENT

This section serves as an introduction to the area of freight transport efficiency and environment, and aims at explaining some of the complexities when dealing with these concepts, based on literature. The review of the concepts is meant as a short reference guide for the reader of the paper in order to help out in the understanding of the different factors identified that affect transport efficiency and environmental impact.

Efficiency of transport systems is of most importance for reducing environmental impact from freight transport while also staying competitive. However, the terminology of transport efficiency is used with no common definition, which makes it important to highlight its significance and relation to reducing environmental impact from freight transport as a part of a sustainable freight transport system. From the literature at least two aspects in trying to define transport efficiency can be identified: 1) Several types of measures; smart, economically and environmentally sustainable or "optimal" use of "resources". 2) Clear trade-offs and different meanings for various actors.

Caplice and Sheffi (1994) propose a series of ratios as logistical KPI for performance measurement in logistics: Utilisation, Productivity and Effectiveness. These logistics metrics is later reworked by McKinnon and Ge (2004) and suggested to serve as a base for transport efficiency measures, leading to a series of KPIs: vehicle loading, empty running, fuel efficiency, vehicle time utilization and deviations from schedule. The first three KPIs are utilization measures, the fourth is a productivity measure and the last assessed the effectiveness of the delivery operation. In another report, transport efficiency in terms of reducing $CO_2$ emissions from a macro perspective is presented (Piecyk and McKinnon, 2010). The used framework maps the linkages between determinants, key variables and output. All these measures combined with fuel efficiency result in an analytical tool to reduce environmental impact in terms of $CO_2$.

Rodrigue et al. (2001) focuses more on the paradoxes of green logistics such as; environmental costs are often externalized, modes used are the least environmentally efficient: trucks and air, and inventory shifted in part to roads contributing to congestion and space consumption with the argument that reducing logistics costs does not necessarily reduce environmental impacts and also stresses the importance of integrating logistics with other fields of research. McIntyre et al. (1998) highlight the trade-off between reducing environmental impact and decreasing financial costs. Most KPIs used have been found to be time and cost focused. This approach tends to promote a short term perspective and work on greening the supply chain benefits from a more long term perspective. The suggestion presented by McIntyre et al. (1998) is to amalgamate both perspectives so that the long term is represented in the performance measurement.

There are, obviously, different levels of efficiency in transport and logistical systems. Reducing costs is naturally of more importance on a micro level. Literature focusing on reducing environmental impact takes to a larger extent the macro level dimension. The indicators that measure efficiency on these levels may differ. Literature shows that a number of measures are necessary in order to present the broad picture of efficiency as such and level of environmental impact in particular. In the interviews and focus groups undertaken in this study a common definition of transport efficiency or what kind of environmental impact that is to be reduced was not presented or brought up. Rather a focus has been on what factors impacting a reduction of environmental impact while improving competitiveness on a general level spring boarding from each actor's perspective.

# 4 PERSPECTIVES OF DIFFERERENT ACTORS

Factors that affect the level of transport efficiency and environmental impact from freight transport have been identified. Every factor below is described according to both transport providers' and transport buyers' perspectives, respectively. Some factors are more important for one actor group, while others are important for both, sometimes in contrasting ways. The factors are the outcome from the study, based on the different viewpoints that were brought up from the two actor groups, both in the performed interviews and the undertaken focus groups.

## 4.1 Competence and resources

The transport providers in both the interviews and focus group raised the issue of lack of competence as a factor affecting their environmental work and ability to make more efficient transport solutions. One small provider highlighted that they do not have the economic conditions for hiring specialists in all areas, especially environmental. Furthermore they have limited possibilities to invest in other technical improvements that might be better off for environment and efficiency, such as information systems or new vehicles. Another provider raised the point that employees responsible for environmental issues may not have enough knowledge about how to actually work with these issues or that there is a large work load and not time for reflecting and analyzing possible new projects. In the focus group, how to attract new and young professionals to the transport sector in general was another issue of concern for the providers. There is a growing lack of truck drivers and competent business people in transportation. The transport providers believe that their business is not attractive enough, especially for women. Two reasons mentioned in the focus group was the unpleasant working hours which may limit the co-ordination of family life, such as picking up kids at day care, but also the general reputation of the branch as such with myths about overbalance of male employees and a “rough” working environment.

## 4.2 Knowledge and information

The transport buyers in the focus group stated challenges concerning knowledge about their transport systems. In both the interviews and the focus group, companies painted a picture of lack of knowledge regarding their purchased transports. This concerns knowledge of the amount of purchased transport as well as the amount of environmental impact from the purchased transport. There were a number of the transport buying companies that experienced they have not full control of their own transport flows. One company mentioned that about 80 percent of its transport flows are known while the rest is unknown for the company; "a lot of people in the company buy transport services". Another company stated in the interview that because of new company structures and a large expansion in the company the first aim is to actually get control of its own flows, i.e. to identify what transport structures exist in the company at the moment.

When it comes to environmental issues, there are different views about the level of knowledge. In the focus group there were examples of transport buying companies who experience they have knowledge about their environmental impacts from transportation, but also the opposite. From the focus group, the impression was that there is an issue concerning detail level. To base an environmental measurement on very general assumptions, such as on transport mode and distances mentioned as a possibility, while being more detailed was stated as more difficult. Another issue mentioned in the focus group was the lack of knowledge concerning how important the transport service is for society.

## 4.3 Demands

According to the transport providers in the focus group, the transport buyers traditionally dictate the terms while purchasing the service from the transport providers by setting different kind of demands. In order to improve the efficiency or reduce the environmental impact of freight transportation demands from the transport buyers can constrain this work. In both the interviews and the focus group the transport providers agreed on that to save cost is traditionally one important focus of the transport buyers. However, the larger part of the discussion concerned the stricter time constraints that were partly seen as limiting the ability to act efficient from a transport providers' point of view.

Time demands are connected to several different issues; point for ordering the transport, point for picking up goods, point for delivery and also the total time in between these points. From both the interviews and the focus group this issue was mentioned in different ways, but it was also clear that it was not a completely uniform picture within the transport providers regarding time. The transport providers highlighted that in order to stay competitive it is of importance to focus on time, the goods need to be delivered quickly and just in time. One reason for this development is that the competitors also are offering fast deliveries and that the customers (the transport buyers) demand it. Furthermore, a trend was recognized from the transport providers, that the transport buyers are making the order later and requiring the delivery earlier. This trend was mentioned to be negative for optimizing the transport system, since it shortens the time for planning the transport in an efficient way and also leaves less room for error and flexibility. Also greater time windows at delivery were viewed as something that would improve the possibilities for increasing the efficiency in the system. However, other transport providers stated that they already have their time table to which the transport buyers do have to adapt to. The important issues in order to make a transport efficient are to consolidate a large goods flow.

Also, there were examples raised of when the delivery requirements in terms of time would increase the environmental impact, e.g. intermodal transport. A provider transporting goods between the Swedish west coast and Stockholm had a customer requiring delivery at 7 am in the Stockholm area; which was impossible using rail. Instead road transport had to be used in this example.

Several transport providers in the focus group suppose that it is not always that the demands regarding time need to be stressed as hard as firstly perceived. In general, some of the transport providers clearly express the need for having better knowledge in terms of the actual need from the transport buyer. The transport providers believe that the transport buyers often are not really aware of what they want. The reasons for this, according to the transport providers in the focus group, can be that the person responsible for purchasing transport does not have enough detailed knowledge about the actual operations in the company. Demands are framed in a traditional way - and a change of that (if not to a better service level) may be seen as lowering the service even if it may lead to a better total efficiency of the system. The perception from the transport provider's point of view was that transport providers today are generally bad at questioning the transport buyers' demands and starting a dialogue about the different options that are actually available. The transport buyers may fear that these type of questions can be seen as a way to reduce service - when it is actually about finding ways to make the transport more efficient by delivering the service that is satisfying their needs. One transport provider mentioned the importance of information in the dialogue when meeting the demands from the transport buyer: "It is important to deliver facts to the buyer; to be able to say that your decision A will have the following effects. But if we do B, this is what we will save". In this dialogue it is important to have information about the operations, tools for calculating environmental effects and know potential cost savings. Additionally, the environmental demands are often not included in the original discussion, but are later added, sometimes by the environmental department. The transport providers would like to see the buyers ask how they could best use the provider's network, instead of stating how and when a transport should be performed. A more extensive dialogue with the transport buyers regarding their actual needs was of major concern among the transport providers.

In the focus group, it was obvious that a robust transport chain is a necessity for the transport buyers' business. The transport buyers stated several aspects concerning demands that are important for their efficiency of their transports; such as cost, time and robustness. Concerning environmental demands, in the interviews, all transport buyers did state that they put environmental demands on their transport providers, where the majority using Q3 as a guideline[1]. However, in the focus groups, the most concern regarding demands was about cost and time.

The transport buyers in the focus group did say that price is an important factor in the choice of transport supplier, but expressed that they would like to see the transport providers to sell services on other aspects than price, like flexibility and adaptation. They agree on that if all qualitative factors are equal between the transport providers, price is an order winner, but it was also identified that an open dialogue, and an understanding from the transport provider about the transport buyers' logistics system, is important. It is however of main concern for the buyer to keep prices low.

In addition, strict lead times can also be a deal breakers according to the majority of the transport buyers. If the robustness in the transport chain is disturbed, leading to e.g. delivery delays, serious effects in terms of costs for the transport buying companies might occur. One example, mentioned by one transport buyer, was the problems in Rotterdam harbor last year which lead to extensive delays on their shipping on products. This forced the transport buyer to ship by air instead, which of course generated higher transport costs.

Most participating transport buyers in the focus group identified robustness and smaller time windows at delivery as important. The transport buyers agreed on that "just in time" was very important, by that meaning "just in delivery time". However, some transport buyers recognized that they did plan and book transport quite late in the process, which was mentioned to be possible to be made earlier. Furthermore, the question was raised whether the transport providers could handle order information that was sent out a couple of days earlier than customary. Some of the transport buyers were in doubt.

## 4.4 Service and offers

In order to offer an attractive service to the transport buyers, price of transport is perceived as an important factor, as identified in section 0 and 4.6. The market for transport providers are tough, with low margins and fierce competition. One reason for this, which was mentioned by the transport providers, is the growing availability of inexpensive hauliers from low cost countries, such as Poland. This issue worries the Swedish transport providers from a perspective of competition on equal terms. Furthermore, the entry levels to start a trucking firm and to invest in a truck within Sweden are low, which contributes to an over-capacity of

1 Q3 is a non-profit-making association assisting transport buyers when setting demands in the areas of safety, working conditions and environment. For more information see their webpage: www.q3.se.

transport providers on the market, according to some transport providers in the work shop. However, some of the transport providers mentioned a change in trends, where the larger transport providers are growing, collaborating with or taking over smaller hauliers in the surrounding area, in order to get a higher goods flow and better profitability.

A suggestion mentioned by the transport providers in order to both raise the profitability in offers and efficiency in the system was differentiated time requirements. In the offer this meant to vary the price with different services connected to time of transports, e.g., more expensive express transports and cheaper price for non-urgent transports. To differentiate between the regular and "slow" goods, would make it possible to leave some goods waiting for the next day which would make only full vehicles to leave the terminal. The idea was brought up to identify the goods that actually do not have the strict time requirements. However, as discussed by the transport providers in the focus group, this is not only a positive arrangement for the transport providers, since it would require another type of terminal handling including more storage - which in turn raises the cost.

One problem that was raised by a large transport provider concerned keeping the promised service level when delivering goods to a receiver which is not prepared to receive the goods. The problem was concerning the common situation whereby the transport provider makes an attempt to deliver the goods, but the receiver is not available, or the timing of delivery is not right. This in turn generates many unnecessary transports. Approximately five percent (estimation by the transport provider) of the transport provider's deliveries cannot be finalized due to that the receiver does not know about the details of the delivery and are therefore not prepared to receive the goods. The reason for this to happen, according to the transport provider, was that the dialogue between the transport buyer and receiver were lacking. Major improvement possibilities were identified within the area of planning in this respect, where the transport providers expressed a need for the transport buyer to take a larger responsibility of the supply chain in order to plan the goods flow all the way from pick up to delivery.

As discussed in section 0, the transport providers stated clearly that transport buyers in a too large extent dictate the demands, what service level must be kept and indirectly then also the conditions in the offer. The transport providers wanted to have a more open discussion in terms of how they can create a better transportation offer and service for the buyer, instead of just reacting to demands.

The transport buyers in turn, state that transport providers must elevate their gaze in order to offer an attractive product, where cooperation and a dialogue in between the two actors are very important. Some transport buyers did mention that they think the transport providers are too passive regarding offering new solutions that may be more efficient and environmentally preferable. One transport buyer expressed it as: "The confidence of transport providers is low -- they do as they are told". The transport buyer meant that their experience was that all initiatives were taken by themselves – not by the transport provider.

On the other hand, regarding offerings including environmental improvements, some of the transport buyers questioned if the transport providers had a hidden agenda in terms of selling an "environmental product" and wondered if they did package an environmental service to make money or actually lessen the environmental impact. The transport buyers mentioned that there can be suspiciousness towards the transport providers when they are "packaging" an environmental service. There is a feeling from the transport buyers that the transport providers do offer environmentally preferable services in a way to make more money rather than improving the transport itself.

To differentiate prices was also mentioned as an option from the transport buyers; such as a book early discount or different price levels dependent on if return flow exist or not.

## 4.5 Follow up environmental goals

The transport providers in both the focus group and interviews described that they are setting environmental goals; most of them concretizing the goals into numerical emission reductions. The most common goals among the respondents were to decrease $CO_2$ emissions. Some goals are more ambitious than others, such as reducing $CO_2$ emissions / tonkm with 50 percent to 2020. These goals were set on a voluntary basis only and no discussion of potential retributions of non-compliance took place. Other issues brought up in regard to environmental goals were; to increase the use of higher euro classes, to use alternative transport modes, and to use longer vehicles.

One transport provider stated “As long as you do not follow-up, nothing happens”, which was representing the view from the transport providers about the importance of follow up and measuring the fulfillment of environmental goals. However, there was no deeper discussion held on how these measurements could be realized. Although, one point mentioned was the need for standardizing the use of telematics for both increasing efficiency and facilitate measure of transport data.

The transport buyers gave a picture of a situation where it is very difficult to get an overview of transportation and emissions. Far from all transport buyers do have a clear picture of their emissions from transport and their transport flows in general. However, several of the transport buyers do calculate the $CO_2$ emissions, but not at a detailed level. The idea is to start “somewhere”, as one participant put it. Most transport buyers have information regarding used transport mode, distance between origin and destination and amount of goods to be delivered. The exact route is difficult to get hold of, as well as detailed information about vehicle size, load factor etc. On the other hand, there are examples of companies using different calculation tools or models for their estimations.

One important problem raised by the transport buyers was that the “normal” key performance indicators in transport buying companies are not including environmental issues, they are primarily connected to pure costs. So the need for differentiated price settings on environmental issues are mentioned as important by the transport buyers in order to actually make something happen in line with the environmental goals. Goals exist, but more incentives are needed, steering towards these goals, as concluded by another participant. Furthermore, to make an environmental analysis of the transportation when making decisions in the transport buying companies seems very rare, no one of the transport buying companies had made such an analysis.

Some concrete suggestions were raised by the transport buyers. These include; enforcing stricter demands on how the transport providers should declare the emissions. One idea is to declare specific emissions per consignment, another to declare the whole transport chain in detail. Although the transport buyers doubt that the transport provider can deliver this type of information. To have a standard for measuring emissions is seen as important from the transport buyers’ point of view. Or as one participant concluded; maybe such a model needs to be in place before setting such demands?

From a transport buyer’s perspective, the concern about where to draw the line of the system and what to include in their responsibility area was raised. For example, a change from a supplier in China to a supplier in Sweden may result in less transport in total, thus fewer emissions as well. However, the supplier itself may supply from China or have an inefficiency transport system which makes, in total, the first solution better. How to handle these issues when follow up transport and using the material for decision making are issues of importance, as mentioned by one of the transport buyers.

## 4.6 Priority of transport and low transport price

For the transport providers transportation is, naturally, their main business focus. However, one of the most important factors influencing the transport efficiency and environmental action mentioned by the transport providers in the focus group was the need for a higher priority of transports among the transport buyers. A number of reasons were mentioned; the view that the transport buyer are not taking enough responsibility for its supply chain and its transport, the view of the low willingness to pay for transport in itself (too low transport price) and especially more efficient and environmentally preferable solutions. Even though, the common view in the focus group was that economical and environmental goals are not contradicting each other, which means that a more efficient solution is also more environmentally preferable, it was mentioned that the low willingness to pay by the transport buyers is a problem for introducing more efficient and environmentally preferable solutions. On the other hand, there were other examples raised when the goals are contradicting, e.g., the investment and use of trucks using technology for alternative fuels (such as bio gas) are more costly than the conventional alternatives; both regarding the investment, but also when it comes to time consuming operational difficulties due to lack of gas stations.

In the focus group, the transport buyers agreed on that the transport issue is not as high a priority within the transport buying companies as it should be. Several of the transport buyers stated that there is a common view of transportation as something that "is", somehow taken for granted, and not prioritized in the top management team or board rooms. One transport buyer raised this specific topic by saying: “More transports are created because of globalization and too cheap transport prices. One may have a transport flow all the world around without any significant costs”. However, it is clear from the transport buyers that if the robustness in the transport chain gets disturbed, it is a critical issue for the whole company and its performance which also leads to extra costs. In the focus group it was discussed if the location of transport or logistics organization within the organization as a whole can be a hint of its priority. Also, how large part of the total costs arises from transport and logistics is another sign of its priority. In the interviews, the transport buyers showed a difference of total transport costs’ share of total production costs, ranging from a few percent to around 20 percent, the latter a paper mill, which was also related to the companies’ focus in logistics activities. In order to increase the focus on transports within the transport buying companies it was raised that it was essential to communicating the importance and cost of transportation to the top management and also raise the awareness and control of the company´s transportation activities in general.

In line with the transport providers, the common perspective raised in the focus group was that economical and environmental goals do go along and are not contradicting. One transport buyer mentioned examples of successful purchasing that lead to both cheaper and more efficient transportation. However, the willingness to pay more for a more efficient or environmentally preferable transport is not obvious among the transport buyers. One transport buyer in the focus group stated that “to pay more is probably not going to happen”.

# 5 CONCLUDING DISCUSSION

The two actor groups, transport providers and transport buyers, show both similar and dissimilar views concerning challenges when aiming for a more efficient and environmentally preferable transport system. The concluding discussion includes a comparison of the actors perspectives as well a description of the identified factors’ relation.

## 5.1 Comparing perspectives

The major differences from the viewpoints of the actors can be seen from the table 5.1.

*Table 5.1: Summary of the factors identified as most important when improving transport efficiency and reducing environmental impact from freight transport based on the transport providers’ and transport buyers’ perspectives.*

| Important factors | Perspective of the transport provider | Perspective of the transport buyer |
|---|---|---|
| **Competence and resources** | Lack of competence and resources to work with environmental issues within the organization. | Knowledge and information were discussed rather than competence and resources |
| **Knowledge and information** | Competence and resources were discussed rather than knowledge and information | Lack of knowledge about all their transport operations and its environmental impact. |
| **Demands** | Demands, like cost and time can sometimes be viewed as a limiting factor. Greater time windows at delivery are needed and more flexible solutions. | To keep the time, i.e. JIT, and robustness in deliveries is a prerequisite. |
| **Priority of transports** | Notice the low willingness from the transport buyers to pay extra for environmental better solutions. | Low priority of transport in transport buying companies. Agrees on the low willingness to pay for environmentally better solutions. |
| **Service and offers** | Would like the buyers to be more open in discussions about possible solutions. | Would like the operators to offer more environmental services and being more proactive. |
| **Follow up environmental goals** | Raises the need for measuring the fulfillment of the goals. | Raises many challenges in the area of measuring environmental impact, difficult to measure in detail. More information from the transport provider is needed. |

Regarding **competence, resources, knowledge and information** the actors highlighted different challenges. The transport providers mainly discussed the challenge of finding enough competence within their own organizations, such as personnel and knowledge in areas dealing with e.g. environmental issues as well as economical resources for investments. The transport buyers’ challenge is about not having full knowledge and information about their transportation flows, especially on a detailed level.

The transport buyers and transport providers in our study discussed mainly around the importance of two types of **demands**; time requirements and price of transport, not environmental demands. The transport buyers highlighted the need for getting the goods on time (JIT), while the transport providers gave a more differentiated picture around the theme: that greater time windows at delivery or receive orders about the transport well in advance for planning purposes would benefit the efficiency in the system. This was not mentioned by the transport buyers themselves. The issue of how demands are prioritized in the transport purchasing process, such as shorter lead time, delivery requirements, costs and environmental issues, has been discussed by e.g. Crum and Allen (1997), Menon et al., (1998), Lammgård (2007). Lammgård (2007) concludes from her investigation that *“price is important when basic requirements are fulfilled”* which is in line with the view from the transport buyers in our study. The seemingly low priority of environmental demands from a transport buyer has been shown in earlier studies as well, e.g. Wolf and Seuring (2010) state that there is *“limited evidence of environmental issues constituting a buying criteria for 3PL services”*. How the low priority of environmental demands affect the actual outcome in terms of action has been scarcely discussed in earlier research. Rogerson (2011) do mention that the transport providers’ ability to respond to environmental demands will affect the transport buyers’ interest for them as a supplier. The transport providers in our study however, were most concerned about how the high prioritized demands on especially time issues impede more efficient transport solutions. In literature (e.g. McKinnon (2003), Halldórsson and Kovács (2010)) it has been questioned if the trends towards e.g., shorter lead times, more frequent shipments and smaller delivery windows really reduces environmental impact. But examples in practice showing these relations and the actual effects are lacking. In order to influence these requirements it will be of outmost importance for transport providers to communicate in what way a change will lead to both environmental and economical improvements for the transport buyers.

While the transport providers see themselves as a low margin branch with high competition, struggling for survival to make more profitable business steered by the transport buyer's demands, the transport buyers give an impression of viewing transport as a given service. This service is commonly lacking in priority in top management in the transport buying companies even if uncertainties in the transport services, such as interruptions, delays etc. may give raise to huge negative impacts for transport buying companies. Both actors recognized that the price of transport is generally very low and that the will to pay more for better solutions from an environmental perspective seems to be low, or even non-existing. The difference in **priority of transport** issues in the two actors systems might be explained by how efficiency is perceived. It is not always the case that efficiency from a transport buyers’ perspective is the same as efficiency from a transport provider's perspective, where efficiency gains from a transport buyer is also about e.g., production, inventory and marketing strategies at times experienced by the provider to be restrictive in their effort of making a more efficient transport system.

It was apparent that the actors today experienced hierarchies in relation to each other, where both the transport providers and transport buyers were aware of the unbalance in the purchasing dialogue. The challenge seems to be to meet the demands from the transport buyer, turn these demands into a more sustainable offering and getting paid for it. A few transport buyers voiced a concern, accordingly, that the transport providers do package environmentally better offers in a way to make more money rather than improving a transport service. The providers would like to have greater impact in the transport purchasing process instead of just reacting to demands. In terms of **service and offers**, the transport providers were asking for more openness and flexibility from the transport buyers in the discussion about new business solutions and the transport buyers would like to see the transport providers more proactive in the way they offer new solutions. Also, Wolf and Seuring (2010) recognize a superior-subordinate relationship in between 3PLs and transport buying companies in their study: *"Almost inevitably and despite all efforts and shiny visions, 3PL rather remain in a "henchman's" position towards their customers, with few exceptions from this rule"*. On the other hand, since the transport buyers state a need for more initiatives from the transport providers themselves, it is an indication of that the transport providers can front the transport buyers much more proactively in the future than what is done today without venture their position as a supplier – rather the opposite. A closer dialogue and co-operation in between these two actors might then be a necessity.

Both actors identified to **follow up environmental goals** as an important factor. However, the problem was mainly discussed among the transport buyers. Many of the transport buyers do not have a clear picture of their emissions from transport flows, even though many transport buyers do measure their $CO_2$ emissions, it is mainly on a rough detail level. To have a standard for measuring emissions is seen as important from the transport buyers' point of view, where in turn there is a need for information from the transport provider about the performed transport. Other studies also discuss the issue of measuring environmental impact and why it is important to communicate effects from decisions both within a transport buying company, as well as between the transport buyer and transport provider. Blinge (2005) highlight several challenges from a transport buyers perspective; the need for information so that decision makers could understand the consequences from their decisions and the need for common methodologies for calculating on environmental effects from transports. Wolf and Seuring (2010) concluded that most of their investigated companies, transport buyers and 3PLs, have started to measure their environmental impact from transport activities, but with "*limited knowledge on how results of these measurements impact the company's economy*". The many challenges of measuring freight transport trends on a macro level scale have been pointed out by McKinnon (2010) which also could be applied in a micro level environment. Examples of such challenges concerns how accurate distances have been measured or if weight measures includes the loading units or not. When follow up goals and measuring effects it is important to know what the information is used for. There is little doubt that more information concerning freight transports is needed and it can be seen as a prerequisite for raising the awareness about cause and effects from decisions in both actors environment, motivating changes in the system, raising the priority of freight transport and also to increase the willingness to pay for efficiency and environmental improvements. In order to know if it is profitable to change your pattern or make investments it is important to know what you actually pay for and this might in turn generate concrete action by both actors.

## 5.2 The relation between factors

In figure 5.1, the different factors are summarized and their relations to each other are highlighted.


*Figure 5.1 Factors of importance for the actors*

Figure 5.1 is a model of how the factors affect the different actors and what actor could be argued to take the lead in a change towards a more efficient and environmental system, at least from the factors identified in this study. Transport buyers highlighted the importance of knowledge about their transport systems through better information about their transportation flow internally. Transport providers on the other hand lack resources in terms of money and personnel within their companies. In order to provide better internal conditions for both actors, they are both dependent on each other's co-operation and dialogue. Openness for what demands are important as well as an increase of priority of transport must be instigated by the transport buyers in order to open up for a dialogue about efficient and environmentally preferable services and offers from the transport providers. This in turn may be induced by being provided the necessary information from the transport providers in order to motivate the purchasing of efficient and environmentally preferable services and offers or to follow-up environmental goals. Each actor is dependent on the other actor's acting. A better understanding of both systems will be a necessity in order to generate a change from today's situation. Then an open dialogue, information sharing and to be proactive are suggested to be essential.

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Transportation Research Part A 51 (2013) 56–62

Contents lists available at SciVerse ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

# The milk run revisited: A load factor paradox with economic and environmental implications for urban freight transport

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A R T I C L E  I N F O

*Article history:*
Received 26 November 2012
Received in revised form 11 February 2013
Accepted 4 April 2013

*Keywords:*
Load factor
Vehicle utilization
Urban freight
Sustainability
Paradox

A B S T R A C T

Research has shown that time access restrictions in city centers might increase social sustainability aspects such as livability or safety, but might also increase the number of vehicles and the total distance travelled; which have negative environmental impact and can decrease economic sustainability. In this paper we see that this negative effect could also be the result of other access restrictions, like load factor restrictions, and may be related to factors other than the number of vehicles and total distance travelled. Such as if the distribution center is in the outskirts of the city and customers are situated outside the city center. In this study a common urban distribution network scenario is presented – the milk run – where only the load factor is changed. Increasing the load factor is usually regarded as a way of improving efficiency, but we observe that under certain conditions improving the load factor affects economic and environmental sustainability, by increasing total costs and emissions. Following insights from this study, implementation of policies and business decisions in urban freight distribution are recommended not to use single key performance indicators. Following insights from this study, policy makers and companies should be careful when using single key performance indicators in urban freight distribution.


## 1. Introduction

In urban areas, the movement of goods may account for 20–30% of the total vehicle kilometers travelled, and for 16–50% of emissions from transportation (Dablanc, 2007). This presents particular challenges. On the one hand, transportation of goods is an important economic activity, but it also increases congestion, noise and emissions. In the past decade, the transportation industry has been increasingly concerned over the effect of fuel usage on operational costs and on $CO_2$ emissions. This is particularly the case in urban freight transportation, where most logistics chains start or end, and which therefore also deals with "first or last mile" related inefficiencies. The local authorities try to improve the situation by implementing incentives and by imposing restrictions including, for example, local freight networks, access restrictions, consolidation of deliveries, and access to bus lanes. Operators themselves try to improve their efficiency and take environmental consideration by advocating eco-driving and by improving the load.

The concept of "milk run logistics" originates from the dairy industry and describes a situation in which one vehicle distributes or collects goods from a number of customers or suppliers and circulates according to a pre-defined route.

This paper connects to the on-going conversation on the trade-offs in sustainable urban freight distribution, see e.g., Stathopoulos et al. (2012) and Arvidsson et al. (2013), by presenting a counterintuitive theory for milk run distribution in urban areas. It starts by supplying the reader with information on restrictions used in practice and trends in urban freight transport. Then examples of paradoxes and contradictions in sustainable transportation are presented. Drawn on the two

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0965-8564/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.tra.2013.04.001

previous sections a load factor paradox is introduced. Some implications and remarks for local authorities and operators in conjunction with this paradox conclude the paper.

## 2. Inefficiencies in the last mile and some counter-measures

In freight transportation, the last mile is the final phase of a distribution network in which goods move from a supplier to a customer. The Council of Supply Chain Management Professionals (CSCMPs) estimates that as much as 28% of all transportation costs occur in the last mile (Goodman, 2005). This estimate depends on the number of customers, the variety of shipments, and reliability issues related to congestion (Rodrigue et al., 2009). These inefficiencies are tackled in numerous ways. For example, local authorities in European cities have implemented a number of different regulatory- and incentive-based policy measures. The trend is toward more consolidation, co-ordination and regulations paired with incentives. Studies on the effects of these measures on supply chains show the complexity of these issues (Danielis et al., 2010), since the environmental outcomes vary.

Milk runs may be a good way to increase the load factor (vehicle utilization) if very frequent small deliveries are needed on a regular basis and the suppliers – or customers – are located within a small geographic area. The general downside is the increased coordination complexity for all parties involved (Chopra and Meindl, 2007). Hall (1987) states that improving the load factor is not possible without driving vehicles out of their way to visit extra stops, which means longer vehicle routes and travel times (see Woxenius (2012) for a review of freight-related detours). Variable costs of an empty vehicle are always lower than a vehicle operating with a full load if travelling with the same speed, over the same route and using the same type of vehicle (Xiao et al., 2012). In a study by Sahin et al. (2009) it is shown that for a truck travelling 1000 km from Turkey, carrying 20 tons and with a load factor of 70%, the fuel costs constitutes 60% of the total costs where the other parameters are investment costs, operational costs, maintenance, and external costs; see also Table 1. The variance in fuel usage depends on e.g., speed, aerodynamics, tire pressure, and driving behavior.

Research has shown that load factors have been falling, especially in an urban context (OECD, 2003; Browne et al., 2007; De Magalhães, 2010). Thompson and Hassall (2012) and Gonzalez-Feliu and Salanova (2012) suggest a collaborative urban network to achieve higher load factor and lower travel distances, and Cherrett et al. (2012) suggest collaborative procurement of freight services in last mile delivery as a way to consolidate deliveries. Local authorities have long tried to identify opportunities to achieve higher load factor (Cherrett et al., 2012), to the extent that it has even been used in the public debate on infrastructure, where politicians have claimed that new investments can be avoided if the operators fill up the vehicles better (Woxenius, 2012). Research has also been carried out to examine the need for collaboration between logistics and marketing professionals (Ellinger et al., 2006; Boyer et al., 2009), where the challenge is to balance short delivery windows with the desire of the logistic companies for longer delivery windows which yield more efficient routes (Boyer et al., 2009). Others have surveyed hauliers to calculate the load factor as well as a range of other operational efficiencies (Léonardi and Baumgartner, 2004) pointing out the benefits of consolidation (Ülkü, in press) and ways to improve it (McKinnon, 2000). Public–private and/or private-private collaboration has been suggested as one step to tackle the trade-offs in urban distribution (Allen et al., 2010; Muñuzuri et al., 2005; Crainic et al., 2004). From an urban transport planning perspective a similar notion is used by Bayliss (1977) calling it a "participatory process".

One of the most common policies used by local authorities is access time windows (Muntuzuri, 2005; Danielis et al., 2010). This system dates back to the Roman period, where chariots were banned from the city of Rome at particular times of day (Banister et al., 1993; Nagurney, 2005). Today deliveries restricted to certain times of day are common strategies, implemented by local authorities as a means to increase load factor and separate the interaction between residents and heavy goods vehicles, although the effects on total costs and emissions are often difficult to predict (Danielis et al., 2010; Browne et al. 2005). In most studies, more narrow time windows are shown to negatively correlate with delivery costs (Boyer et al., 2009; Quak, 2007, 2009). However, much of the urban delivery activity unfortunately takes place during the morning congestion period (Allen et al., 2008; Cherrett et al., 2012). And as Muñuzuri et al. (2005, in press), Quak and de Koster (2009, 2007), and Danielis et al. (2010) point out that time window restrictions come at a cost of financial and environmental sustainability, owing to an increase in number of vehicles and total distance travelled. Nonetheless, time window restrictions contribute to social sustainability by improving livability, safety, access to the city center for customers, noise reduction, as well as minimizing visual intrusion and hindrances for citizens.

Efficient vehicle loading, reducing vehicle kilometers travelled and fleet renewal is considered to be important from a policy perspective (Thambiran and Diab, 2011). A number of European cities have introduced environmental zones (OECD, 2003) and low emission zones that help to accelerate the introduction of cleaner vehicles and reduce the num-

**Table 1**
Typical fuel consumption in liters per 100 km for Volvo lorries (Mårtensson, 2003).

| Type of truck | Maximum load weight | Gross weight | Liters/100 km empty | Liters/100 km full |
|---|---|---|---|---|
| *Typical fuel consumption in liters per 100 km for Volvo lorries* | | | | |
| Distribution truck | 8.5 | 14 | 20–25 | 25–30 |
| Regional truck distribution | 14 | 24 | 25–30 | 30–40 |
| Truck with semi-trailer long haul | 26 | 40 | 22–27 | 30–37 |
| Road trains long haul | 40 | 60 | 28–33 | 45–55 |

ber of older, more polluting vehicles (Browne et al. 2005). Another example is legislation against low load factor in vehicles (Munuzuri, 2005; Woxenius, 2012). These access restrictions usually aim at improving traffic, for example by using smaller vehicles for the last mile to fit the narrow roads and which may also facilitate the intermodality that occurs because of the extra transshipment from larger vehicles to smaller (Munuzuri, 2005). In Copenhagen high load factor was used as a criterion to access the medieval region of the city center (Copenhagen municipality, 2003). The Certificate scheme introduced there aimed to improve the utilization of the vehicles and the number of vehicles entering the city center by only allowing vehicles with a load factor of at least 60% with a truck no older than 8 years (SMILE, 2003; Geroliminis and Daganzo, 2005). In 2007, Gothenburg implemented load factor restrictions in parts of the city as a means to making the deliveries within the city more efficient. The environmental zone was introduced in 1996 with access restrictions on heavy diesel vehicles older than 8 years. The voluntary load factor restrictions were implemented within this environmental zone, and delivery vehicles greater than 3.5 tonnes were allowed within the zone only if the load factor was greater than 70%. However, after one year of tests the scheme was cancelled due to problems with monitoring of compliance (START, 2009).

It is also important to mention the spatial freight reconfiguration taking place over the last decades in many urban areas; the impact of "logistics sprawl" as Dablanc and Rakotonarivo (2010) and Dablanc and Ross (in press) call it. They found a slow dispersion of parcel transport terminals to the outer areas of the city originally placed in the city centers in the 1970s. This development has generated an increase in $CO_2$ emissions due to an increase in mileage. Cidell (2010) and Kawamura (2001) come to the same conclusion regarding the location of North American freight facilities.

## 3. Examples of paradoxes and contradictions in transportation

Researchers have put forward a series of paradoxes related to transportation in different network settings; most notably examples of adjustments to various networks showing counter-intuitive negative effects for network users. These effects have been proven theoretically (Braess, 1968; Nagurney, 2000; Braess et al., 2005), in lab settings (Morgan et al., 2009) and practically (http://video.pbs.org/video/2192347741/; Nagurney, 2005). The Braess paradox is an example of a road link being added to a network with the aim of improving the situation for travellers, but in which the total travel time increases, consequently leading to overall performance being reduced. The Downs-Thomson paradox shows investing in one traffic mode can be detrimental to another mode (Afimeimounga et al., 2005) and Pigou-Knight-Downs paradox shows that expanding road capacity might elicit new demand with no improvement in congestion as a result (Arnott and Small, 1994). The more-for-less paradox shows that it is possible to send more flow from supply to demand nodes at lower costs (Ryan, 2000). Bayliss (1977), an early advocate of the study of environmental effects of goods movement, points out that public and political concern could lead to uninformed and economically destructive actions if the sole aim is to seek environmental gains (p. 12). Rodrigue et al. (2001) focus on the paradoxes of green logistics: environmental costs are often externalized, modes used are the least environmentally efficient (trucks and air), and inventory shifted to roads contribute to congestion and space consumption with the argument that reducing logistics costs does not necessarily reduce environmental impacts. Comparing sustainable transport initiatives in Stockholm and Delhi, Thynell et al. (2010) point out the inherent conflict between social and ecological sustainability. The ecological goal of lessening the carbon footprint is not always aligned with the social goal of improving the quality of life by providing access in urban areas and improving livability, equity and housing for people with an already low footprint. Some instances of idling with currently used technologies are contradictory when comparing the environment and economy with driver well-being (Gaines and Levinson, 2011). Holden and Linnerud (2011) show that three well known policies to reduce emissions in urban areas may have the opposite effect on leisure travel, developing more compact cities, building pro-environment awareness and attitudes, and promoting the use of ICT. The authors mentions several reasons, one being that people seem to have relatively fixed money and time budgets for travel, and the time and money saved on everyday travel are then consumed on leisure travel.

## 4. A load factor paradox with economic and environmental impacts

As previous research has indicated (Kara et al., 2007; Bektaş and Laporte, 2011; Xiao, 2012) many suggested routing solution models only account for distance and not, for example, for variations in fuel consumption in vehicles with different loads, different types of vehicles, and driver costs. Although increasing the load factor is generally something to strive for, an exception that should be taken into account is presented below. In this example improved load factor is worse for the environment and increases operating costs.

To calculate the fuel consumption I use a version of Liimatainen and Pöllänen's (2010, p. 7680) formula, in which $d_{ij}$ is distance in kilometers, $l_{ij}$ is the load, and w is the weight of the truck in tonnes:

$$\text{Urban fuel consumption} = \sum_{i,j}^{n} 0.057767 \times d_{ij}(w + l_{ij})^{0.6672}$$

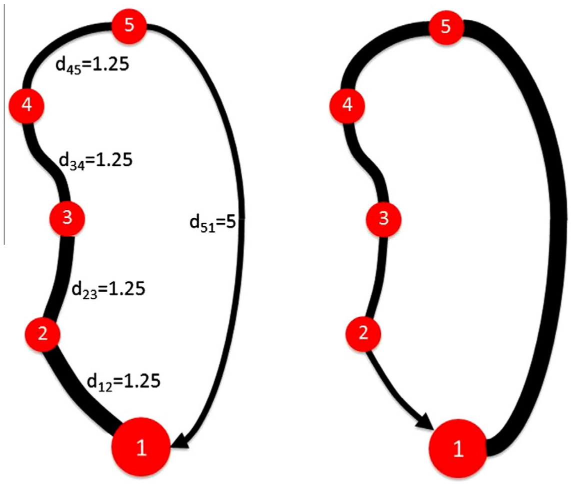


**Fig. 1.** Load factor paradox.

Assume a network as the network depicted in the Fig. 1 in which there are five nodes: 1, 2, 3, 4, 5 and five consecutive links: (1, 2), (2, 3), (3, 4), (4, 5), (5, 1). The round trip starts and ends in 1, the distribution center. There are two 10 km paths available to the operator, either clockwise (1, 2, 3, 4, 5, 1) or counter clockwise (1, 5, 4, 3, 2, 1). A distribution truck with own weight of 5.5 tonnes and a capacity of 8.5 tonnes delivering the amount of 2.125 tonnes of goods to four customers each has the urban fuel functions:

Clockwise fuel consumption

$$= 0.057767 \times 1.25((5.5 + 8.5) \wedge 0.6672 + (5.5 + 6.38) \wedge 0.6672 + (5.5 + 4.25) \wedge 0.6672 + (5.5 + 2.13) \wedge 0.6672) + 0.057767 \times 5(5.5) \wedge 0.6672 = 2.31 \text{ l}/10 \text{ km}$$

Counter clockwise fuel consumption

$$= 0.057767 \times 5(5.5 + 8.5) \wedge 0.6672 + 0.057767 \times 1.25((5.5 + 6.38) \wedge 0.6672 + (5.5 + 4.25) \wedge 0.6672 + (5.5 + 2.13) \wedge 0.6672 + (5.5) \wedge 0.6672) = 2.89 \text{ l}/10 \text{ km}$$

With a conversion rate of 2.66 kg/l of $CO_2$ for diesel (Liimatainen and Pöllänen, 2010) the clockwise path emits 6.1 kilos of $CO_2$ and the counter clockwise path emits 26% more, 7.7 kilos of $CO_2$. An approach that considers a milk run in which the truck returns to the point of origin after deliveries could be sub-optimized if the main indicator ruling routing is only distance. If this was the case, common routing software would not be able to tell the operator which way to go simply because the distance is the same. Traffic work is constant, but transport work is different in the two cases illustrated above. Although the average load factor is higher in the right route this solution is more expensive and worse for the environment in terms of emissions, see Table 1. In practice, the load factor is usually measured as a fixed number of the utilization of the vehicle leaving the depot (Quak and de Koster, 2009, p. 220; Olsson, 2012, p. 63) or by observation at a single delivery point (Ljungberg and Gebresenbet, 2004). In many cases vehicles collect and/or deliver goods to each customer on a route. Therefore the load of the vehicle changes throughout a tour.

The following section aims to illustrate how this paradox might happen in practice. Consider a city center in node number 5, Fig. 2, with the distribution center located in the suburban periphery (see Dablanc and Rakotonarivo, 2010; Dablanc and Ross, in press). If the city center has access restriction in terms of load factor or time window restrictions in the city center, what route does the operator choose? Would the truck start full, choose the longer route and deliver to the city center first and successively deliver to customers on its way back? If that is the case this would lead to a higher average load factor than the left side alternative but also higher $CO_2$ emissions partly because the truck is full half of the way (right) rather than empty (left), thereby highlighting a contradiction between load factor and emissions in this case instigated by local authorities in urban areas (see Table 2). A presentation of customer density in and around city centers can be found in Boyer et al. (2009, p. 186) and Muñuzuri et al. (in press, p. 2).

Research shows that fuel use for workday idling requires further attention; however available data on this type of idling are rather scarce (Gaines et al., 2006). Workday idling may occur when waiting to load or unload goods, to power a device on the truck like the hydraulic lift or to slow movement in a queue. According to one operator, loading and unloading time was 3–4 h per trip while driving time was only 30 min (Ljungberg and Gebresenbet, 2004). While the length of time of workday

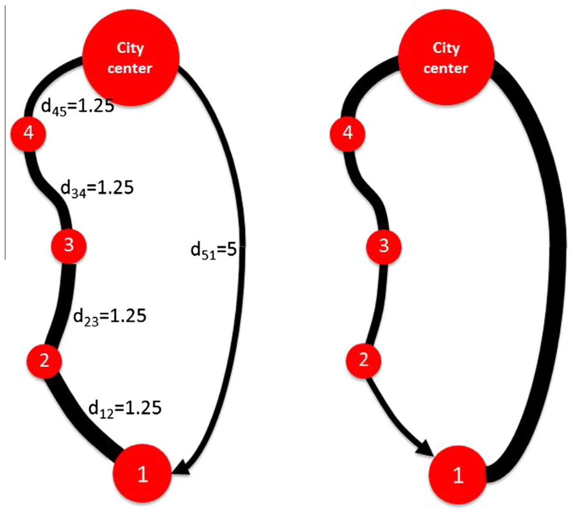


**Fig. 2.** A load factor paradox with access restrictions in urban areas.

**Table 2**
Fuel consumption calculations.

| Path | Weight of vehicle (tonnes) | Weight of load (tonnes) | Distance (km) | Transport work (tkm) | Fuel consumption (l) |
|---|---|---|---|---|---|
| *A distribution truck travelling clockwise on a route of 10 km with a payload of 8.5 tonnes with four drops of 2.125 tonnes each* | | | | | |
| (1, 2) | 5.5 | 8.5 | 1.25 | 10.63 | 0.42 |
| (2, 3) | 5.5 | 6.375 | 1.25 | 7.97 | 0.38 |
| (3, 4) | 5.5 | 4.25 | 1.25 | 5.31 | 0.33 |
| (4, 5) | 5.5 | 2.125 | 1.25 | 2.66 | 0.28 |
| (5, 1) | 5.5 | 0 | 5 | 0 | 0.90 |
| Sum | | | 10 | 26.56 | 2.31 |
| *A distribution truck travelling counter clockwise on a route of 10 km with a payload of 8.5 tonnes with four drops of 2.125 tonnes each* | | | | | |
| (1, 5) | 5.5 | 8.5 | 5 | 42.50 | 1.68 |
| (5, 4) | 5.5 | 6.375 | 1.25 | 7.97 | 0.38 |
| (4, 3) | 5.5 | 4.25 | 1.25 | 5.31 | 0.33 |
| (3, 2) | 5.5 | 2.125 | 1.25 | 2.66 | 0.28 |
| (2, 1) | 5.5 | 0 | 1.25 | 0.00 | 0.23 |
| Sum | | | 10 | 58.44 | 2.89 |

idling is lower than long-haul sleepers' idling, the number of vehicles is considerable higher. Using the more conservative estimate of idling proposed by Gaines et al. (2006) of a fuel usage of 1.5 l per hour for a distribution truck (p 9) and half an hour of idling per day (p 11) in this paper adds an extra 0.75 l to the milk run.

## 5. Concluding remarks and implications

Muñuzuri et al. (2005, in press), Quak and de Koster (2009, 2007), and Danielis et al. (2010) have called attention to that time access restrictions may have a negative effect on number of vehicles and total distance travelled. The paradox neither supports nor challenges that finding since the two routes provided have the same distance and only one truck. However, it adds to the argument. Both time and load access restrictions might have a negative effect on fuel consumption due to other factors than amount of vehicles and distance. Factors such as if the distribution center is located on the outskirts of the city and if some of the customers included in the milk run are located outside the city center closer to the distribution center. This may trigger an almost counterintuitive behavior of operators to drive longer distances than necessary with a fuller load. However it is important to point out that time access restrictions fulfill a social sustainability objective, whether that is true or not for load rate access restrictions might require further studies.

In the meantime and for local authorities it is always good to evaluate the effectiveness of legislative changes in operational terms. Before applying access restrictions, at least on load factor, it may be valuable to identify the location of the city distribution terminals, to take account of whether these are located in the outskirts of the city. Secondly, it is important to identify whether the operators have customers on the way into the city. If this is the case, restrictions on load factor within the city might not be the best option. Overall it is important to consider the consequences of modifying a distribution network; local authorities should pay careful attention to how operators respond to changes to added restrictions and the different effects these changes have on economic, environmental and social sustainability.

For the operators it is important not just to consider one performance indicator. Instead, operators in urban areas would benefit from applying multiple criteria when making strategic decisions (as suggested by e.g. Nagurney and Dong, 2001), so that they may minimize costs related to route choices as well as emissions. This could perhaps be achieved by using a weighted objective function in vehicle routing, (as also proposed by Quak and de Koster, 2009; Kara et al., 2007; Bektaş and Laporte, 2011; Xiao, 2012), where fuel consumption and other costs as well as vehicles are taken into account. Possible questions for future research could be to explore how the business model relationship looks like between the operator and forwarder. Who is responsible for the improvement of load rate? Does the fuel surcharge setup protect the operators and forwarders from price fluctuations or affect the willingness to work with efficiency improvements? Exactly how prevalent is this paradox?

## Acknowledgments

I would like to extend my deepest gratitude to Anna Nagurney and Johan Woxenius for the valuable and constructive suggestions during the completion of this research paper.

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# ROAD FREIGHT ENERGY EFFICIENCY AND $CO_2$ EMISSIONS IN THE NORDIC COUNTRIES

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## ABSTRACT

**1. Objective:** In line with the White paper from the European Commission all Nordic countries have committed to improve the energy efficiency and decrease the $CO_2$ emissions of freight transportation. The aim of this paper is to compare the energy efficiency and $CO_2$ emissions in the road industry for the Nordic countries, except Iceland, in 2010, in order to identify the key factors and their impact on the energy efficiency and $CO_2$ emissions.

**2. Data/Methodology:** Joint analysing method for comparison is created where quantitative is used data to conduct decomposition analysis for several sectors and of several indicators, such as $CO_2$ intensity, transport intensity and energy efficiency. Statistics from Denmark, Finland, Norway and Sweden include continuous road haulier surveys, national accounts data and fuel consumption data.

**3. Results/Findings:** The $CO_2$ emissions of road freight transport in the Nordic countries vary from 1.14 Mt in Denmark to 2.27 Mt in Sweden. While the size of the economy, measured in gross value added (GVA), is a major determinant for the emissions, the differences in transport intensity and energy efficiency also have a significant effect on the total emissions. This is highlighted by the fact that Finland has almost the same $CO_2$ emissions as Sweden, but half the GVA.

**4. Implications for Research/Policy:** Previous research in energy efficiency in road transportation is available for some European countries. However, this study is the first of its kind for the Nordic countries and the sectoral analysis has not previously been published. Our research can be used as a first step in a continuous evaluation of the determinants of road freight $CO_2$ emissions in the Nordic countries.

*Keywords: road freight transport, $CO_2$ intensity, transport intensity, energy efficiency*

# INTRODUCTION

Sustainable development, especially improving the energy efficiency, in this paper defined as road haulage per energy consumption (tkm/kWh), 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 in every sector of the society in order to mitigate climate change and to respond to rising energy prices. This trend can also be seen in 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 and 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 White Paper also highlights that limiting mobility is not an option, so the targets should be achieved without reducing the mobility of goods because freight transport is essential to economic growth.

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 and Baumgartner 2004) and UK (McKinnon and Piecyk 2009) show that the share of freight in road transport emissions has been increasing.

As an EU member states, Denmark, Finland and Sweden are 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 realise 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 efficiency improvements, 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, such as 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.

In line with the EU target, Norway has also committed to improve the energy efficiency and reduce the $CO_2$ emissions of road freight transportation. However, Norway has not worked out a similar detailed plan as the EU action plan for energy efficiency, but the Norwegian master plan for transport that is worked out every fourth year (The Norwegian Ministry of Transport and Communications 2009) has measures for how the emission targets can be realised for both passenger and freight transport.

The aim of this paper is to compare the energy efficiency and $CO_2$ emissions in the road freight transport for the Nordic countries, except Iceland, in 2010 and thus highlight various factors affecting these key indicators and identify opportunities for policy measures towards better energy efficiency and reduced $CO_2$ emissions. To enable this, a joint analysing method for comparison is created with indicators that can be used in data sets for all countries.

## LITERATURE REVIEW

Earlier studies in the field of sustainable development of freight transport have performed development assessment at international and national level, though the emphasis has been at the national level. Historical development has been used to examine the trends of different phenomena. Based on historical development Liimatainen and Pöllänen (2010) establish that in Finland the energy efficiency of road freight improved during 1995-2002 and has since declined. The same kind of trend was found in US from 1975 to 2004, where efficiency improvements have been employed to increase a truck's performance and comfort rather than reduce consumption (Lutsey and Sperling 2005). Ramanathan's (2000) study reveals that in India there has been slight improvement in the energy efficiency of rail transport but road transport was more energy efficient in the late eighties than in the nineties. Ediger and Camdali (2007) argue that in Turkey the energy efficiency of the transport sector over the period from 1988 to 2004 has been cyclical but improved a little. Sorrell et al. (2012) conclude that the aggregate energy intensity, defined as road freight fuel consumption per GDP (l/£), of UK road freight sector fell considerably during the period 1989 to 2004, achieving relative decoupling from GDP. Though, Sorrell et al. argue that this development was due to current economic trends and it cannot be derived as a direct result of the policy actions.

At the international level historical development has enabled the comparison between different countries. Kamakaté and Schipper (2009) evaluate the energy intensity (MJ/tkm) of road freight in Australia, France, Japan, the United Kingdom and the United States from 1973 to 2005. The research relies on a bottom-up model which shows that the energy intensity is influenced by geography, transportation infrastructure and truck utilization. Eom et al. (2012) analyze freight $CO_2$ emissions in 11 IEA countries from 2007 to 2010. According to the study, an explicit trend to the energy intensity (MJ/tkm) of trucking is hard to find and thus the limiting of the freight $CO_2$ emissions is challenging. The whole Europe is covered in the study of Ruzzenenti and Basosi (2009), which evaluates the reliability of the energy efficiency metrics and as a result the study argues that the energy efficiency of the European transport sector has improved during 1970-2000. This is due to technological progress but also more powerful and heavier vehicles, i.e. a result of the ratio properties of efficiency; higher efficiency can either be due to lower input as well as a higher output.

Another common theme other than historical developments in freight energy efficiency research is to analyse variations of future trends of energy efficiency in freight transportation. Trucking activity will double to 2050 and grow faster than passenger transport (IPCC 2007). These trends could lead to a doubling of transport energy use worldwide (IEA 2009). For a more local context, according to Zanni and Bristow (2010) road freight $CO_2$ emission in London might increase about 109% by 2050. Hao's et al. (2012) study utilizes a bottom-up model to predict future fuel consumption and life cycle GHG emissions of the on-road trucks of China. According to the study China's on-road truck fuel consumption and GHG emission in 2050 will reach 498 million toe and 2125 million tons, approximately 5.2 times the level in 2010.

These are the results if a business as usual pathway is chosen and actions to counter this development are proposed by some of the researchers. Change the way goods are transported, shifting more transport to the most efficient modes, adopt cost-effective, incremental technologies to improve vehicle efficiency and shift to low-$CO_2$ fuels (IEA 2009) and introduce new policy actions (Zanni and Bristow 2010). Analysis of policy targets for overall reduction of emissions from transport in the UK together with emission increases in forecasts were put forward by Tight et al. (2005), concluding the need for behavioural change to complement technological improvements. Hao et al. (2012) provide impact assessment to improve the mileage utilization rate, fuel consumption rate and penetration of liquefied natural gas in the road freight sector of China. According to Usón et al. (2011) a more ecological future requires a decrease in freight tonnes and tonne-kilometres, an increase in the share of the rail transport, the optimisation of logistics and improvements on the awareness of consumers.

Ruzzenenti and Basosi, (2009), identify deficiencies in the use of fuel consumption as a measurement in energy efficiency; uncertainty over vehicle size and maximum power of the engine, and assessment method, like; fuel, load, speed, infrastructure, traffic and climate conditions. However, they conclude that this measurement is the best candidate. For a UK context, Sorell et al. (2012) point out the lack of data on total tonne kilometres, loaded and empty running vehicle kilometers by type of commodity and vehicle, truck movements of foreign trucks, as well as difficulties in translating various commodity classifications present in statistics.

# METHODOLOGY

We use quantitative data to conduct a sectoral analysis of several indicators affecting the energy efficiency and $CO_2$ emissions. Statistics from Denmark, Finland, Norway and Sweden include national accounts data and continuous goods transport by road surveys worked out by the national statistics offices in the Nordic countries. The transport data are combined with fuel consumption data from LIPASTO (2010) and NTM (2008) to enable energy and $CO_2$ analysis.

## Framework

The widely accepted framework for analysing the relationships between the economy and road freight transport was introduced by McKinnon and Woodburn (1996) and further enhanced in a wide European research on the subject (REDEFINE 1999). Cooper et al. (1998) extended the framework to include the environmental effects and McKinnon (2010) 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 the same.

For this study, the framework is slightly altered. Monetary valuation and other environmental effects than energy consumption and $CO_2$ emissions are omitted from the framework (Figure 1) as the focus is on acquiring in-depth information on energy efficiency and $CO_2$ emissions. The framework is thus similar to the one Piecyk (2010) used, but with an addition of three key indicators and a replacement of 'lading factor' with average load on laden trips and thus an addition of laden mileage 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 the data.

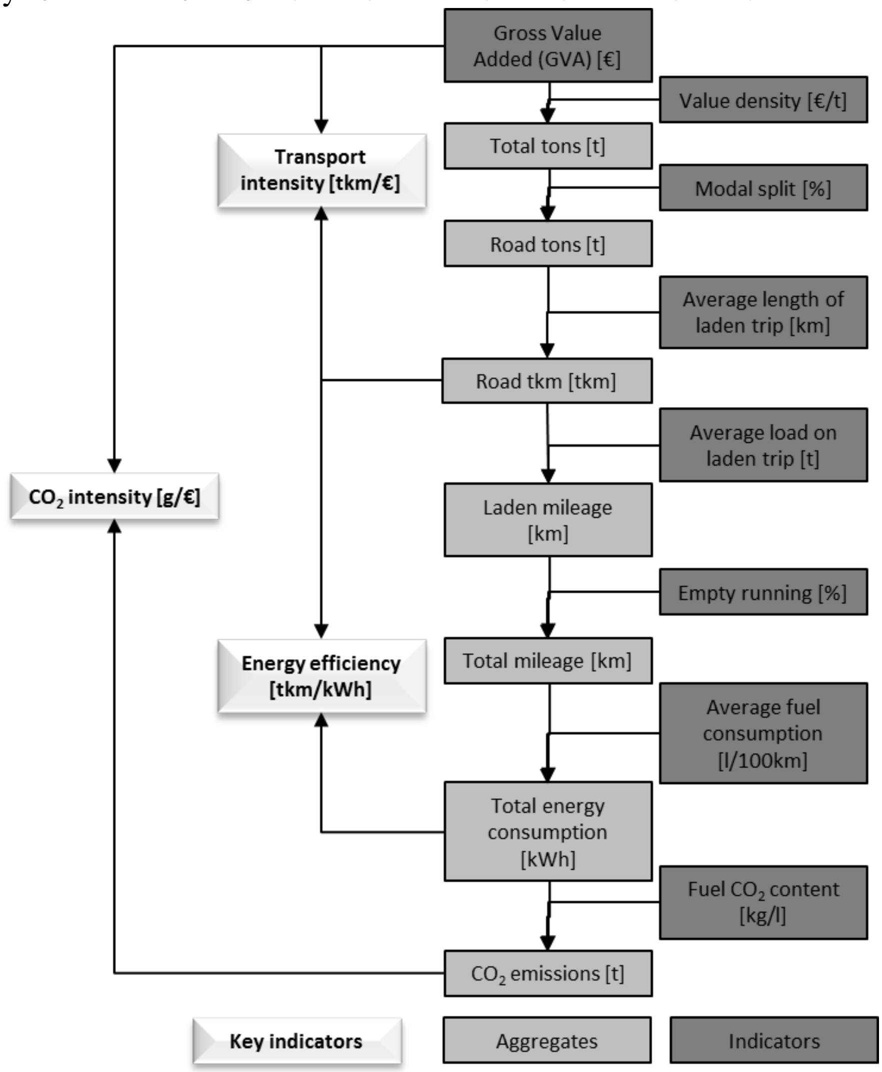


Figure 1. Road freight decarbonisation framework.

### *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 the **Gross value added (GVA)** in Euros using fixed prices of year 2005 to enable time series analysis. Gross value added is widely used indicator for the national economic output.

The **value density** is in this research defined at national level as the ratio of GVA and the total weight of goods transported within each of the Nordic countries except Iceland by all modes of transport. At sectoral level the value density is the ratio of sectoral GVA and the weight of goods transported by road. Other modes are not considered at sectoral level, because sectoral data on the use of other modes is inadequate. 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. Modal split is used only on national level in this paper, because sectoral data on the use of other modes is inadequate. The energy efficiency and $CO_2$ emissions of other modes than road freight can be studied using a similar framework as in Figure 1 for each mode. However, the scope of this study is the road freight transport because it is the most important mode of freight in all the four target countries. In 2010, road freight transport accounted about 92% in Denmark, 90% in Finland, 88% in Norway and 86% in Sweden of total domestic freight transport when measured in the weight of goods (Finavia 2011; Liikennevirasto 2011a; Liikennevirasto 2011b; Statistics Denmark 2012; Statistics Finland 2011; Statistics Norway 2012).

**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 2010), but this method is slightly misleading as the weight of goods 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 is 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 2010. The difference in average load and average length on 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 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 Liimatainen and Pöllänen (2010) and used in this paper.

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 Nordic countries the fuel used in trucks is virtually solely diesel. Diesel has a fixed $CO_2$ content of 2.66 kg/l (LIPASTO 2011). 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 GVA (g/€), so decreasing $CO_2$ intensity means decarbonisation has occurred. However, usually some additional information about the reasons for decarbonisation is sought after and the simplest way of doing this is by introducing the key indicators of transport intensity and energy (or $CO_2$) efficiency.

**Transport intensity** is the ratio between road haulage (tkm) and economic output (GVA). It expresses the changes in the demand for road freight transport in the economy (Piecyk and McKinnon 2009, Åhman 2004, Stead 2001, Tapio et al. 2007, Kveiborg and Fosgerau 2007, Sorrell et al. 2012, McKinnon 2007).

**Energy efficiency** expresses the changes in the efficiency of the supply of road freight transport. 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 and 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 and 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 2011).

### *Limitations of the decarbonisation framework*

The decarbonising 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 doing that some complexity may be lost and one should be cautious not to lose sight of the various feedback loops between the indicators. 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). Further, the rebound effect can partly offset energy savings from improvements of the fuel economy of the individual trucks as haulages may become cheaper and the demand increase (Sorrell, 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.

## Data, classifications and calculations

The energy consumption of road freight transport is dependent on series of factors, among those the type of commodity hauled. To be able to link energy consumption to the economic activity in different sectors, a simple linkage between commodities and sectors at an aggregate level has been applied. A high aggregation level has been chosen to ease the comparison between the countries.

Although the national road survey in each of the four countries follow the same standard nomenclature (NST2007, COM/2007/1304), the implementation is quite different in the continuous goods transport by road surveys of the four countries. For the commodity classification the available statistics had different aggregation levels. For this study, the commodities have been aggregated to six large groups making the linking to the economic sectors simple. In Table 1 the six sectors and the commodities are shown. In appendix 1 the commodities and the national account sectors are defined.

Table 1 Classifications of freight commodities and national accounts sectors.

| **Sector** | **NST2007** | **National accounts** |
|---|---|---|
| Agriculture and forestry | 1 | A |
| Mining and construction | 3, 9 | B (excl. oil and gas extraction), F |
| Food industry | 4 | CA |
| Chemical industry | 2, 7, 8 | CD, CE, CF |
| Wood and paper industry | 6 | CC |
| Technology industry | 5, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20 | Rest of C |

The commodity groups are linked pair wise to production sectors as shown in Table 1. There exists information for some countries on the distribution of the produced commodity types for each national accounts sector (e.g. Statistics Denmark, 2003), but since the commodities vary from country to country and the aggregation level is high, such information is difficult to apply in this context, and a one-to-one linking has been used. In appendix 2 the national account sectors are defined.

The calculations of energy consumption and $CO_2$ emissions follow the procedure described in Liimatainen and Pöllänen (2010). They are carried out at the individual trip level using the detailed data from the haulier surveys of the four countries. The trips are divided into urban and rural according to the reported start and end points of the trips, and the energy consumption in litres per kilometre is first calculated using the following equations:

(Eq 1) $Litres\ per\ 100\ km = 5.7767(Gross\ weight)^{0.6672}$ for urban trips, and

(Eq. 2) $Litres\ per\ 100\ km = 5.9463(Gross\ weight)^{0.5515}$ for rural trips

The gross weight includes the own weight of truck, trailer and the weight of goods, measured in tons. These equations are estimated using average fuel consumptions for trucks of various sizes given by LIPASTO (2010) and NTM (2008) and are further explained in Liimatainen and Pöllänen (2010). The rural trips have lower energy consumption because of the freeflow traffic conditions, while urban trips more often takes place under saturated conditions.

These equations estimate the fuel consumption for a truck produced before 1994. Thereafter, the specific energy consumption is reduced according to the Euro class defined according to the vintage of the truck by multiplying by the energy factors presented in Table 2:

Table 2. The effect of Euro class on fuel consumption of trucks (Liimatainen & Pöllänen 2010).

| Vintage | Euro class | Energy factor |
|---|---|---|
| before 1994 | - | 1.000 |
| 1994-1996 | Euro I | 0.931 |
| 1997-2000 | Euro II | 0.924 |
| 2001-2006 | Euro III | 0.948 |
| 2007-2008 | Euro IV | 0.899 |
| 2009- | Euro V | 0.909 |

In the next step the sector information is used to adjust fuel consumption: Agriculture and forestry is adjusted up by 30% and Mining and construction by 20%. This is because some of these hauls take place on dirt roads or under other tough conditions and the motors are running for a long time when the truck is loaded and unloaded, resulting in higher fuel consumption than would be estimated based on gross weight and type of road. (Liimatainen et al. 2012)

Finally, energy consumption is reduced by 10% if the trip is a “round trip”. Typically, these trips have multiple stops and return empty, but the weight of goods reported is the maximum weight during the trip. This adjustment is described further in Liimatainen and Pöllänen (2010).

The $CO_2$-emissions are simply estimated using the above mentioned emission coefficient of 2.66 kg $CO_2$ per litre diesel.

### *Limitations of national data*

The method for analysis was developed using the Finnish data and although the basic principle for collecting the data is similar in all countries, there are differences, which have minor effect on the results and should be taken into account when interpreting the results. The major differences consider the definition of urban haulage, the possibility of calculating sectoral empty running and the availability of vehicle weight data.

The Danish data suffers from two main limitations: 1) it is difficult to pinpoint urban hauls since the country is divided into only 11 zones, which means that Copenhagen is the only city which can be identified. All other zones cover both rural and urban areas. 2) There is no sector information for the hauls – only commodity information. Therefore it is not possible to attach empty running to any sector.

In the Norwegian data set there is missing information for own weight, payload and/or total weight for some vehicles. In cases where we only have information about total weight, vehicle's own weight is assumed to be one third of the total weight. In cases where both these variables are missing, shipment size is used as a proxy for the vehicle payload. Own weight is assumed to be half the vehicle's payload. For Norway urban distribution is including all transport that starts and ends in the same municipality or is executed in the Oslo area, defined as transports inside Oslo and Akershus counties. This approach is similar to the one used in Finland.

Some of the trailer own weight and total weight is missing in the Swedish data. In those instances where the load rate is higher than 100 percent, the weight of an average dummy trailer of 7 tonnes has been added. Swedish data also lacks data to determine the urban hauls, so all hauls under the length of 24 km are considered as urban hauls.

# RESULTS

## $CO_2$ emissions

The $CO_2$ emissions of road freight transport from the four countries are presented in Table 3. Total emissions for Denmark are half the emissions of Sweden, with Finland close to Sweden and Norway in between Finland and Denmark. Although the total emissions vary considerably, the shares of emissions in different sectors are very similar. Technology industry has clearly the largest share in all countries, while chemical industry and wood and paper industry have the smallest shares.

Table 3. The $CO_2$ emissions and shares of sectors in 2010.

| | Denmark | Finland | Norway | Sweden |
|---|---|---|---|---|
| Agriculture and forestry | 14.4% | 14.7% | 9.0% | 12.6% |
| Food industry | 16.5% | 11.9% | 16.6% | 13.3% |
| Chemical industry | 4.8% | 6.3% | 5.2% | 4.6% |
| Mining and construction | 15.4% | 13.9% | 13.6% | 10.0% |
| Technology industry | 33.8% | 28.6% | 33.0% | 39.3% |
| Wood and paper industry | 3.8% | 5.9% | 5.2% | 6.5% |
| Empty running | 11.3% | 18.8% | 17.4% | 13.8% |
| Total $CO_2$ emissions [Mt] | 1.14 | 2.21 | 1.57 | 2.27 |

## $CO_2$ intensity

The road freight $CO_2$ intensities in various sectors of economy in Denmark, Finland, Norway and Sweden are presented in Table 4, which reveals major differences in the $CO_2$ intensities between countries. Finland has the highest intensity in 3 of the 6 sectors and also in national total, while Denmark and Sweden have about half the $CO_2$ intensity of Finland when the national GVA (includes services) is considered.

Table 4. Road freight $CO_2$ intensities [$CO_2$ g/€] in 2010.

| | Denmark | Finland | Norway | Sweden |
|---|---|---|---|---|
| Agriculture and forestry | 79 | 75 | 34 | 89 |
| Food industry | 52 | 117 | 70 | 67 |
| Chemical industry | 14 | 45 | 29 | 12 |
| Mining and construction | 21 | 30 | 19 | 16 |
| Technology industry | 29 | 32 | 42 | 25 |
| Wood and paper industry | 30 | 27 | 47 | 21 |
| Total (6 sectors' GVA) | 35 | 50 | 44 | 31 |
| Total (national GVA) | 6 | 15 | 9 | 8 |

Sectoral differences are also apparent in Table 4. The food industry has the highest $CO_2$ intensity in Finland and Norway, while in Denmark and Sweden agriculture and forestry has higher intensity. The lowest intensities are found in chemical industry in Denmark and Sweden, wood and paper industry in Finland and mining and construction in Norway. This result is perhaps rather surprising as these sectors include transport of bulk goods, i.e. heavy and low value goods such as basic chemicals in chemical industry; gravel and soil in mining and construction sector and pulp in wood and paper industry. However, bulk goods are suitable for rail or water transport and may thus be left out, especially on long distances, of our analysis focusing on road freight transport. Furthermore, these sectors also include sub sectors, which have low demand for transport within the country and high global added value such as pharmaceuticals in chemical industry; valuable ores in mining and construction sector and printed media in wood and paper industry. This highlights the limitations of the statistics and highlights the importance of deep understanding of the connections of the economy, freight transport and energy use. In order to gain deeper understanding, it is necessary to analyse the sectoral transport intensities and energy efficiencies further.

## Transport intensity

The transport intensities vary from 0.06 tkm/€ in Denmark to 0.18 tkm/€ in Finland (Table 5). These figures are well in line with the figures reported by Eom et al. (2012) for Denmark (0.1 tkm/$) and Sweden (0.15 tkm/$), taking into account that direct comparison cannot be made, because their figures included the haulage by light goods vehicles and their monetary value was the purchasing power parity GDP in $ at 2000 prices.

On a national level, the transport intensity is on a higher level in Finland and Sweden than in Denmark and Norway (Table 5). An explanation to this may be that the 6 sectors analysed here have approximately 30% share total added value in Finland and 25% share in Sweden, but only 20% share in Denmark and Norway. However, if only the added value of the 6 sectors is considered, Denmark still has much lower transport intensity than other countries, while Finland has considerably higher. Denmark also has the lowest transport intensity in all but one sector. This is due to the geographical location of Denmark as a part of the continental Europe, which allows Danish businesses to easily operate internationally. On the other hand, foreign transport companies can easily operate in Denmark and both these factors decrease the transport intensity in Denmark. These factors are reflected in the high share of exports and imports (50% and 45% of GDP) in Denmark as well as in the share of international (4.5% of national tonnage in t) and cabotage (3.9% of national haulage in tkm) transport on road in Denmark (Eurostat 2012). Transport intensity is affected by three indicators: value density, modal split and average length of laden trips.

The value density of the 6 sectors in Denmark and Sweden is approximately double the value density of Finland (Denmark 209 €/t, Sweden 230 €/t, Finland 111 €/t), while Norway has a value density of 136 €/t. The differences in value density between Denmark and Sweden with Finland and Norway are particularly great in the mining and construction sector, Denmark and Sweden having more than twice the value density of Finland and Norway (162 €/t and 135 €/t compared to 50 €/t and 82 €/t, respectively). In Denmark the GVA of mining and construction is 19% lower than in Finland, but the tonnage transported by road in this sector is 50 Mt in Denmark and 200 Mt in Finland. Most of the tonnage for mining and construction sector is due to short hauls of gravel and soil for the foundations of roads and buildings, so the difference between Denmark, Finland and Norway may be largely due to the greater need for gravel in foundations in Finland and Norway in order to prevent damages to infrastructure caused by ground frost during the harsh winters. This explanation is confirmed by the fact that the average length of haul in mining and construction sector is much longer in Denmark (52 km) than in Finland and Norway (20 km and 19 km, respectively).

The differences in transport intensity are largely due to the differences in value density, as the differences in modal split and average length of laden trips are smaller between countries.

Modal split can be assessed only on national level, and there is not much variation between countries. The share of the road is about 92% of total national tonnage in Denmark, 90% in Finland, 88% in Norway and 86% in Sweden. The second largest mode of transport with an 8% share in Denmark and 11% in Norway is sea transport, while in Finland and Sweden rail transport has an 8% and 11% share, respectively. Finland and Norway have an average length of laden trips of around 60 km, while in Denmark and Sweden it is around 80 km, although the average length may change more than 10 km year-on-year in each country.

Table 5. Road freight transport intensities in tonne-kilometres per added value [tkm/€] in 2010.

| | Denmark | Finland | Norway | Sweden |
|---|---|---|---|---|
| Agriculture and forestry | 0.82 | 1.23 | 0.41 | 1.70 |
| Food industry | 0.62 | 1.45 | 0.97 | 1.16 |
| Chemical industry | 0.20 | 0.89 | 0.56 | 0.26 |
| Mining and construction | 0.25 | 0.51 | 0.24 | 0.26 |
| Technology industry | 0.25 | 0.34 | 0.47 | 0.37 |
| Wood and paper industry | 0.31 | 0.57 | 0.61 | 0.45 |
| Total (6 sectors' GVA) | 0.32 | 0.59 | 0.46 | 0.45 |
| Total (national GVA) | 0.06 | 0.18 | 0.09 | 0.12 |

Also sectoral differences can be seen from Table 5. Food industry has the highest transport intensity in two countries as does agriculture and forestry. Mining and construction has the lowest transport intensity in three countries. The food industry has the longest average length of haul in all the countries, while having an average value density and this combination results in high transport intensity. Mining and construction sector, on the other hand, has the lowest value density, but also by far the shortest average length of haul, which decreases its transport intensity. In Finland technology industry has a very high value density compared to other sectors and it also has fairly short hauls, which results in low transport intensity.

## Energy efficiency

The energy efficiency of road freight transport varies from 2.44 tkm/kWh in Denmark to 3,80 tkm/kWh in Sweden (Table 6). These values seem to be much greater than the around 2 MJ/tkm (1.8 tkm/kWh) for Sweden and 4 MJ/tkm (0.9 tkm/kWh) for Denmark given by Eom et al. (2012). However, Eom et al. included light goods vehicles in their analysis, which decreases the energy efficiency. They also included the energy used by international transport, which is omitted from our analysis and this further decreases the energy efficiency, so the values are not directly comparable.

The energy efficiency is the result of three indicators: average load on laden trips, share of empty running of total mileage and the average fuel consumption. All three indicators are interrelated as the loading directly affects the fuel consumption. Average load and empty running are also related, as the bulk goods sectors (agriculture and forestry, chemical industry, mining and construction, wood and paper industry) have higher average loads but also higher share of empty running than the general cargo sectors (food industry, technology industry) (Liimatainen & Pöllänen 2011).

Average load on laden trips is a major contributing factor to the national differences seen in Table 6. In Finland the average load is 13.9 tons, while in it is Sweden 12.9 t, in Norway 11.6 t and in Denmark 9.8 t. The high average load in Finland is partly caused by the large share of bulk goods sectors (62% of total haulage in tkm) compared to Sweden (45%), Norway (43%) and Denmark (47%).

Denmark has very low level of empty running compare to the other countries. McKinnon & Ge (2006) identify various reasons for low empty running, these include: outsourcing of road haulage operations, balance of traffic flows, long average length of hauls, high cost of transport, high share of distribution trips, high level of reverse logistics, high use of load matching services and adoption of new management initiatives. In Denmark and Sweden the average length of haul is longer and the balance of transport flows is better than in Finland and Norway, resulting in low level of empty running. Denmark has much higher population density (130 inh./$km^2$) than other countries, which balances the transport flow. Sweden, on the other hand, has three major economic regions in the southern part of the country (Stockholm, Gothenburg and Malmö/Öresund region), which balances the transport flows and decreases empty running. In Finland and Norway population and economic activity is to great extent centred in the metropolitan regions of capital cities while other parts of the countries are sparsely populated. This causes structural imbalance in transport flows to and from the rural areas.

Table 6. Road freight energy efficiencies in tonne-kilometres per kilowatt-hours [tkm/kWh] in 2010.

| | Denmark | Finland | Norway | Sweden |
|---|---|---|---|---|
| Agriculture and forestry | 2.75 | 4.29 | 3.15 | 5.03 |
| Food industry | 3.14 | 3.26 | 3.63 | 4.54 |
| Chemical industry | 3.58 | 5.28 | 5.04 | 5.82 |
| Mining and construction | 3.09 | 4.51 | 3.28 | 4.24 |
| Technology industry | 2.28 | 2.78 | 2.96 | 3.82 |
| Wood and paper industry | 2.73 | 5.63 | 3.42 | 5.73 |
| Total (includes energy used in empty runs) | 2.44 | 3.10 | 2.75 | 3.80 |
| Empty running (share of total km run empty) | 14.5% | 27.4% | 24.8% | 19.1% |

The average fuel consumption of the trucks is 33.1 l/100km in Denmark, 35.7 l/100km in Finland, 32.3 l/100km in Norway and 34.4 l/100km in Sweden. Average fuel consumption is affected by the average load, but also by the truck technology and the type of road the transport takes place. The truck technology is in our study taken into account using energy factors for trucks of different Euro classes. This energy factor is 0.922 in Denmark, 0.930 in Finland, 0.925 in Norway and 0.927 in Sweden, indicating that the truck fleet is renewed more rapidly in Denmark than in other countries. In terms of the share of mileage driven on urban roads the data from different countries does not enable a fair comparison, so its effect remains unclear.

In terms of sectoral energy efficiency, technology sector has the lowest value in all countries while chemical industry has the highest value in all countries, except Finland where wood and paper industry has slightly higher value. The greatest reason why the technology industry has the lowest efficiency for all countries is that in this sector there is a higher share of volume goods than in the other sectors, i.e. the capacity utilisation is lower in tonnes as illustrated by the average load on laden trips is 7.9 t in Denmark, 6.6 t in Finland, 8.0 t in Norway and 7.1 t in Sweden in this sector. The same reason is behind the high energy efficiency of chemical industry as the average loads are 18.6 t in Denmark, 25.2 t in Finland, 15.5 t in Norway and 25.5 t in Sweden in this sector. High loads increase the fuel consumption (l/100km), but the resulting increase in energy consumption (kWh) is smaller than the increase in haulage (tkm), so there is a decrease in energy efficiency (tkm/kWh).

# CONCLUSIONS

In this paper, we have contributed to the understanding of road freight energy efficiency and $CO_2$ emissions in Nordic countries. The aim was to carry out a comparative study in order to identify the key factors and their impact on the energy efficiency and $CO_2$ emissions. In our analysis, we found a high degree of consistency in the indicators in the way that it is largely the same industries in each of the countries which have respectively the highest and lowest efficiency. Despite the uncertainty in the data and the different levels of information available in the four countries, this strengthens the validity of the results. When evaluating the research process of the study generally, the strengths lies on the quantitative joint analysing research method utilized and use of the widely accepted framework for analysing the relationships between the economy and road freight transport as a basis, when carrying out the research. Also the participation of more than one researcher in gathering and analysing the data can be seen as strength. These increase the reliability of the research results and quantitative method also enables generalizability of the results, this comparative study can be carried out in other countries as well.

For energy efficiency, measured in tonne per kilowatt hour, it is the technology industry which has the lowest values, while respectively the wood and paper industry in Sweden and Finland and the chemical industry in Norway and Denmark have the highest values. Lowest energy efficiency in the technology industry may be explained that the sector largely transports goods with relatively high unit value and the capacity utilization limited by the commodities' volume rather than weight, so that capacity utilization is generally lower for these goods than for typical bulk goods.

Also for road transport intensities (measured as tonne-kms per added value) there is high degree of consistency in the results between the Nordic countries, where the mining and construction industry has the lowest values for all the Nordic countries, except for Finland, where the technology industry have the lowest transport intensity. Agriculture and forestry industry has the highest transport intensity in Denmark and Sweden, while the food industry have the highest transport intensity in Finland and Norway.

For the $CO_2$-intensities (measured as grams $CO_2$/€) there is somewhat greater inconsistency between the Nordic countries, where the chemical industry has the lowest emission intensity in Denmark and Sweden, the mining and construction industry has the lowest emission intensity in Norway and the wood and paper industry has the lowest emission intensity in Finland. Agriculture and forestry industry has the highest emission intensities in Denmark and Sweden, while the food industry with the highest emission intensities in Finland and Norway.

The study has opened several future research avenues. Most importantly, future research could create time series of the historical development of the indicators for each country. This would also lay the foundation for future projections of these indicators. It is also of interest to study the urban context more in detail. A more uniform definition of urban distribution, taking into account the lack of urban information from all countries, would be valuable. Lastly, another approach is to analyse the total average of the indicators for all countries in relation to other countries in Europe. A Nordic average indicator would accommodate to some of the inconsistencies of each individual country's data set and make it even more robust in future comparisons.

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## Appendix 1

Haulier survey commodity types

| **NST2007** | |
|---|---|
| 1 | Products from agriculture, forestry, and fishery |
| 2 | Coal, crude oil and natural gas |
| 3 | Metal ores, stone, gravel, and soil |
| 4 | Food and beverages |
| 5 | Fabrics and leather |
| 6 | Wooden products (excl. furniture), pulp, and paper |
| 7 | Refined oil products |
| 8 | Chemicals, plastics, and rubber |
| 9 | Other non-metallic mineral products |
| 10 | Metal products excluding machines and equipment |
| 11 | Machines and instruments |
| 12 | Vehicle and vessels |
| 13 | Furniture and other manufactured goods |
| 14 | Household and municipal waste |
| 15 | Letters and parcels |
| 16 | Equipment for transportation |
| 17 | Removals and vehicles for repair |
| 18 | Mixed cargo |
| 19 | Unidentified goods |
| 20 | Goods not mentioned elsewhere |

## Appendix 2

National account sectors

| | |
|---|---|
| A | Agriculture, forestry and fishery |
| B | Mining |
| CA | Food and beverages |
| CB | Fabrics and leather |
| CC | Wood and Paper |
| CD | Oil refineries |
| CE | Chemicals |
| CF | Medical industry |
| CG | Technology |
| CH | Metals |
| CI | Electronics |
| CJ | Electric equipment |
| CK | Machines |
| CL | Vehicles and vessels |
| CM | Furniture and other manufacturing |
| F | Construction |

ISBN: 978-91-628-8808-4