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Fill Rate in Road Freight Transport

Master of Science Thesis in Supply Chain Management

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Abstract

Increasing the role of logistics in business area due to globalization in production and consumption market, and competition pressure to cut costs and offer on time, reliable and affordable services, make transportation role more fundamental in business strategy. In this respect, consideration to have more efficient transportation and higher utilization of transport capacity leads to focusing on filling rate measurement as an efficiency measurement system in decision making process.

The purpose of this study is to investigate different ways of measuring fill rate in road freight transport and evaluating them. To achieve this purpose, previous studies on role of filling rate in efficiency measurement systems, factors affecting filling rate, and different methods for its calculation have been studied. To get more practical data interviews have been performed with leading companies in logistics industry as well as scholar specialists in academic area.

The outcome of the study is an analysis of fill rate perception and application in transportation industry, comparison and evaluation of existing methods of measuring fill rate (ton-km, weight, volume, number of pallets), and possible ways to improve it. The relation of fill rate with companies' business model and government policies, which could influence filling rate, is analyzed as well.

Key words: Fill rate, Resource utilization, Efficiency measurement, Road freight transport

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List of abbreviations

3PL: Third Party Logistics

BIE: Bureau of Industry Economics

EEA: European Environment Agency

ERP: Enterprise Resource Planning

FTL: Full Truck Load

FPMS: Freight Performance Measurement System

HTL: Half Truck Load

HGV: Heavy Good Vehicle

JIT: Just In Time

KPI: Key Performance Indicator

LTL: Less than Truck Load

LHV: Longer and Heavier Vehicle

NCFPR: National Cooperative Freight Research Program

NIRPC: Northwestern Indiana Regional Planning Commission

PF: Paying Freight

PMS: Performance Measurement System

SCP: Supply Chain Performance

SCPMS: Supply Chain Performance Measurement System

TPL: Third Party Logistics

1 Introduction

This chapter presents the background to this report, following by the purpose of the research. Finally it will describe the delimitations of the report together with a presentation of how the remaining part of the report is organized.

1.1 Background

In recent decades, there has been a trend in increasing the role of logistics in business strategies and the effect of transportation as a large part of logistics process on companies' productivity and profitability (Christopher, 1998).

Logistics sector as many other industries and businesses has been affected by globalization trends. Due to cope with cost pressure, companies try to revise their business processes, services and operational systems. Specifically in transportation business, better utilization of available capacity has proven to be the most effective and efficient way of competitive strategy. (Dorer & Calisti, 2005) (Christopher, 1998)

Increasing transportation costs due to raise in fuel cost, longer distance, faster and on-time deliveries have forced companies to use their transport resources in a more efficient and effective way in order to stay in competitive business environment. In this respect, increasing filling rate in different transportation modes (road, rail, sea and air) plays a fundamental role in high resource utilization and profitability of transportation activities.

Another context that caused more emphasis on the importance of filling rate was the raising awareness about sustainability. Nowadays, it would be a negative image for the company to have empty or partly loaded trucks travelling around. It shows that the company does not care about efficient use of scarce resources and consequently operating in an unsustainable manner. Thus, besides the importance of increasing efficiency to cut costs, trying to be more sustainable through being efficient is another target that can be achieved by increasing fill rate. (Enarsson, 1998) (McKinnon, 2003) (Lieb & Lieb, 2010)

Looking into filling rate concept from different perspectives as physical or economic filling rate, and from different actors' point of view as transport companies, customers, government and public has led to large diversity in filling rate perception. Transportation actors used their own models based on their criteria and point of view and there is not a standard definition and model for calculating filling rate that could be applicable based on different situations of use.

However, despite the crucial importance of filling rate in various decisions making activities, lack of academic studies in this area is tangible. Some articles have considered filling rate just as a part of performance measurement and not in details, and many mentioned filling rate as a measure to show the number of customer orders which are fulfilled directly from the stock. In this thesis, the fill rate term is just for referring to the fullness amount of the vehicle. (McMullen & Monsere, 2010) (Cottrell, 2008) (Lai et al., 2004) (Harrison et al., 2006) (Mentzer & Konrad, 1991) (Caplice & Sheff, 1995)

1.2 Purpose

The purpose of this thesis would be:

To investigate different ways of measuring fill rate and evaluate them.

The importance fill rate in environmental and efficiency contexts make the measurement of fill rate necessary. Thus this study tries to explore the ways of measuring fill rate that are currently being used in practice or mentioned in the literature. Then these different ways need to be evaluated in comparison with each other, especially regarding advantages and disadvantages of them.

This topic can be of interest for government and public sector (to see how “green” companies are and how they are following laws and regulations), transportation companies (to know how efficient they are and to be able to set a real target for resource utilization for the future, and also may help them for pricing), and probably customers (to understand the pricing method and also to contribute in making freight transportation more efficient in cooperation with the transport company, for instance by planning the transportation in a way which increases fill rate instead of the way customer initially wants). These different parties may have a different perception about fill rate and measure it differently, thus a study to cover different aspects of filling rate, seems to be needed, which hopefully will help to have a common understanding and therefore gives the better capability to improve it further.

1.3 Scope and limitation

As far as the research topic sweeps wide area of logistic sector (air, rail, road and sea mode of transport) both in respect to freight and passenger transport it is needed to delimit the research due to time and resource limitation. Considering the fact that each transportation mode has different characteristics and conditions, the filling rate definition and calculation would vary in large degree. Moreover, the difference between goods and passengers’ transportation and their business models, would affect filling rate features and calculation. Therefore, our focus on this study is limited to goods transport (freight) on road mode of transportation. Although it is tried to cover several actors’ perspective on the subject, the focus is more on transport companies. In this report, the transport company is the one that connects the shipper to the haulier, such as DHL and Schenker.

1.4 Disposition of the report

In chapter 2, problem analysis and research questions, and in chapter 3, methodology and applied methods for data collection and analysis are explained. In chapter 4, theoretical framework is discussed based on the literature review. To build a clear background and simplify the understanding of the topic, the theoretical discussion is started from performance measurement systems and step by step it goes forward towards the main topic, fill rate. The empirical findings resulted from data collection process is presented in chapter 5. Based on these empirical findings and literature study, analysis of the situation has been done which is described in chapter 6. In chapter 7, the discussion about the topic and findings is presented, along with some recommendations and areas for further research. In chapter 8, the conclusion of the report is presented.

2 Problem analysis

In this part of study the authors investigate research problems and identify the key issues which are involved in this research topic.

According to U.S. Department of Transportation (2010), 19 billion tones of goods, by value of $ 13 trillion, moved within U.S. in 2002. In terms of ton-mileage the ration of each mode in freight transport is as follow: trucks (28%). Rail (39%), pipeline (20%), ships (12%) and remaining were transported by aircraft. Trucks are the most frequently used mode for freight transport and accounted for 70% of value and 60% of the weight of all U.S movements in 2007. (U.S. Department of Transportation, 2010)

Considering this crucial importance of freight industry and its influence on economic, environment, and society, there is a need to measure its performance and possibly increase its efficiency. Despite this fundamental need, there is little uniformity in freight performance metrics and measurement. This diversity is more tangible across five modes as some measures are applicable only to one mode, and even among each mode there is little agreement on the best performance measurement.

As it is stated in pervious parts, the purpose of this study is to identify and analyze different perceptions of filling rate as a performance measurement indicator in freight transport. Filling rate has been considered from different points of view by different people involved. Transportation companies, government and authority organizations, customers and public sector each have its own perception and definition of filling rate. Many logistics companies use filling rate measurement in some degree based on their own experiment and business strategies, and not an academic proven method for their models. Moreover, there is not a general understanding for filling rate utilization that could be applicable for all parties with different expectations.

In spite of the fundamental importance of filling rate in performance measurement system and managerial activities, lack of academic studies in this area is obvious. Lots of academic research is performed about performance measurement indicators within supply chain activities, logistics operations, and passenger's transportation. However, there are a few articles that investigate fill rate in freight transportation and its characteristics. This need of academic study in performance metrics in freight industry and its influence on public and private sector has led to recent movement toward more research and investigation in this area, for example, National Cooperative Freight Research Program (NCFPR) has allocated $300,000 in the project "Performance Metrics for Freight Transportation" (Cottrell, 2008).

Therefore, this research tries to bridge the gap between practical and academic knowledge, and investigate filling rate and its characteristics. The study aims to find out different perceptions on filling rate, different ways to calculate it, and their consequences on parties involved.

2.1 Research questions

According to Andrews (2003), by research question researcher is framing and controlling the study. A usual pattern in research is that a broad aim is refined to a manageable research question to determine the direction, shape and progress of study.

These questions are created by critical thinking and discussion on problem analysis part and should have specific characteristics as follow: Research questions must be answerable, they should not be impossible to answer within the border of research. The questions should be rationale and have clear reason for asking. Scale of research questions depends on boundaries and parameters of constraints on research, e.g. time, cost, resource. (Andrews, 2003)

Considering the problem analysis part the authors came up with some research questions, which have been evolved during the literature review by exploring more on the research topic and after achieving more knowledge on the scope of the issue. Some questions that came up in the initial part of the study has delimited due to boundaries and limitation of the study; such as: what are other alternatives that can be used instead of filling rate? Or what is filling rate measurement in passenger transportation?

Finally the authors formularized the research questions in four main groups and some subsidiaries questions that answering to these questions will be the research ultimate purpose.

- First of all, the concept of filling rate. To be able to understand the problem and looking for its possible solution, a common definition of the issue is needed. This definition would help the authors to get better perception of the topic and to see the issue from different perspectives.
  - ✓ How filling rate concept is defined by specialists?
  - ✓ Whether this definition differs from different perspectives?

- In second group questions involved with the usage of filling rate, should be in focus. These questions help the authors understand the main purpose of filling rate measurement and its reason.

  - ✓ Is filling rate applicable as a KPI in practical environment? Would it be sufficient to use fill rate as the only KPI or it should be used with other KPIs? What would be the result of its usage?
  - ✓ For which parties in logistics environment filling rate measurement is applicable?

- Thirdly, after realizing the concept and its utilization it is needed to know the way fill rate is measured and which parameters should be included in filling rate measurement (weight, volume, etc.)?
  - ✓ Which factors can influence filling rate?
  - ✓ How fill rate can be measured?
  - ✓ How fill rate can be improved?

- Forth, the last part of research questions includes the advantages and disadvantages of different methods for filling rate measurement and their applicability in practical environment.

3 Methodology

This part describes the methodology and research technique of this study, which is going to be used to achieve study's goals. The methodology consists of the way in which the study is carried out and also how the report writing is performed.

3.1 Research Strategy:

Various methodologies exist for research and methodology refer to the authors' choices about cases to study, data collection method, and data analysis, etc (Silverman, 2005).

The main purpose of this study is to identify and explain how filling rate is measured especially in road freight transportation. It leads to exploration of different types of filling rate measurement and different factors that affect it.

Considering this purpose the authors perform the study using the model in Figure 1:

The first step is selection of research area and then formulation of research questions. As it is discussed in pervious parts by considering the importance of research subject and exploring related articles and literatures, the authors came up with four major research questions that are mentioned in section 2.1 in details.

After clarifying the research topic and research questions the next steps based on the model are selection of research method, formulation of data collection methods, gathering data, and finally analyzing data and conclusion which are discussed in following parts in details.

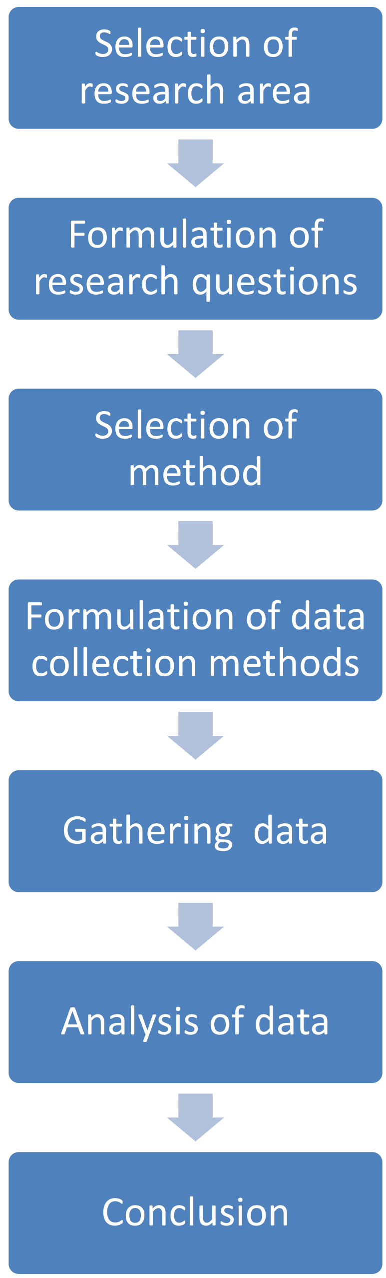


Figure 1: Research strategy

3.2 Selection of methods:

In general, research methods are divided into qualitative and quantitative classification. Bryman & Bel (2007) discused the difference between quantitative and qualitative classification, in which quantitative method emphasizes quantification in collection and analysis of data that:

- Includes a deductive approach to connect theory and research and mostly tests the theories.
- Incorporates the practices and theories of the natural scientific model.
- Entails a view of social reality as an objective reality.

On the other hand, qualitative research usually emphasizes words rather than quantification in data gathering and analysis, and has following characteristics in brief:

- Includes inductive approach to the relationship between theory and research, and mostly on generation of theories.
- Usually rejects the practices and theories of the natural scientific model and emphasizes on the ways that individuals interpret their social world
- Entails a view of social reality as a shifting property of individuals' creation.

In this study the authors use a qualitative evaluation as a methodology. The characteristic of qualitative research allows flexibility between data gathering and analyzing them within framed theories. Qualitative studies usually deal with few cases and explore in depth; which is very different from qualitative research that aim for larger number of cases and statistical significance (Miles & Huberman, 1994).

It is also defined by O'Leary (2004) that qualitative studies is not necessarily to generalize the results but to find a better understanding of research's topic, focus more on finding the ideas, and experiences to produce subjective data and try to answer questions about why, how and what.

Qualitative studies look for the "why", "what", and the "how" of subject through the exploration of unstructured data by using data gathering tools like: performing interview and recording, emails, photos and videos, and notes. The qualitative studies do not only rely on statistics or numbers that are the main source of quantitative research. Moreover, focus groups, in-depth interviews and analysis are within qualitative research method. (Zainal, 2007)

According to Silverman (2005) both quantitative and qualitative research are affected by individual's viewpoint. However, qualitative researchers can get closer to actor's perspective through interview and observation, rather quantitative researchers use more remote materials and methods, and less likely to capture subjects' perspectives.

In this study, authors have made a research strategy that is customized to thesis purpose. Using qualitative research method following by some case studies of logistics companies is chosen to represent and compare different ways of measuring filling rate by different companies. The focus is mostly on companies which have logistics activities in freight transportation and especially road mode of transport.

3.3 Formulation of data collection methods

According to Saunders *et al*. (2009) there are some data and information that help researchers to examine their research problem. Data can be either quantitative or qualitative in which quantitative data is based on gathering information in an objective view. However the qualitative approach is a research in a subjective theoretical view. Table 1 shows the distinctions between quantitative and qualitative data.

Table 1: Comparing qualitative and quantitative data (Saunders *et al*. (2009))

Quantitative data	**Qualitative data**
Based on meanings derived from numbers	Based on meanings expressed through words
Collection result in numerical and standardized data.	Collection results in non-standardized data requiring classification into categories.
Analyses conducted through the use of diagrams and statistics.	Analysis conducted through the use of conceptualization.

According to Miles and Huberman (1994), by linking qualitative and quantitative data the advantages of both can be gained and it is not essential to tie to one kind of data. They believe that by using both sorts of data one can benefit from (a) confirmation and corroboration of each, (b) providing detailed analysis, (c) initiate new lines of thinking through attention to paradoxes.

Moreover, data can be categorized into primary and secondary data. Secondary data are gathered from articles and literature which are already done and are fairly inexpensive to apply in research. Primary data is collected for unique purpose and can be done by telephone, personal interview, questionnaires, observation and experiment. (Saunders et al., 2009)

The authors use interviews as a primary data collection. According to Sliverman (2005) the majority of published qualitative research use interviews compared to other methods as it is economical in terms of time and resources. Saunders et al (2009) defines three types of interview as:

Structured interview: in this method interviewer meets the respondent, reads the same set of questions in order and records their answer to questions.

Semi-structured interview: interviewer starts to ask questions but not in predetermined order and is ready to ask new questions according to situation.

Unstructured interview: informally performed interview that starts with one theme without a predetermined list of questions to ask.

Also there are three different ways of doing interview according to Bryman & Bell (2007): Personal interview, telephone interview and also mail interview. They explained the differences between these three ways as follow. Mail interview takes the most time while telephone is the fastest one and personal interview is somewhat between. Telephone and personal interview are more reliable than letter and also have higher flexibility, and ability to change the questions during the interview is much better in face to face talking than telephone, while letter does not support this factor at all.

3.4 Gathering Data:

The multi-data gathering methods are used from various sources to ensure the reliability of the research. These sources include selected firms including staff in logistics departments and performing interview with them. Authors also use both primary and secondary data in data gathering and analysis part:

- Secondary data: through articles and literature related to logistics, transportation.
- Primary data: through personal interviews, mail interview, phone interview.

3.4.1 Literature review:

In gathering secondary data, the authors faced lack of academic study about filling rate due to its novelty in business area. As mentioned earlier the topic is more popular for practitioners within the industry and is less discussed in literature. Since not much is documented about this topic, it is necessary to start it from one step back and first assess the performance measurement systems in transportation, because looking into filling rate as an efficiency measurement tool is more discussed and studied in the literature.

Therefore, numbers of articles, reports, and books have been studied in order to investigate the different perception of fill rate from the perspective of different parties. By reviewing the literature better understanding of research topic has been achieved which helps the authors to find out the problem involves in the area.

It became clearer that filling rate in goods transport is dramatically different with passenger flow which has different models and formulation to calculate. Besides, even in freight transport there is huge diversity on different mode of transport, as air cargo or rail cargo needs special study that is different from road freight. Realizing the wide scope of filling rate after this review, the authors decided to delimit research topic on filling rate measurement in road transportation in freight industry.

The theoretical part of study became complete by focusing on literature about efficiency measurement, resource utilization, and capacity measurement. Different viewpoints have been reviewed on utilization of filling rate and the factors that impact it. The next step of study was gathering more data from practical people who are dealing with filling rate concept in logistics companies as well as academic researchers.

3.4.2 Interview

As mentioned earlier interview is one method of primary data collection to achieve study objectives. As it is focused specifically on the problem of survey, interview has great impact on discussion part of the study.

The interviews which the authors performed contain mail and personal interview. Interview with different logistics companies provides better understanding of company's point of view on filling rate. Accordingly, the researchers could compare these viewpoints and different way of considering filling degree. For example, how transportation companies measure fill rate and what reasons are behind that.

The first step in performing interview is identifying the key informants. The key informant is someone who has important information about the research issue and can help researchers to collect desired data. Key informant can be teacher, community leader, agency staff and even funders.

Before interviewing, researchers should know what type of information is needed to be collected from key informant. One approach is to write some key questions that cover important areas and then some follow-up questions for each main question. According to Patton (2006) in qualitative research open-ended questions are more typical and useful rather than yes-no questions. Open-ended questions are more flexible and provide in-depth information about the topic. The questionnaire that authors used are open-ended questions (see Appendix I) and allows interviewee to express their opinion in more flexible way.

Each interview is tape-recorded and researchers are able to review and fill the interview notes in more details. Each interview takes around two hours and questions are semi-structured. Because semi-structured interview allows researchers to get more detailed information arising out of the questionnaire by discussing the answer with interviewee, it even allows to cover the points that did not manage to put in the questionnaire.

After performing all interviews the answers were noted down by reviewing the recorded files and sorting them in more organized format. Doing this step, data gathering part of study became complete and the next step is evaluating the data in discussion part of the study.

3.4.3 Interviewees

The selected interviewees are among specialists in transport field, and are both scholar experts who have performed many research within the topic, and practical people who deal with road freight transport in logistics industry. The informants in this study consist of two scholar specialists and two logistics companies that are described as follow (see Table 2):

Scholar Interviewee 1 (Researcher consultant):

The scholar interviewee has years of experience in different areas of the transportation industry. Hi is specialist in the fields of logistics, vehicle telematics, database programming and environmental issues, besides being lecturer and logistics researcher at Chalmers University of Technology. He is knowledgably in filling rate measurement and how companies deal with it in transport industry, due to his work experience and number of related researches he has preformed.

Scholar Interviewee 2 (Researcher):

He holds a master degree in automation and mechatronics. He has gained academical experience in logistics and transportation fields during his PHD study at Chalmers University of Technology. His licentiate thesis is about foliated transport networks (get benefits of combination of direct shipment, and hub and spoke), which is directly related to resource utilization.

Forwarder Company 1:

The first interviewee has work experience in logistics area in different companies as well as academic experience at Chalmers University of Technology. Being logistics manager, sales manager, consultant and having PhD in logistics are some of his professional and academical experiences. Now he is working as a logistics consultant at one of the leading forwarder companies.

The second interviewee is doing an industrial PhD program that is cooperation between the company and Chalmers University of Technology. He is a researcher and a consultant at the forwarder 1 with the research focused on logistics.

The company has more than 91,000 employees in 130 countries and offers logistics services in 2000 locations in the world. The logistics division of the company is second largest transportation and logistics service provider in the world based on sales and performance. Its revenue in the year 2010 for transport and logistics service was 18.9 billion Euros. The company holds top position in global air and ocean freight transport and has Europe's most extensive land transport network and largest rail Freight Company in Europe. (Company's website)

Forwarder Company 2:

The interviewee has a university degree in logistics from University of Gothenburg. He is working at one of the leading forwarder companies, and expert in procurement of subcontractors (hauliers). He had been in charge of domestic network in Sweden with more than 450 units of daily transportation within 26 terminals. Now he is in charge of marketing and sales area for big customers in Sweden in freight business.

The forwarder company2 is the global market leader in logistics industry and offers its services in international express, air and ocean freight, road and rail transportation, contract logistics and international mail services. The global network composed of more than 220 countries and about 300,000 employees worldwide and the revenue of more than 46 billion EU in 2009. (Company's website)

Table 2: The interviewees' description

Interviewee	Position	Field of specialization	Company description
Scholar Interviewee 1	Researcher & consultant	Logistics and transport, vehicle telematics	Chalmers University of Technology
Scholar Interviewee 2	Researcher	Logistics and transport	Chalmers University of Technology
Forwarder Company 1	Researcher & logistics consultant	Logistics, sales, consultant	One of the leading companies in logistics
Forwarder Company 2	Marketing and sale manager	Procurement of hauliers , manager of domestic transport network in Sweden	One of the leading companies in logistics

4 Theoretical framework

In this chapter, the theoretical framework related to the thesis subject is presented. Instead of jumping right into the fill rate topic, authors decide to start from a few steps back to make a clear understanding of the thesis topic. The way that theoretical framework is structured is elaborated in next section.

4.1 Structure of theoretical framework

The theoretical discussion is started from performance measurement systems and step by step it goes forward towards the main topic, fill rate. First the performance measurement systems, in general, is discussed and then performance measurement systems in supply chain and logistics. Then performance measurement system (PMS) in freight transport and different views on efficiency KPIs are presented. In the next section resource utilization, and then vehicle utilization as one of the most important components of resource utilization in transport industry is presented. At the end fill rate, as a measure of vehicle utilization and its relation to other topics, which is the focus of this report, is discussed. These steps are shown in the Figure 2.

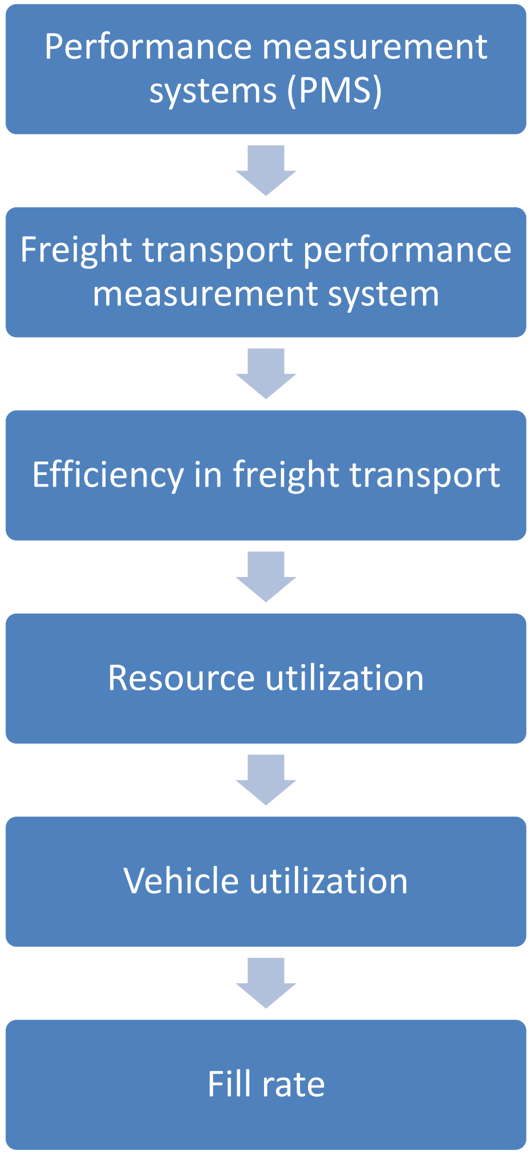


Figure 2: The structure of theoretical framework

4.2 Performance measurement systems (PMS)

The U.S. Government Accountability Office (GAO) defined *performance measurement* as "the ongoing monitoring and reporting of program accomplishments, particularly progress toward pre-established goals. It is typically conducted by program or agency management. Performance measures may address the type or level of program activities conducted (process), the direct products and services delivered by a program (outputs), or the results of those products and services (outcomes). A "program" may be any activity, project, function, or policy that has an identifiable purpose or set of objectives." (GAO, 2005, p.3)

Franceschini et al. (2007) mentioned some reasons to adopt a performance measurement system:

- It provides a structured approach for focusing on a program's strategic plan, goals, and performances.
- It helps organizations to concentrate time, resources, and energy on achievement of objectives, and provides feedback on progress towards objectives.
- It improves communications internally among employees, as well as externally between the organization and its customers and stakeholders.
- It helps justify programs and their costs, and supports the decision making process.

The performance measurement is implied through performance measures (or indicators), which are composed of a number and a unit of measure. They are used to understand, manage, and improve organization activities. Well-defined performance measures help to understand (Franceschini et al., 2007):

- How well the activity is performing
- If the goals are achieved
- If the customers are satisfied
- If the processes are in control
- If and where process improvements are necessary

However, performance measures must have some characteristics in order to be effective and help organizations to reach their goals. Lichiello (1999) defined the key attributes of a performance measure as follow:

- Validity: a valid measure captures the essence of what it intends to measure.
- Reliability: reliable measure has low level of random error in results and high level of accurate result.
- Functionality: a functional measure is directly related to objectives.
- Credibility: the measurement should be supported by stakeholders.
- Understandability: an understandable measure is easy to understand and minimal to explain.
- Availability: an available measure should be readily available through the means on hand.
- Abuse-proof: an abuse-proof measure is unlikely to be used against factors which are measured.

There are different ways to categorize performance measures. Commonly, they are divided into cost and non-cost measures. Non-cost measures are further divided into quality, flexibility and time measures (Neely et al., 2005) (De Toni & Tonchia, 2001). Measures that should be used might depend on the type of industry (e.g. manufacturing or service provider) and also the type of action which its performance is going to be measured in order to check how they are approaching organizational goals and objectives.

Performance measurement systems have evolved during time and some trends and specifications have been mentioned in the literature. For example, PMSs are evolving from being based on measuring costs to one that measure the creation of value and therefore towards measuring non-cost performances. The characteristics of this evolution of PMSs from traditional to innovative ones have been listed in Table 3. (De Toni & Tonchia, 2001)

Table 3: PMS evolution (De Toni & Tonchia, 2001)

Traditional PMS	Innovative PMS
Based on cost/efficiency	Value-based
Trade-off between performances	Performance compatibility
Profit-oriented	Customer-oriented
Short-term orientation	Long-term orientation
Prevalence of individual measures	Prevalence of team measures
Prevalence of functional measures	Prevalence of transversal measures
Comparison with standard	Improvement monitoring
Aim at evaluating	Aim at evaluating and involving

By introducing the concept of supply chain and trend towards optimization of supply network, the area of supply chain performance measurement attracted many academic researches. Stewart (1995) identified four key operational areas that give superior revenue to supply chain; delivery performance, flexibility, logistics costs, and asset management. According to him performance measures need to assess these areas:

- Delivery performance: it drives customer's satisfaction and is controlled by supply chain management. Delivery to request date is percentage of orders fulfilled on or before customer request date. Delivery to commit date is percentage of orders fulfilled on or before schedule or committed date.
- Flexibility and responsiveness: supply chain flexibility that contains: communication to end-product, feeder plants, product sourcing, and lead time.
- Logistics costs: order management costs, materials usage cost, inventory carrying cost, supply chain finance, planning and management information system cost.
- Asset management: supply chain asset consists of accounts receivable, inventories, selected plant, property and equipment.

Beamon (1999) argued that traditional performance measurement generally focused on developing new performance measures for specific applications, benchmarking, and categorizing existing performance measures. The author introduced a model (see Table 4) that three types of performance measures are identified: resource, output and flexibility. He argued, although many supply chain performance measures exist for resource and output, there are a few number of flexibility evaluation.

Table 4: PMS in Supply Chain (Beamon, 1999)

Performance measure type	Goal	Purpose
Resources	High level of efficiency	Efficient resource management is critical to profitability
Output	High level of customer service	Without acceptable output, customers will turn to other supply chains
Flexibility	Ability to respond to a changing environment	In an uncertain environment, supply chain must be able to respond to change

Lai *et al.* (2002) argued that in the supply chain perspective, firms must use integrated performance measurement to cover entire supply chain operation and not just focus on activities within the focal firm. Also they discussed that the measurement system should consider both effectiveness and efficiency aspects of activities. The authors used SCOR model (see Table 5) as a framework for measurement in transport logistics in supply chain based on four parameters: supply chain reliability, flexibility/responsiveness, costs and assets. The first two measure effectiveness (customer facing) and the other two assess efficiency (internal facing) which cover following KPIs:

- Customer facing: delivery reliability, order fulfillment, supply chain response time, and production flexibility.
- Internal facing: total logistics management cost, value adding activities, cash to cash cycle time, return processing costs, assets turns.

Table 5: SCOR model (Lai et al., 2002)

	Customer facing			Internal facing	
Metrics	Reliability	Responsiveness	Flexibility	Costs	Assets
Perfect order fulfillment	✓				
Order fulfillment cycle time		✓			
Upside supply chain flexibility			✓		
Upside supply chain adaptability			✓		
Downside supply chain adaptability			✓		
Supply chain management costs				✓	
Costs of goods sold				✓	
Cash to cash cycle time					✓
Return on supply chain fixed assets					✓
Return on working capital					✓

Lai *et al*. (2004) extended their previous study by doing a survey within three transport logistics industry sectors, which are air, sea, freight forwarders, and 3PLs. According to authors' analysis, firms are generally conscious of their supply chain performance (SCP) in transport logistics. However, firms in 3PL logistics service seem to have higher level of SCP compared to three other sectors. The authors claimed that it is due to wider operation of 3PLs services and more contact with different parties in transport sector.

4.3 Performance measurement system in transport operations

By focusing more on logistics PMS as a part of supply chain performance measurement system (SCPMS), Mentzer and Konrad (1991) categorized freight performance measurement system (FPMS) in five groups of transportation, warehousing, inventory controlling, order processing, and logistics administration. According to Mentzer and Konrad (1991) the trend for improving logistics performance has increased significantly since deregulation increased flexibility in logistics. Due to this dramatic change, even the performance of entire distribution system of a company needs to be improved and this leads to the need for measurement of performance and improving the activities.

Keebler and Plank (2009) provided a benchmark of logistics performance measurement in the US. According to their study following results can be achieved:

- Logistics measurement can improve firm's performance.
- Most firms in the survey do not comprehensively measure logistics performance.
- There is a need for definition of linking activities between firms and their performance measures.

Moreover, the authors claimed that logistics planning and control systems cannot be effective without measures and firms measure logistics performance in order to reduce operating costs, drive revenue growth and enhance shareholder value.

MCKinnon (1999) in his study on vehicle utilization and energy efficiency in the food supply chain identified five key performance indicators in transportation function:

- Vehicle fills: measured by payload weight, pallet numbers and average pallet height.
- Empty running: the distance the vehicle travelled empty
- Time utilization: that is classified into following activities: running on the road, being loaded or unloaded, preloaded and waiting departure, delayed, and undergoing maintenance, empty and stationary.
- Deviation from schedule
- Fuel efficiency: both the motive power unit and the equipment.

By delimitation of literature review and focusing more on freight industry within logistics sector, it is identified that academic studies have different perspectives on the FPMS. Duma (1999) studied PMS in freight transportation and argued that although ton-kilometers is traditional and universal measure tool in PMS, it could not properly characterize the transport performance in our time due to special changes in recent years. Transport performance in ton-kilometer is used widely in macroeconomic level, e.g. by state and policy makers, but service providers and users do not use this indicator for their decision making. The authors suggest the following measurement tool to be considered:

- Weight of transported goods

- Transport distance
- Transport tariff revenue
- Transported units
- Number of vehicles
- Capacity measures
- Operation time

Cottrell (2008) in his study about different transportation modes in the U.S. came up with two findings. First, the performance measures used by freight transport providers are different with those that are in use or of interest to public sector. It is mainly due to the deregulation of transport industry, which makes transport operators function freely as a business in the market, and consequently focus more on financial and customer service oriented performance measures. His second finding was that due to natural differences among transportation modes, they require different performance measures. Finally, six measures were introduced that is claimed are used by many, if not most, of the transport service providers in all modes:

- Average length of haul
- Operating ratio
- Revenue per ton-mile
- Tonnage (total, all loads)
- Ton-miles or barrel-miles
- Terminal dwell time or empty miles factor

Australia's Bureau of Industry Economics (BIE, 1992) performed a survey on Australian freight transport providers. The result of the study was identifying two major types of indicators for road freight: customer-oriented and operating efficiency indicators, which coincides with effectiveness and efficiency. Some customer-oriented performance indicators have been listed that are mostly determined through a survey asking customers which aspects of transportation are perceived the most important by them. Thus, it covers areas like price, timeliness and other aspects of the quality of transport service. BIE (1992) claimed that there are no universal measures used by firms to measure their operating efficiency, since each company tailors them to their operations, however six measures are introduced as the most common indicators of operating efficiency:

- Total kilometers per vehicle per year
- Total ton-kilometers per vehicle per year
- Kilometers travelled empty as a proportion of total kilometers travelled
- Average actual load as a proportion of full load capacity
- Number of kilometers per driver per year
- Fuel usage by vehicle type

The main factors that these indicators highlight are vehicle utilization and productivity during an operating period and driver and fuel efficiency. The four customer service measures include: On time pickup, on time delivery, damage rate, and ratio of claim paid. These indicators cover areas like price, timeline and other factors of quality of service that are important in competing in national and international markets. (BIE, 1992)

4.4 Efficiency measures

Neely et al. (2005) and Mentzer & Konrad (1991) have defined the *performance measurement* as the process of quantifying/analyzing the efficiency and effectiveness of an action. Mentzer & Konrad (1991) defined efficiency as the ratio of resources utilized against the results derived; and effectiveness as the degree to which a goal is achieved. Since Neely et al. (2005) assumed that customer satisfaction is the organizations' ultimate goal; they defined effectiveness as the extent to which customer requirements are met, while efficiency is a measure of how economically the firm's resources are utilized when providing a given level of customer satisfaction.

The evaluation and measurement of performance might not be right if only efficiency or effectiveness is tried to be measured. The total effort will be partially successful if the goal is partially achieved, although to reach this part of the goal the resources have been 100% utilized. Thus for measuring the performance both effectiveness (incorporating the goal structure for determining standard outputs) and efficiency (incorporating inputs) must be taken into consideration. (Mentzer & Konrad, 1991)

Samuelsson *et al.* (2002) argued that efficiencies can be assessed either *ex post* or *ex ante*. When it is assessed *ex post*, the potential for improvement can be derived, by understanding the transport process and causal relationships between efficiency and its explanatory factors. Both a low and high efficiency may have still high or low potential for improvement. When efficiencies are assessed *ex ante*, they are usually used for planning purposes. Hence they need to be forecasted. In this case, efficiencies become stochastic variables with a mathematic expectation and a variance. Thus, in planning a freight transport system, reducing the variability of the efficiency of different transport operations can be the goal for improvement.

An efficiency of 100% means that the theoretical, ideal situation is achieved. In some cases efficiency can be more than 100%, for instance if the speed limitation is 80 km/h, but the actual driving speed is above that, or if a truck loading capacity is 40 m^3, but more freight is loaded because some of the freight is loaded in driver's cabin. (Samuelsson & Tilanus, 2002)

4.5 Resource utilization

Following the report's path, articles on resource utilization are needed to be studied that is one step before filling rate measurement as a KPI. Research performed by Cottrel (2008), Duma (1999), Harrison *et al.* (2006), and McMullen& Monsere (2010) about fright transport PMS argued that resource utilization is a main part of PMS in this sector and fright companies tend to measure this factor in order to reduce their cost and increase revenue.

From a company perspective, a resource is defined as "a factor that has the potential to contribute economic benefit" (Galbreath, 2005, p.980), or simply "something your organization owns or has access to even if that access is temporary" (Mills et al., 2002, p.19). Resources can be categorized in different ways but one of the very common ways is to categorize them into tangible and intangible resources.

Tangible resources are physical and financial assets, such as buildings, equipments, vehicles, and stocks, while intangible resources include intellectual property assets, organizational assets, and skills, knowledge and capabilities of not only employees, but also partners.

Resource utilization is defined as the proportion of utilized resources divided by available resources, which describes to what extent the company utilizes its available resources (Lumsden, 2007). Resource utilization can be considered from two different points of view: Physical and economic. The difference between these two viewpoints is elaborated in section 4.5.1. Since economic resource utilization is beyond the scope of this report, the focus is on physical resource utilization.

Beamon (1999) in his performance measurement framework claimed each PMS should contain measurement of resource, output and flexibility. And each individual measures must coincide with organization's strategic goals. According to him resource measures includes: inventory levels, personal requirement, equipment utilization, energy usage, and cost. Resources generally are measured in terms of quantity or efficiency measures. Efficiency assesses the utilization of resources in the system and is an important part of measurement system.

Chan (2003) categorized performance measurement in two major groups of quantitative and qualitative measures. Quantitative measures consist of cost and resource utilization which according to him are the most important and easily understood measures. Qualitative measures include: quality, flexibility, visibility, trust, and innovativeness. Moreover, he discussed that performance measurement needs to focus on both input and output of the system, and resource utilization measures input of the system and shows the efficiency of the company. Optimum use of resources leads to saving time and money, and improve the performance.

Keebler (2009) categorized logistics performance measures to effectiveness measures that covers customers side (order fulfillment, on time delivery, etc) and efficiency measures (cost, productivity, utilization), in which utilization covers area of space utilization, equipment downtown, equipment utilization, and labor utilization. He argued that firms' consideration on internal resource utilization, productivity and cost measures is necessary to improve its performance and companies need to define appropriate measures of their inter-firm process.

Companies, to be efficient and make profit, need to use their resources efficiently as much as possible. Therefore it is necessary to measure how efficient resources are being used. Beamon (1999) believes that efficient resource management is critical to profitability and one of companies' goals is to reach to a high level of efficiency. To emphasize more on the importance of resources, Mills *et al.* (2002) believe that resources are building blocks of competences or activities that if are arranged in an appropriate way, will lead to an out-performed result that valued by customers. It means that the performance of a competence or activity is dependent on the management of its underlying resources, as well as health and appropriateness of those resources.

Lumsden (2009) argued that for studying resource utilization in transportation, it is not enough to focus only on the goods flow, since goods flow is just a one way flow from sender to receiver but resource flow is a two way flow. Resources (e.g. trailers, containers, or pallets) usually return back from the destination to their origin, either filled or empty. If there is imbalance in goods flow, it will definitely cause some losses in resource utilization. These imbalances can be categorized as (Lumsden, 2009):

Structural imbalances: This imbalance is caused due to an uneven transport demand in a two-directional transport relationship. The example of this situation can be transporting goods from a producing region to a consuming region, which makes it difficult to find freights on the return direction.

Operational imbalances: It usually occurs when the goods and resources are not adapted to each other by the haulier due to operational reasons. For example if the vehicle has to leave not fully loaded because of poor time adjustment.

Technical imbalances: It occurs when carriers are not technically adapted to varying types of goods. For example, a container is not appropriate for carrying frozen food products, thus it cannot be fully utilized on the return direction.

Chain imbalances: It is caused by the transport chain through which the freights are transported. For example, when a vehicle is distributing goods to a number of customers, the filling rate of the vehicle is constantly reduced during its distribution route, resulting in low resource utilization.

Safety imbalances: These imbalances are caused by variations in demand of resources. To deal with demand variations, transport companies usually try to have over-capacity, in order to prevent saying no to customers because of resource shortages. Consequently, it leads to lower resource utilization.

There are lots of factors which affect the system's resource utilization, in a very complicated manner. Since it is impossible to analyze all of them in a quantitative model, a qualitative model has being used to describe their influences on resource utilization (Lumsden, 2009). This model is shown in Figure 3 and is explained in the following part.

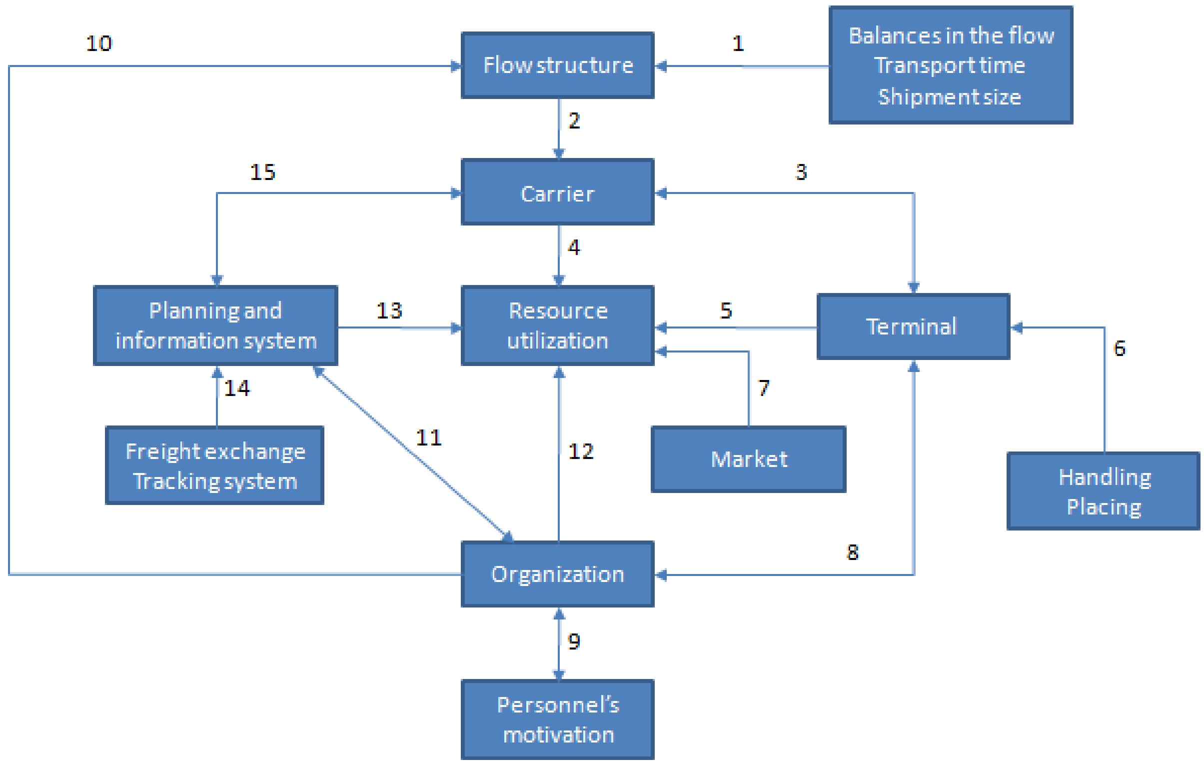


Figure 3: Influences on resource utilization (Lumsden, 2009)

1. Imbalances, transportation time, and shipment size are factors which characterize the flow structure.
2. The flow structure affects or determines the choice of carrier.
3. The characteristics of carrier and terminal influence each other. For example, a special design of carrier makes it necessary to use special handling equipments in the terminal and vice versa.
4. The ability to maximize the carrier use, affects the resource utilization.
5. The terminal performance and cost affect the system's resource utilization.
6. The location of terminal and its handling equipment influence the terminal performance.
7. Unpredicted events in the market, such as a strike, impact the resource utilization.
8. The organization of terminal activities yields the demand for possible terminal handling.
9. Organization can create motivation among personnel and personnel can influence the successfulness of the organization.
10. Having appropriate organization and right tools, the company can avoid imbalances and get access to suitable flows.
11. The organization can provide a planning/information system for the operative personnel. Old information systems are usually difficult to redesign, thus the organization might be structured based on this old information system.

12. This relation can be described through this example that an oversized organization usually makes poor use of its resources.
13. The performance of planning/information system will obviously affects the resource utilization.
14. The right mix of information including freight exchange, tracking and tracing systems is needed to have an acceptable planning system.
15. The information system might be able to track a limited number of carriers. On the other hand, based on the carriers' requirements, adjustments on the information system might need to be made.

4.5.1 Physical vs. economic resource utilization

Lumsden (2009) argued that resource utilization is difficult to specify and varies greatly depending on what is measured and how it is measured. To clarify this situation, he gave an example in passenger transport by a taxi. The taxi has the capacity of three passengers. Assuming that the taxi receives an assignment to take one passenger from the taxi station to a destination, it will be empty on its way back to the station.

From economic point of view, the resource utilization of the taxi is 100%, since the customer is paying for the whole journey, although in one way the taxi is physically empty. Here, no physical occupation of the vehicle is important, but the economic gain from the customer, thus it does not matter for the driver or the taxi owner to have all seats occupied, as long as the taxi's operation is economically profitable.

The other way that can be used to calculate resource utilization is to look at the empty running. It can be argued that since the taxi is transporting passenger on one way and it is empty on the return journey, the resource utilization would be 50%. Going into a more detailed level, it can be said that just one seat out of three is being used only in one of the two ways of transportation, thus the resource utilization would be $\frac{1}{2} \times \frac{1}{3} = \frac{1}{6}$ or 16%. These two last calculations are based on physical resource utilization, but in different levels. In physical resource utilization, the physical occupation of the vehicle is considered to be important. These three ways of calculating resource utilization for this example are shown in the Figure 4.

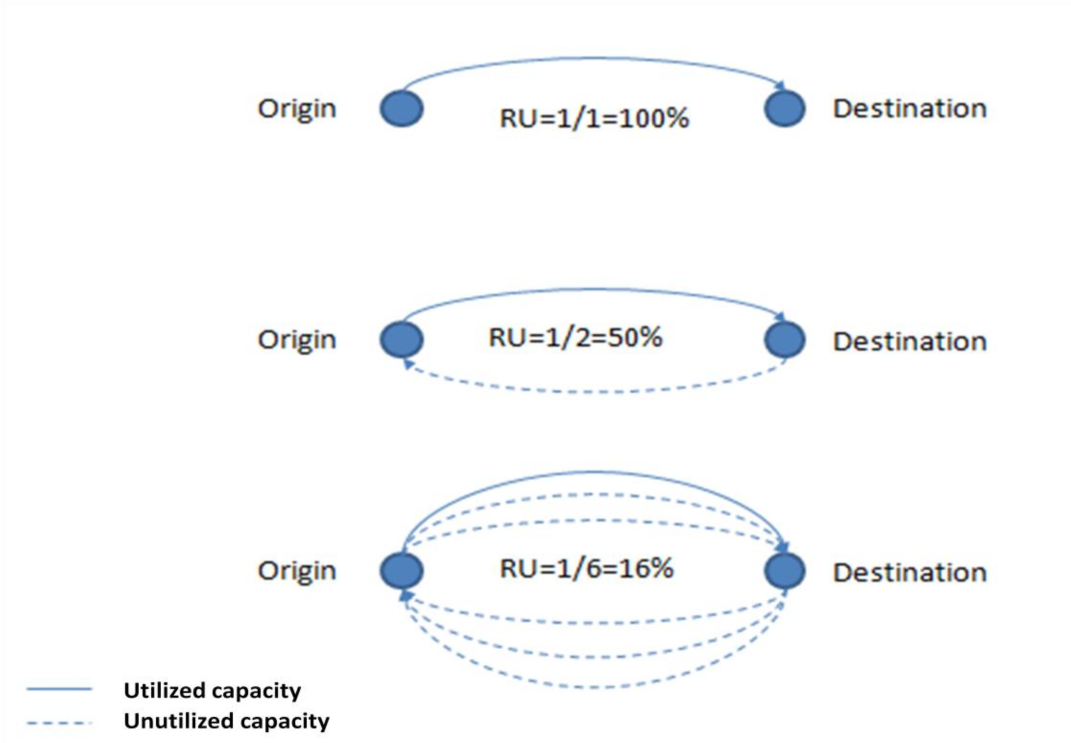


Figure 4: Different methods to measure resource utilization in the taxi example. Top: Economic resource utilization, Middle: Physical resource utilization considering one way full and the return way empty, Down: Physical resource utilization considering the number of occupied seats (Lumsden, 2009)

This example shows that how different the results of resource utilization can be when it is being treated from different perspectives. The results vary from 100% to 16%, and still no one can claim that one specific method is the most accurate or some are meaningless. It is in their specific context framework that each of these calculations would gain accuracy or importance. From the taxi owner or driver's viewpoint, it is just economic utilization that matters, and it is obvious that he/she would sacrifice physical utilization in favor of economic utilization. But from government's point of view, the second and third methods of calculating resource utilization might be interesting, and from socio-economic perspective, the last one would be the right way of measuring resource utilization.

The same logic is valid for freight transport too. Economic perspective to resource utilization can be from transporter or vehicle owner's point of view. For example, it might not be important for the truck owner that the truck is 100% full or 50% full, as long as the customer is paying the transportation price. Another example mentioned by Lumsden (2007) is a vehicle which is driven fully loaded from one node to another one, and is driven back empty to the initial node. If the customer pays for the transportation in both directions, the economic resource utilization would be 100%, but the physical resource utilization would be maximum 50%, since the vehicle is empty in its way back to origin.

In some cases, government and public sector might be more interested in achieving higher physical resource utilization, mainly due to its impact on reducing transportation in general and consequently decreasing its negative impacts, such as congestion, accidents, fuel consumption, air and sound pollution.

To be concluded, it must be said that although there is a great difference among economic and physical resource utilization (e.g. physical resource utilization can be maximum 100%, while economic resource utilization can be theoretically unlimited), it seems that there is also a direct relation between them. Novriady (2007) showed that there is a strong correlation between economic and physical resource utilization. It seems to be logical since from the first sight in the taxi example or freight transport, when the physical utilization increases, the economic gains can be predicted to be increased too. He has also claimed that companies usually focus on economic resource utilization for their high end products, such as luxury airlines and express shipping, but on the other hand, for ordinary products, such as low cost airlines and regular shipping, physical resource utilization is more in concern.

It must be mentioned again that the scope of this thesis just covers the physical resource utilization, and the economic resource utilization is not further discussed.

4.5.2 Vehicle utilization

Vehicles are one of the most important resources in transport industry. Obviously, vehicle is a tangible resource that competitors can have the same or even better ones. But the combination of this resource with other resources (tangible or intangible), such as terminals and networks, knowledge and skills, can build a competitive advantage for the company. It is the capability of managing vehicles and getting the most out of them, which to a great extent, puts a company in a better situation compared to its competitors. Trying to get the capability of achieving higher rates of fill rate can be seen in this respect.

Since transport sector is accounted for a large part of emissions and road freight transport is generally the dominant mode of freight transportation in most of the countries, if vehicles are efficiently used this burden would be remarkably reduced. Some statistics shows that, for example, 25% of truck kilometers in EU countries is run empty, or in the UK, 44-ton trucks that can carry a maximum payload of 29 tons only transport on average 17.6 tons when laden and 12.7 if empty running is considered (McKinnon & Edwards, 2010).

There are many methods for calculating and measuring vehicle utilization in the literature, from very simple measures to complicated mathematical calculations. It shows that there is no consensus about measuring vehicle utilization among practitioners and academics. In this section, it is tried to explain some of these methods.

Lumsden (2007) divided the physical utilization into three dimensions: capacity, speed, and time. Since in road transportation maximum speed is usually determined by regulations, the focus can be on the capacity and time. The capacity is considered to be measured based on volume or weight. It can be calculated as shown in the Equation 1.

$$Resource\ utilization\ (capacity) = \frac{Utilized\ load\ capacity}{Aavilable\ load\ capacity}$$ **Equation 1**

In the same way time utilization of resources can be calculated as shown in the Equation 2.

$$Resource\ utilization\ (time) = \frac{Utilized\ time}{Available\ time}$$ **Equation 2**

The total physical resource utilization can be calculated by considering both capacity and time utilization as formulated in Equation 3.

$$Physical\ resource\ utilization = capacity\ utilization \times time\ utilization$$

Equation 3: Physical resource utilization

Samuelsson *et al.* (2002) first defined the theoretical, ideal situation for goods transportation, and argued that efficiency of actual performance must be assessed in comparison with that. The theoretical, ideal situation for freight transportation is defined as "non-stop movement from origin (A) to destination (B), and back, along a minimum distance route, at maximum speed, with a full load" (Samuelsson & Tilanus, 2002, p.335), which gives the maximum freight transport output. Then the overall efficiency (E) which indicates the actual transportation output would be a percentage of the theoretical, ideal output, and is equal to:

$$E = T \times D \times S \times C$$ **Equation 4**

Time efficiency (T) is the percentage of the available time which the vehicle is actually utilized. Distance efficiency (D) is the percentage of transportation output reduction due to not using the shortest route between origin and destination. Speed efficiency (S) refers to the percentage by which maximum transportation output is reduced by not travelling at maximum speed. Capacity efficiency (C) is defined as the percentage by which maximum transportation output is reduced by not travelling at maximum capacity. For each of these time, distance, speed, and capacity efficiencies, some more detailed partial efficiency are introduced, but since except capacity aspect others are out of the scope of this thesis, just capacity efficiency is described.

Capacity efficiency (C) can be broken down to some partial efficiencies, depending on whether weight or volume is the binding constraint. Since Samuelsson *et al.* (2002) assess a case study of a road-based regional less-than-truckload (LTL) goods distribution/collection, they argue that volume is the binding constraint in these operations. Thus, capacity efficiency is defined as:

$$C = C_c \times C_f \times C_h \times C_p \times C_b \times C_n \times C_a$$ **Equation 5**

In which, C_c = capacity factor, C_f = floor occupancy, C_h = height utilization, C_p = pallet load factor, C_b = box load factor, C_n = net product factor, and C_a = actual loading execution efficiency.

The capacity factor (C_c) is the actual load volume in cubic meters divided by the maximum possible load volume in cubic meters permitted by technology (e.g. short coupling) and law (e.g. maximum vehicle length and height and width).

The floor space occupancy factor (C_f) is the percentage of the floor space that is occupied by the freight. Due to use of protruding pallets or odd-shaped cargo, such as machines and carpets, floor space may be lost.

The height utilization factor (C_h) is the average proportion of the vehicle's available loading height that is occupied by the freight. For example, if two pallets of 15 cm thickness are stacking above each other with 9 cm maneuvering space above them, the gross weight is already reduced by 39 cm. Thus if the available height is 3 meters, the height utilization factor would be 0.87. The authors believe that height utilization is generally very low, giving possibilities to be improved more.

The pallet load factor (C_p) is the proportion of available volume inside the pallet which is occupied by the boxes loaded onto the pallet. The box load factor (C_b), similarly refers to the internal capacity of the boxes on the pallet and is calculated as the percentage of the total volume capacity of the boxes that is occupied by, let us assume, the final smallest packaging unit. This factor can be repeated more if there are more packaging levels of the product.

The net product factor (C_n) is the percentage of the space in the final packaging unit which is occupied by the actual product. This factor might be very low, as due to commercial reasons, manufacturers tend to use sophisticated packaging in order to make the product more desirable for the customers.

Finally, the actual loading execution efficiency (C_a) is a residual efficiency to take account of all volume efficiency losses which have not been taken into account and might be caused by the fact that actual stowage is not according to the plan.

As can be seen in this case, the method to calculate resource utilization can be very complicated depending on how much it goes into details. One advantage of this method is that the potential areas of improvement can be recognized clearly, as in the mentioned case; Samuelsson *et al.* (2002) found that there are rooms for improvement regarding floor space utilization (C_f), height utilization (C_h), and actual loading execution (C_a).

Besides these methods, some measures exist in the literature under the title of vehicle utilization. Piecyk (2010) has simply categorized them into *empty running* and *loading factor*. McKinnon & Edwards (2010) mentioned these measures: *Ton-kilometers per vehicle per annum*, *weight-based loading factor*, *space-utilization/vehicle fill*, and *empty running*. McKinnon (2010a) in another document introduced these measures: *Level of empty running*, *Weight-based loading factor*, *Ton-km loading factor*, *Volumetric loading factor*, and *Deck-area coverage (or 'load area length')*. In the European Environment Agency's documents the ton-km is considered as the indicator for measuring filling rate (European Environment Agency, 2010).

Empty running is the proportion of total kilometers that the truck runs empty. Sometimes it is inevitable due to repositioning of the fleet or existed imbalances in the transportation network, as mentioned in section 4.5. *Ton-kilometers per vehicle per annum* is a productivity measure for truck industry. It is greatly dependent on the maximum weight limitation of trucks by regulation. This is a poor measure regarding vehicle utilization, since it does not indicate how much of the available vehicle capacity is utilized. The other measures are put under the umbrella of fill rate, as the different ways of measuring fill rate, and are discussed in the section 4.6.4.

Finally, it must be said that there is no company that under-utilized its vehicles intentionally. If statistics show that vehicle utilization is not in its ideal level, there are also some reasons for having empty runs or partly loaded trucks, such as imbalances. McKinnon & Edwards (2010) mentioned some constraints that influencing vehicle utilization and categorized them into five categories (see Figure 5) as follow:

- Market-related: These constraints are related to the characteristics of market and fluctuations on the freight flow.
- Regulatory: They are including weight and size of vehicles, timing of deliveries, and safety regulations.
- Inter-functional: These are constraints caused by other departments within the business.
- Infrastructural: These constraints are related to the physical capacity of transport network.
- Equipment-related: They are caused when vehicles, handling equipment and loads are not adapted to each other.

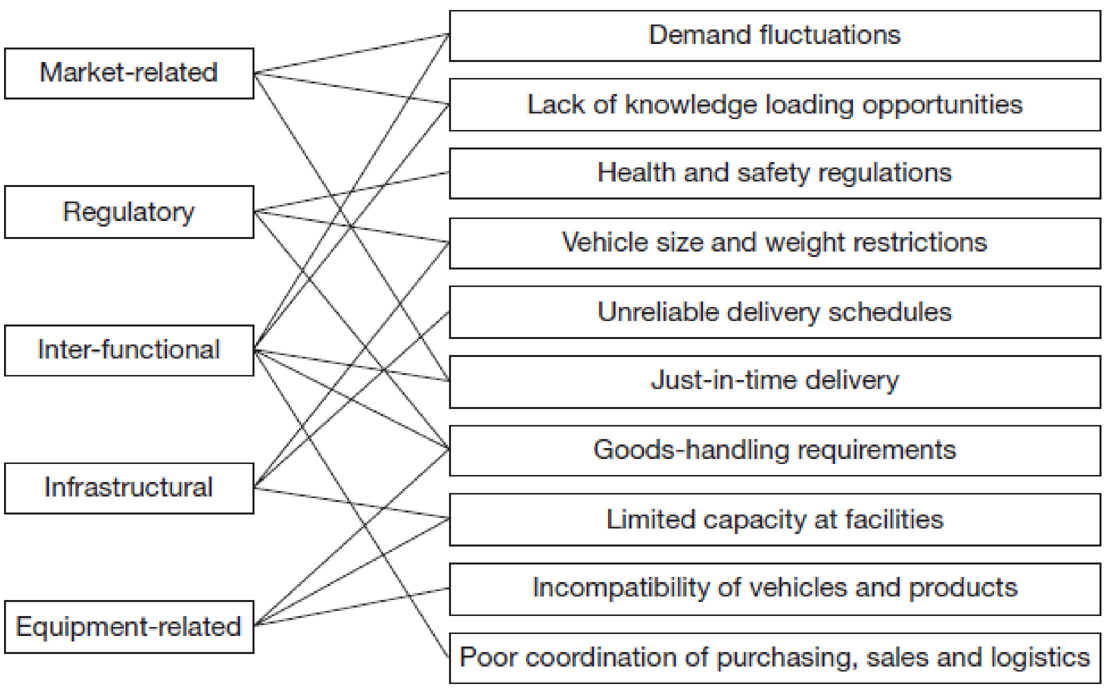


Figure 5: Classification of the constraints on vehicle utilization (McKinnon & Edwards, 2010)

4.6 Fill rate

Fill rate is not a single-dimension entity; it has different dimensions and can be looked upon at different levels and perspectives. To name a few of these levels and viewpoints, filling rate can be categorized and assessed in the context of passenger and freight transportation, different modes of transport, different actors' perspective (e.g. transport company, policy maker, customer) and so on, therefore based on these factors, fill rate might have different definitions, measuring parameters, and applications. In this part it is tried to explain this multi-dimensional nature of fill rate, aiming to describe it from different levels and perspectives, and then briefly discuss what factors are affecting first the amount of fill rate, and second the way it is measured.

4.6.1 Definition

The definition of fill rate seems to be simple and clear, and in the literature no big differences could be found in this regard, although it is named differently. Besides the term fill rate, it is also called filling rate, filling ratio, load factor, loading factor, load fill, vehicle fill, vehicle load, cabin ratio, etc. It simply indicates how much of the available capacity of a certain resource (or resources) is used, but when it comes to the practice, different approaches can be seen towards measuring it, that is discussed more in the next sections.

Here some of the definitions found in the literature are stated:

Kalantari (2009, p.20) defined "average system fill rate" as "the ratio of the total amount of goods and the total loading capacity of the fleet of trucks deployed."

Piecyk (2010, p.58) has defined it as the "ratio of the actual weight of goods to the maximum weight that could have been carried on a laden trip."

European Environment Agency (2010), defined fill rate (load factor) for freight transport as "the ratio of the average load to total vehicle freight capacity (vans, lorries, train wagons, ships), expressed in terms of vehicle kilometers. Empty running is excluded from the calculation. Empty running is calculated as the percentage of total vehicle-kilometers which are run empty."

Jordan (2011) defined fill rate as "the ratio of the average load being carried by a vehicle to the theoretical maximum load capacity of that vehicle."

Northwestern Indiana Regional Planning Commission (NIRPC) has introduced some measures for passenger transport and among them load factor, with the definition of "Load Factor is an accurate way of measuring how much capacity was being used in a transit system", is categorized under "convenience performance measures", with the argument that it not only shows the resource utilization, but also the comfort of a ride as well (NIRPC, 2011).

4.6.2 The Fill Rate context

Depending on from which perspective fill rate is being looked at; it can be put into different contexts. From the view of government and policy makers, improving fill rate can reduce the transport volume and thus will lead to a better use of infrastructure and also less negative environmental impacts.

Freight transport is responsible for 80-90% of logistics-related carbon emissions, thus there is a high focus on this section to reduce the emissions. One effort which helps in this respect is to increase vehicle utilization. The aim would be to improve the loading of vehicles which leads to reduction in the amount of traffic (measured in vehicle-kms) needed to move a given quantity of freight (measured in ton-kms), which eventually reduces the energy consumption and CO_2 emissions. (McKinnon, 2010b)

The relation between fill rate and fuel consumption can be seen in the Equation 6. It shows that the fuel consumption does not increase in a linear manner when the amount of cargo increases. In the equation, FC is the fuel consumption for a given cargo, FC_{empty} and FC_{full} are the fuel consumption when the vehicle is empty and full respectively.

$$FC = FC_{empty} + \left(FC_{full} - FC_{empty}\right) \times Fill\ rate$$

Equation 6 (adapted from (NTM, 2008))

This is also stated in European Commission policy documents related to transport and its environmental impacts. European Environment Agency (2010) emphasizes on the vehicle utilization as a measure that shows how efficiently the freight sector is transporting goods with its vehicles. If vehicle utilization can be improved, through reduced empty running and making better use of each vehicle's carrying capacity then the same goods can be carried with fewer vehicle movements. This helps to reduce total freight vehicle traffic, measured as vehicle-km, thereby leading to reduced congestion, emissions, accidents and other environmental impacts of freight transport. In this regard, it looks at some policies influencing vehicle utilization. One of these policies is the liberalization of the internal EU market which led to complex freight transport movements, which one of its results was the practice of cabotage. Cabotage means that hauliers from one country can pick up and transport goods within another country. The current regulation within EU is that hauliers can only conduct up to three cabotage operations in the country of destination within seven days of completing a delivery. To further reduce the levels of empty running and improving the efficiency of transporting goods, the European Parliament has called for the lifting of all limits on cabotage by 2014.

In the context of transport companies, fill rate would be of interest for them due to the increase in efficiency and thus decreasing the costs. As discussed in section 4.5.1, here the economic and physical resource utilization must be differentiated. It is obvious that the transport company can earn more money by adding freight to unfilled vehicle, since the operation costs, especially fuel, does not increase drastically. Therefore, companies try to utilize their vehicles as much as possible, to gain more revenue and cut the cost over larger amount of freight, also with considering the fact that profit margin in transportation is rather low compared to other industries. The different aspects of filling rate context are schematically shown in the Figure 6.

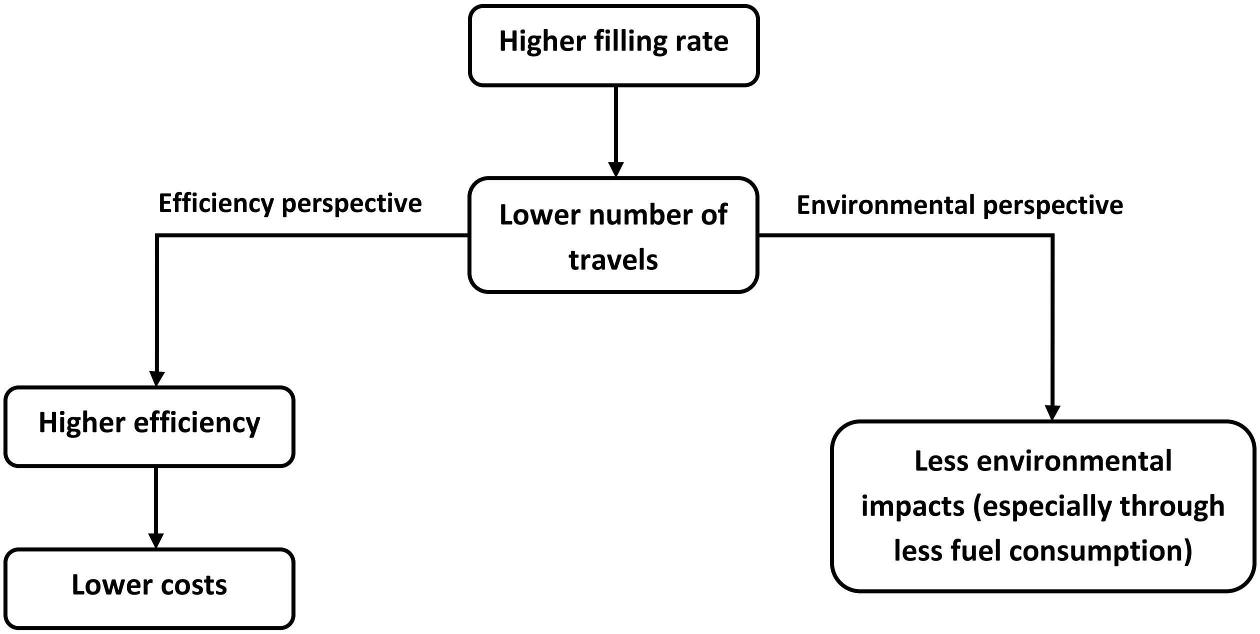


Figure 6: The efficiency and environmental aspects of fill rate

4.6.3 Relation between pricing and freight's volume and weight:

As it is mentioned in the introduction, studying fill rate can help to understand the pricing process both for transport providers and customers, since the pricing deals with weight and volume of the freight and how much the freight contributes to make the carrier full-loaded.

Noonan *et al.* (2006) described a model that is used by transport companies to generate quotations. They mention that pricing of transportation services is usually complicated because it is dependent on many parameters and factors. There are differences for the pricing calculations among various modes (air, sea, road and rail), but the principles are the same. Here the pricing method for transportation by truck is described.

There are five parameters that the transportation pricing is based on them: Origin, destination, weight, volume, and service level. Based on these parameters, six calculations must be made to determine the price:

- Chargeable weight
- Minimum charge
- Chargeable weight multiplied by price per pound
- Half truck load (HTL) price
- Full truck load (FTL) price
- Fuel surcharge

Chargeable weight: Chargeable weight depends on the cargo density. If the cargo is dense enough, the chargeable weight will be equal to the actual weight of the cargo; otherwise the actual weight will be multiplied by a factor to compensate for the excessive use of space.

Minimum charge: Minimum charge depends on the origin and destination of the freight. All carriers charge customers by a minimum charge to ensure that the transportation is profitable for them, when the chargeable weight is very low. Therefore, it is better for the shipper to consolidate small shipments as much as possible.

Chargeable weight multiplied by price per pound: First of all, price per pound should be defined, which is determined by the zones of origin and destination. It means that the farther apart origin and destination are, the higher the cost per pound will be. Then the calculation is made by multiplying the chargeable weight by the price per pound.

Half truck load (HTL) price: When the weight is close to the half truck load, the price will be lower, as it is more possible for the forwarder to change it to a standard unit load. Thus, it is more economical if the customer consolidates its freight as much as possible.

Full truck load (FTL) price: When the weight is close to the full truck load, the price per pound will be lower again, since it is more economical to ship by full truck load rather than half truck load.

Fuel surcharge: Fuel surcharges are added to the base freight cost in order to protect the carrier against fuel cost fluctuations.

The above calculated price is based on standard services and usual transit times. Other service level criteria such as emergency transit requirements, or special handling needs will also affect the price. The interesting point here is about HTL and FTL prices, which shows the direct relation between fill rate concept and pricing calculation. If the shipment size facilitates the fill rate improvement, it decreases the costs of transportation, thus the price would be lower. Also chargeable weight is a concept that relates weight and volume to each other, by considering the chargeable weight when the volume is higher in relation to its corresponding weight.

There are two other concepts in freight transport pricing that are related to fill rate aspects. These concepts, *paying freight* and *bulky weight* introduced by Lumsden (2009), are elaborated in the following part.

Paying freight:

The freight can be divided based on volume or weight to cover the transportation cost. The basic idea is to divide transportation costs onto the maximum volume capacity of the truck, or the maximum weight capacity of the truck.

Assume the truck has the volume capacity of $\bar{V}\ [m^3]$ and weight capacity of $\bar{M}\ [kg]$. If the cost of a given transportation assignment is $\bar{K}$, the unit price based on volume and weight can be calculated. The volume-dependent unit price $P_V\ [\frac{SEK}{m^3}]$ can be calculated as:

$$P_V = \frac{\bar{K}}{\bar{V}} \qquad \text{Equation 7}$$

And the weight-dependent unit price $P_M\ [\frac{SEK}{kg}]$ is:

$$P_M = \frac{\overline{K}}{\overline{M}}$$ Equation 8

Thus, the income or paying freight (PF) per truck based on volume will be:

$$PF_V = V \times P_V$$ Equation 9

And the paying freight based on weight yields:

$$PF_M = M \times P_M$$ Equation 10

Since volume and weight are normally mixed together, the total income or paying freight can be expressed as:

$$PF = PF_V + PF_M = V \times P_V + M \times P_M$$ Equation 11

By finding the suitable combinations of volume and weight loads, paying freight can be maximized, and it is what transport companies are striving for, to gain a situation that paying freight (PF) is higher than the transportation cost ($\overline{K}$). Consequently, the transport company would be profitable.

Bulky weight:

If the transportation cost is divided based on the weight capacity of the truck, transport companies might get suffered from bulky freights that corresponds to a small portion of weight capacity but take a large part of the volume capacity of the carrier. In order to avoid this situation, transport companies are trying to reach an optimal density for the goods, which considerations to both volume and weight are taken into account. This optimal density is defined as:

$$\rho_{opt} = \frac{\overline{M}}{\overline{V}}$$ Equation 12

ρ_{opt} is called the bulk number, and assuming ρ_{opt} being 0.7 tons per m^3, if the density of the goods is lower than 0.7, they should be calculated based on volume. It means that both volume and weight have to be considered when calculating paying freight. Since transportation cost is usually divided based on the weight capacity of the carrier, it is necessary to transform volume into weight. Therefore, when the current density of goods (ρ) is lower than ρ_{opt} the paying freight will be:

$$PF = P_M \times (M + \rho_{opt} \cdot V)$$ Equation 13

In which, V is the volume of goods with the density of less than ρ_{opt}.

4.6.4 Measuring fill rate

Although the fill rate definition seems to be clear, measuring it in practice is rather complex. It can be measured differently dependent on different factors in every single situation. Here it is tried to elaborate these factors which make measuring fill rate complicated. Then the ways for measuring fill rate stated in the literature are presented.

When it comes to passenger and freight transportation, the application of fill rate becomes different. It is clearly true that the available capacity and the occupied capacity in passenger transportation can be easily measured, regardless of the mode of transportation, since a single passenger corresponds to a single seat. But in freight transport, measuring both the available capacity and occupied capacity is not straight forward, as in passenger transport is (Kasilingam, 1996).

Another difference among passenger and freight transport is that passengers usually come back to their origin node, making the capacity be utilized in both direction, while in freight transport usually goods are transferred from the point of production to the point of consumption, thus causing empty running in the return flow, which negatively affects the level of vehicle utilization and making the reduction of this empty running a challenging goal for freight transport companies (McKinnon & Ge, 2006).

Therefore, the other consideration is that fill rate is not the only measure to determine the vehicle utilization, and other measures such as empty running are widely used. In some cases, empty running is mixed with the filling rate, in a way that the whole journey (from the origin to the destination together with the return journey) is subjected to be considered. In other cases just the journey from the origin to the destination is considered in measuring fill rate, and empty running is used along with that to give a complete view of the resource utilization. But a problem with measuring empty running is that companies usually calculate the empty running for the tractor and not the trailer, which consequently makes the data useless in the cases that the trailer is detached regularly.

Another consideration is the effect of taking to account the time utilization and where it should be started and ended. The vehicle is not suffering only from empty running, but also waiting, repair and maintenance, loading/unloading etc, as McKinnon (1999) showed in one survey that a semi-trailer was only 35% running on-road. Thus it should be cleared first that whether the measurement must be done at a specific single moment or a given period of time.

Another problem with measuring fill rate is that it is not clear whether the reverse flow (empty handling equipments, e.g. pallets) should be considered as a loading freight or as empty running, and thus with the fill rate of zero.

When it comes to what should be measured regarding fill rate in road freight transport, it must be said that filling rate can be measured by measuring different parameters. These parameters are weight, ton-kilometer, deck-area, number of pallets, and volume. These methods of measuring fill rate are elaborated in the following section.

Ton-km:

This measure is mentioned in European Environment Agency (EEA) documents about load factor. Filling rate based on ton-km is calculated by dividing the actual ton-km moved to the maximum available ton-km capacity (European Environment Agency, 2010). In the first document about loading factor published by EEA in 2001, another indicator was introduced that was defined as the number of ton-km divided by the number of vehicle-km. At that moment, very limited data were available just for a few number of EU members. In that document it is mentioned that more study is needed to find a better indicator of freight vehicle utilization, as for example, volume of goods is becoming more important and weight-based load factors might underestimate the true level of vehicle utilization (European Environment Agency, 2001). The same indicator has been used in 2002 document (European Environment Agency, 2002). In the next documents published in 2004 and later, the ton-km indicator is being used. The reason for this change mentioned to be partly due to erratic results from the previous indicator, and partly because the improvements in tons per vehicle could have been explained by changes in vehicle size rather than improving the utilization of available capacity (European Environment Agency, 2004) (European Environment Agency, 2005).

One different of ton-km measure with weight-based fill rate is that the weight-based one assumes that the fill rate is constant on a particular trip, while ton-km measure allows it to vary during the trip, as consignments are delivered or collected (McKinnon, 2010a).

The selection of ton-km indicator is justified based on the fact that efficient loading of vehicles leads to less vehicle-kilometers being needed to transport the same number of tons, thus less environmental damage will occur (European Environment Agency, 2010).

It seems that still there are data collection problem among EU countries, as some countries report utilization as percentage of available ton-km, and others as percentage of tons, without taking the distances travelled into account. Also still it is not clear that empty running should be included or not. Once more, it is mentioned that ton-km indicator is not correct for volume (European Environment Agency, 2010). The road freight load factors for EU countries are shown in the Figure 7.

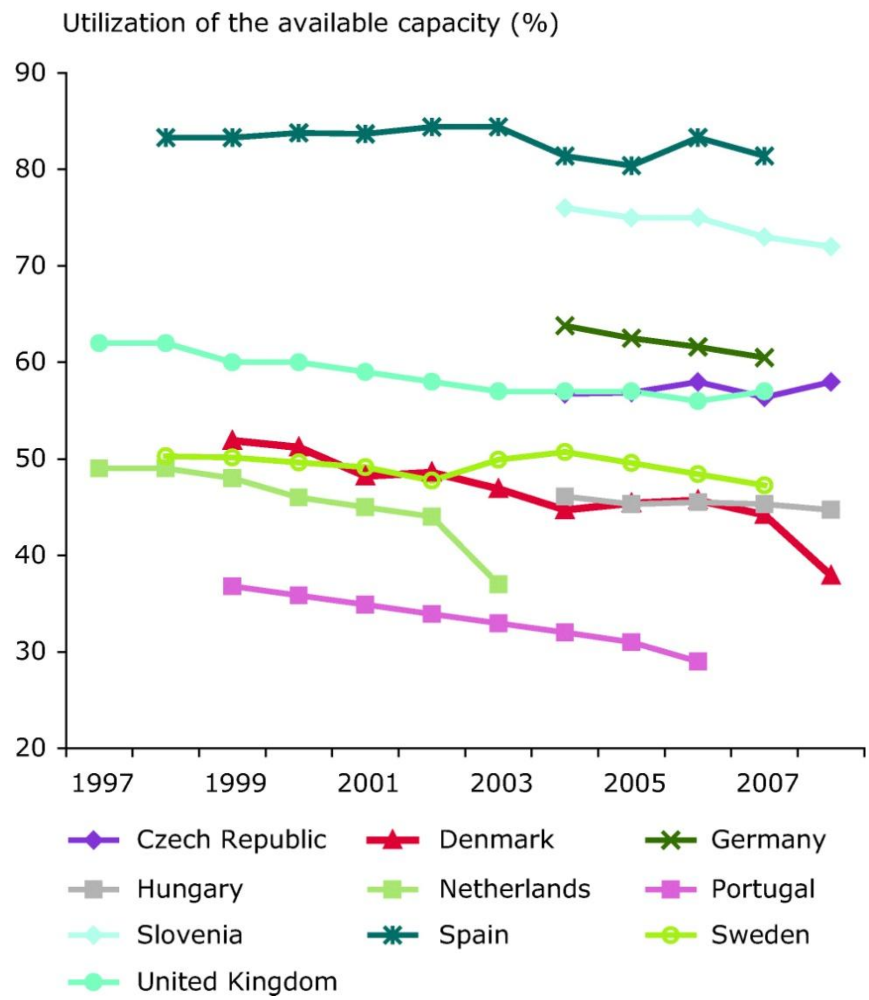


Figure 7: Road freight load factors, during the laden trips (European Environment Agency, 2010)

Weight-based fill rate:

It is defined as the ratio of the weight of the actual goods carried to the maximum weight that could have been carried on a laden trip (McKinnon, 2010a). This is a measure that is commonly used, since measuring weight is much easier than, for example volume. Also historical data is available for this measure, so it is possible to study the trends, to some extent.

McKinnon (2010a) mentioned some drawbacks of this measure. If the goal is to analyze the effects of the weight-based fill rate on energy consumption and emissions, data is also required on the tare weight of the trucks. Vehicle tare weights have significant impacts on fuel consumption, however this data is absent from official freight statistics. Weight-based fill rate also presents just a partial view of vehicle utilization, as it does not consider that some freight might “cube out” or “floor out” before maximum vehicle weight is reached.

Due to these drawbacks, information about weight-based fill rate should be interpreted carefully. For example, McKinnon & Edwards (2010) mentioned that in the UK fill rate have declined from 63% in 1990 to 57% in 2007. A large part of this reduction occurred when maximum truck weight was increased in

1999 and 2001 from 38 to 44 tons. Since it takes time for the transport industry to adapt its ordering pattern to exploit this additional capacity, the average fill rate can be reduced consequently.

Volume-based fill rate:

It can be measured in three dimensions by the percentage of available volume capacity that is occupied by a load. There is no systematic collection of volumetric fill rate for road freight transport, thus assessing this kind of fill rate is very problematic (McKinnon & Edwards, 2010).

The first barrier to use this indicator is that sometimes it is difficult to measure the accurate volume of the freight, due to its possible abnormal shape. In the case of unitized loads, such as pallets, it is possible to calculate it approximately, by dividing the actual number of units carried to the maximum number of units that could have been loaded.

As mentioned for the weight-based fill rate, some loads might be constrained by volume rather than weight, hence necessary to consider volume utilization instead of weight utilization. McKinnon (2010a) argued that the proportion of such freights have been increasing due to first, increase in the maximum legal weight of trucks, and second, a decrease in the average density of road freight (e.g. switch from heavier materials such as metal and wood to lighter plastics, and an increase in the amount of packaging).

As it is explained more in the section 4.6.3, transport companies consider the density of loads when it comes to bulky freights. They basically charge more per kg if the density of freight is lower than the optimum density. McKinnon (2010a) mentioned that the optimum density of freight for a 40 ton articulated truck with a 13.6 meter trailer of 4 meter high, is around 0.3 ton/m^3. It means that a load with this density would fill the available volume capacity of the trailer and reach the maximum weight capacity at the same time. In practice, the density of loads varies greatly depending on the type of the freight, as it can be seen in Figure 8.

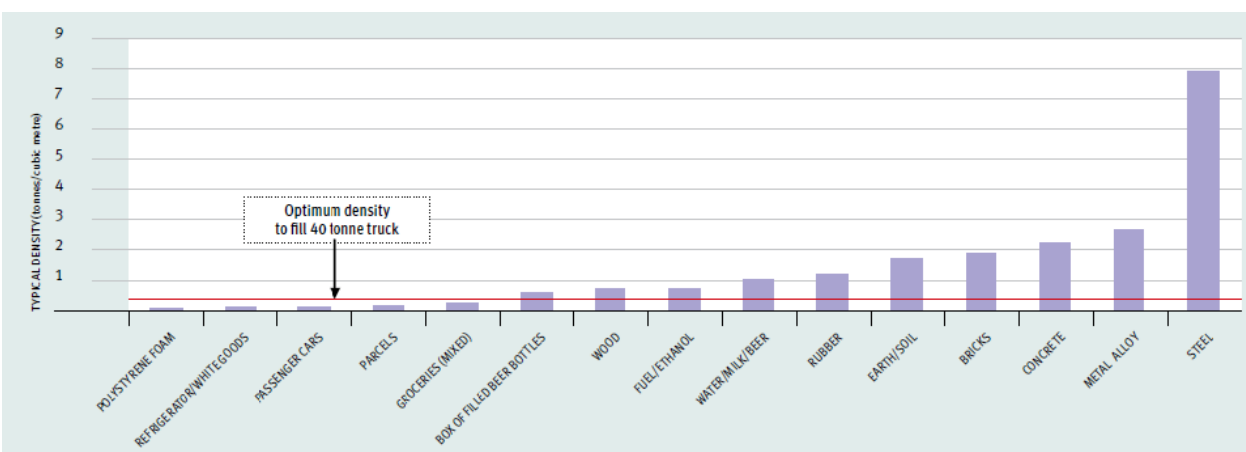


Figure 8: Variations in the average product density (McKinnon, 2010a)

One problem of lack of volume-based data in road freight transport is that the decision for increasing the size and weight limitation of trucks cannot be based on true analysis of distribution of load dimensions and densities. This problem has occurred for analyzing the costs and benefits of allowing longer and heavier vehicles (LHVs) to operate in European countries (McKinnon, 2010a).

Deck-area:

It is the proportion of the vehicle floor area covered by a load, or in other words, it is a 2-dimensional utilization of vehicle space, calculated by dividing the covered floor area occupied by the load to the total floor area of the vehicle. Vehicle utilization is usually limited more by the available deck-area than by the volume capacity, where the height to which products can be stacked is tightly constrained (McKinnon, 2010a).

There is not much data about this measure in the literature, but it seems that this measure can be useful in the cases that unitized loads are used but they do not have the capability of being stacked upon each other. In the survey conducted by Samuelsson & Tilanus (2002), the floor space utilization was much higher, compared to volume and height utilization, but still with some room for improvement.

Number of pallets:

This measure has not been mentioned individually in the literature but has been described as a way to approximately estimate the volume-based fill rate. Thus in few articles number of pallets has been stated under the category of volume-based fill rate. In this regard, fill rate can be calculated by dividing the number of loaded pallets by the maximum capacity of the vehicle in terms of number of pallets. Obviously, this measure can be useful when pallets can be stacked upon each other and different types of pallets are not mixed and loaded on the same vehicle. (McKinnon, 2010a) (McKinnon & Edwards, 2010)

4.6.5 Comparing weight-based and volume-based fill rate:

Filling rate is almost solely measured based on weight, mostly due to the lack of volume data and the fact that weight can be easily measured compared to volume (McKinnon & Leonardi, 2008). To show how different approaches can be used for measuring fill rate depending on the situation, a case is introduced. McKinnon (1999) conducted a survey about vehicle utilization and energy efficiency in the food supply chain in UK, and one of the KPIs used is “vehicle fill”, which is measured by weight, number of pallets and average pallet height. The reason behind measuring these parameters is that in food industry freight has usually a low density, thus is constrained much more by volume than weight. If only the number of pallets were considered, it would be a two-dimensional measure aiming to measure deck area, but with the average pallet height, volume can be estimated to some extent. The result of his survey shows that measuring fill rate in terms of weight and volume gives totally different results, as it can be seen in the Figure 9, where the average weight utilization was 56% and volume utilization 78%. Also, the difference between deck area utilization and weight utilization is shown in Figure 10. Also in another survey in automotive industry the results show that 74% of the volume has been used while in weight terms 42% of the capacity has been utilized (McKinnon & Leuchars, 2002).

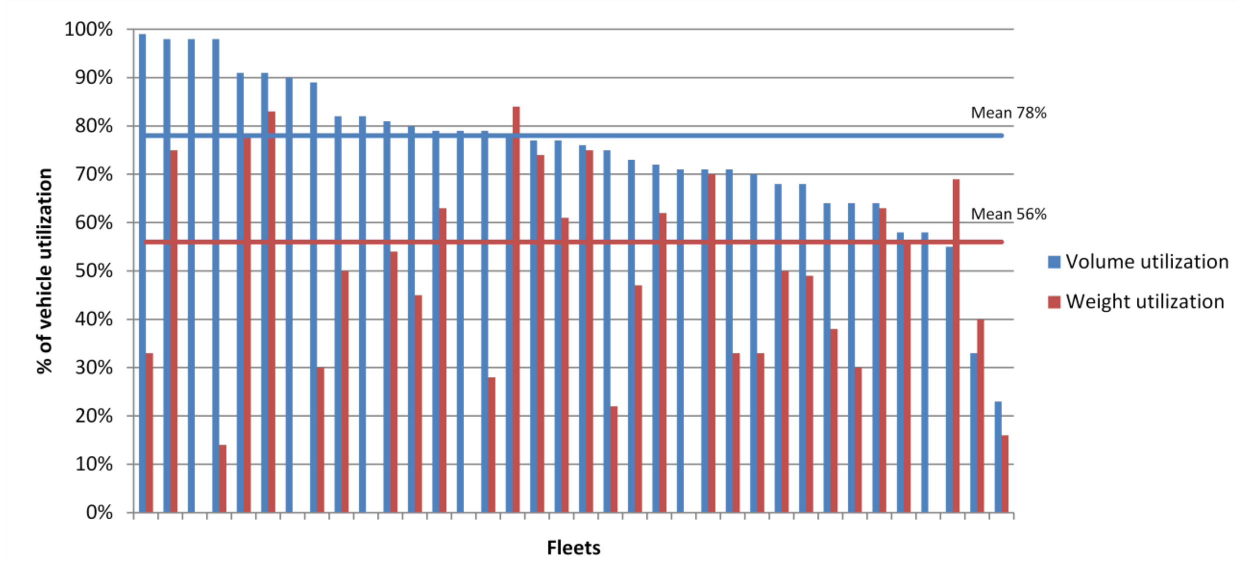


Figure 9: Comparing volume and weight utilization in food supply chain at UK (McKinnon, 1999)

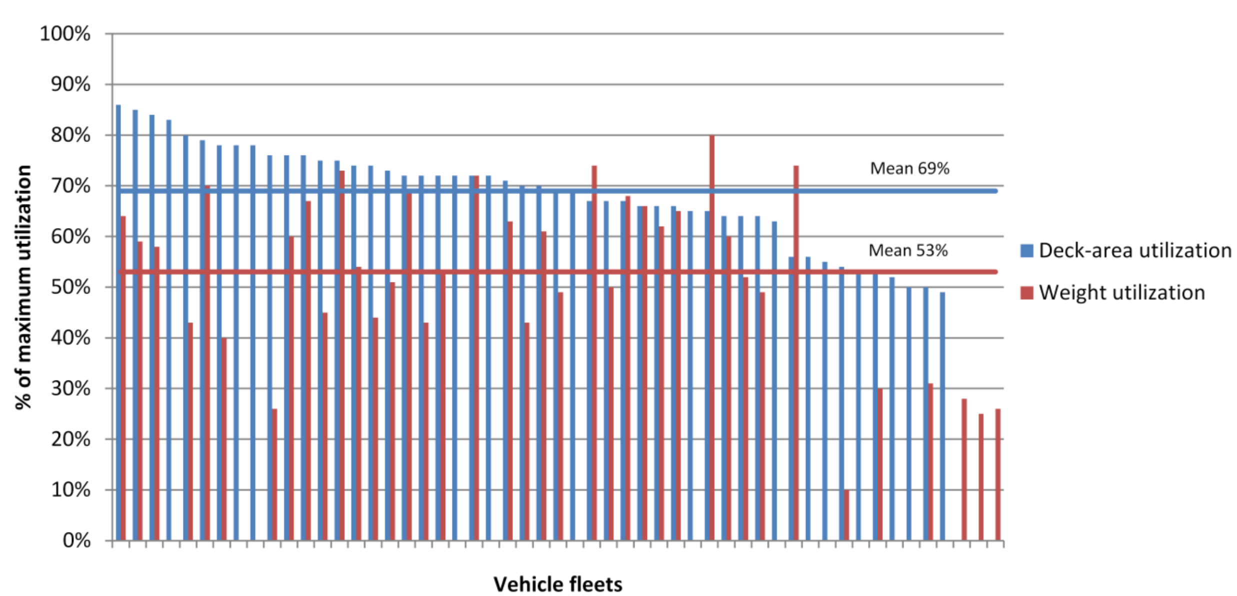


Figure 10: Comparing deck area and weight utilization in food supply chain at UK (McKinnon et al., 2003)

In another survey conducted by NEA and TFK, which is mentioned by Lumsden (2004) and Åkerman *et al.* (2007), five different Dutch hauliers were studied. In about 150 trips of transporting general cargo type of goods, the cargo was measured in number of pallets, weight and volume (see Figure 11). The findings of this survey, by categorizing into measuring method, were:

- Based on number of pallet: the average used pallet capacity was 92%. About 40% of the trips were 100% full, and 2/3 of the trips had the capacity utilization of at least 90%. The minimum capacity utilization by number of pallets was 55%.
- Based on volume: the average used volume capacity was 82%. Almost half of the trips were 90% full. The minimum capacity utilization based on volume was 38%.
- Based on weight: the average used weight capacity was 57%. Just a few trips were fully loaded. Only one out of six trips had the capacity utilization of more than 90%. The minimum capacity utilization by weight was 10%.

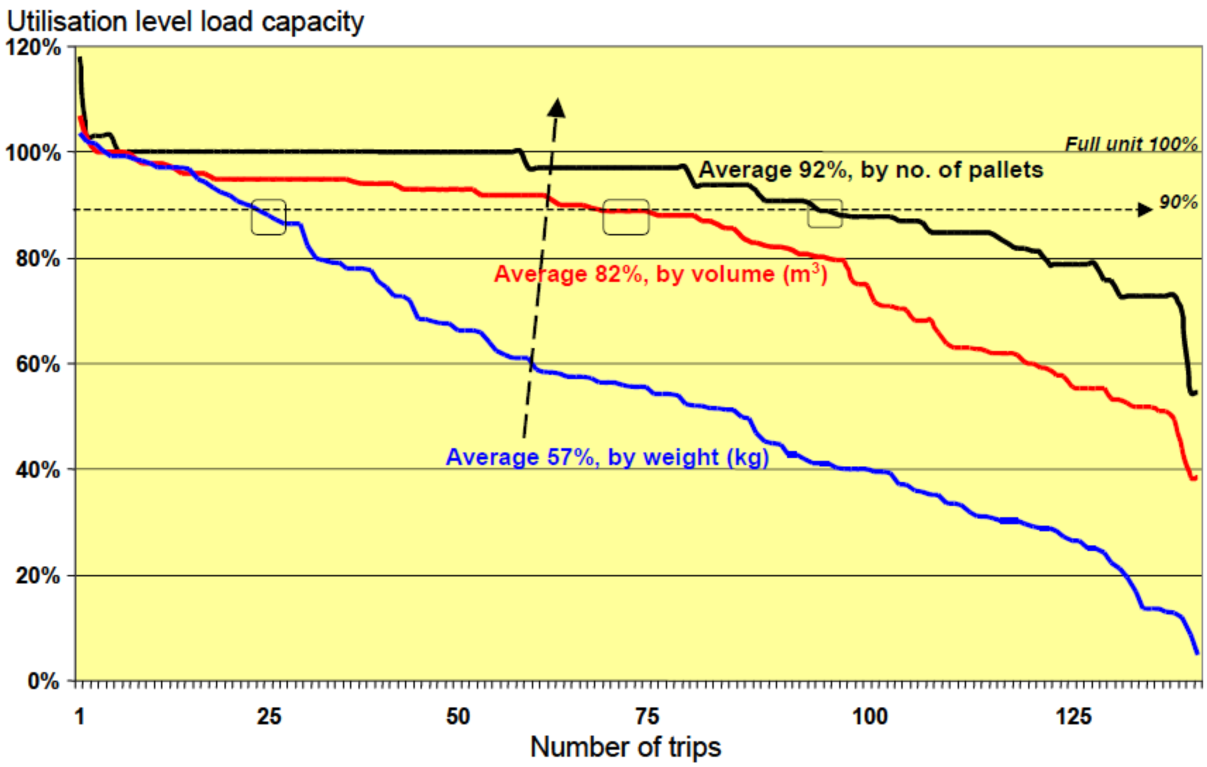


Figure 11: Capacity utilization of trucks when transporting general cargo, based on number of pallets, volume, and weight (Lumsden, 2004)

Again the conclusion that can be derived from this study is that the trucks' capacity is more constrained by number of pallets and volume than by weight. The numbers show that just a few numbers of trucks were fully loaded by weight. Thus, the consideration must be taken into the type and the density of the commodity. Also it can be concluded that an increase in truck dimensions might be a potential way for improving the capacity utilization.

4.6.6 Factors influencing fill rate

In the company level, fill rate can be influenced by decisions taken in different levels of the company. Piecyk (2010) has categorized these decisions into commercial, operational, functional, and product-related factors, as shown in Figure 12.

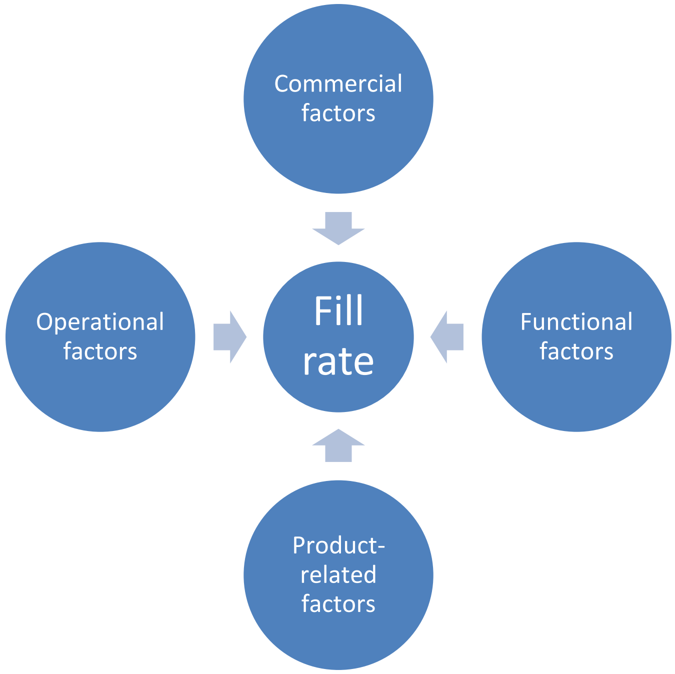


Figure 12: Categorizing factors affecting fill rate (adapted from Piecyk (2010))

Commercial factors: These factors relate to sourcing and distribution strategies and policies of the companies. These decisions are usually made at the top management level and are likely to influence transport mode choice, handling factor, average length of haul and vehicle utilization. Some of these decisions are online retailing, return of products for reuse/recycling, outsourcing of non-core processes, and global sourcing of supplies.

Operational factors: These decisions are usually made at mid-managerial level and they affect the scheduling of product flow. Empty running and fill rate can be directly influenced by operational factors. Application of JIT principle, variability of order size, order lead times, and frequency of deliveries are some examples of such decisions.

Functional factors: They relate to direct management of transport resources, such as the choice of a vehicle, planning of loads and routing of deliveries, thus they affect utilization of vehicles. Use of telematics, use of vehicle routing and scheduling systems, logistical collaboration between companies, backloading of vehicles, matching of vehicle fleet to transport demands, and integration of production and distribution are few examples of functional factors.

Product-related factors: These factors, which are related to the design of products and packaging, affect the nature of the transport operations, such as mode choice and filling rate. As Piecyk (Piecyk, 2010, p.235) mentioned "they can be a result of internal decisions or be imposed by other partners in the supply chain." Some of these decisions are: greater use of space-efficient packaging, use of shelf-ready packaging, and design of products more sensitive to logistical requirements.

Naming every single factors that have an impact on the level of achievable fill rate, gives a long list, approving that fill rate can sometimes be very complicated as it can be influenced by several different factors at the same time. Piecyk (2010) conducted a survey with the participation of logistics specialists from different industries, and the result of that survey about factors which influence fill rate was as following factors:

- Consolidation/collaboration: such practices are believed to become more common within supply chains, helping in achieving a high level of filling rate.
- Just-in-time (JIT) delivery: JIT is widely used in industries aiming to reduce inventory levels by having small frequent deliveries with tight delivery windows, leading to lower the filling rate.
- Packaging/pallet stacking: retailers can influence the vehicle utilization negatively by demanding not only smaller deliveries, but also products to be delivered in shelf-ready packaging. This packaging are usually weak and fragile, make it impossible to stack more product upon each other on a pallet or double-stacking pallets on a vehicle.
- Loads limited by volume: if filling rate is weight-based, it can be suffered from loads that are bulky in a way that volume capacity of the vehicle might be fully occupied while the weight of the freight has not reached to the maximum weight capacity, thus the measured fill rate might be misleading.
- Increase in maximum weight of lorries: due to the fact that transport companies tend to have the fleet with the maximum weight limit to increase their flexibility, it might negatively affect the level of filling rate if the maximum weight of lorries is increased, mainly because transport companies tend to have safety capacity and do not adjusted their operating practices straight away to utilize the full capacity of new trucks. On the other hand, Knight *et al.* (2008) argued that longer and/or longer and heavier vehicles (LHVs) would have higher fill rate compared to heavy good vehicles (HGVs), due to the fact that they are expected to be used on routes with good loading potential in both directions.
- Better inter-functional coordination: coordination of internal operations within a company, usually supported by ERP systems, is helping to improve the filling rate, for example, by integration of manufacturing and logistics.
- Backloading: utilizing the truck capacity on its way back to the origin node, will obviously improve the filling rate considerably, thus consideration should be taken to the return journeys. However, sometimes it may have negative effect on the filling rate; due to the fact that in return journeys empty handling equipments (e.g. pallets) are usually loaded, thus the maximum weight capacity cannot be utilized.
- Centralization: if manufacturing and distribution facilities are centralized, the possibility of having more efficient loading of vehicles will be increased, since different freights can be consolidated. On the other hand, it might decrease the filling rate, as longer haul is needed to deliver to one central location.
- Pricing of transport: in contrast to the traditional pricing system (a standard quote for a load), different rates depending on the degree of vehicle loading would improve the level of filling rate.
- Service requirements: since for the most of the companies fulfilling customers' requirements is on the top of the list, they sacrifice optimum loading of vehicles in order to offer better services

to the customers. In other words, in such situations logistics becomes service-driven instead of cost-driven.

- Decentralization of retailers: the decentralization trend among retailers may impact fill rate negatively, as there would be less possibility for consolidation.
- Multi-drop operation: this is a factor impacting the fill rate negatively, since the vehicle can be 100% full in only a part of its journey.
- Changes in vehicle design: changes in vehicle design, for example using double-deck or high-cube trailers, may help to increase the capacity of vehicle in term of volume, where the volume of goods is a limiting factor, and consequently increasing the level of weight-based fill rate.
- Postponement: another factor that helps transport operators to utilize their vehicles more efficiently is to keep goods in a generic form and/or in a single location.
- Fuel prices: with the higher fuel price, companies will have greater incentives to maximize the utilization of their vehicles.
- Size of the vehicles in the fleet: by having right-size vehicles, corresponding to the size of freights to be transported, filling rate can be improved to some extent.

4.6.7 How to increase fill rate

Based on the factors influencing filling rate, discussed in previous section, some ways to increase the amount of fill rate can be suggested.

As the result of the conducted survey by McKinnon *et al.* (2003) shows, there is room for improving the resource utilization further (see Figure 13), thus increasing the utilization of the vehicle space. In this regard, McKinnon *et al.* (2003) suggested to:

- Increase the degree of load consolidation
- Change packaging and pallet-wrapping systems to increase stackability
- Modify the design and dimensions of handling equipments
- Make greater use of double-deck vehicles that can accommodate two layers of pallets /roll cages
- Reduce the carrying capacity of the vehicle in order to match it to the typical size and weight of loads carried. Reducing the vehicle height is helping in this regard, beside the improvement in the aerodynamic and fuel efficiency.

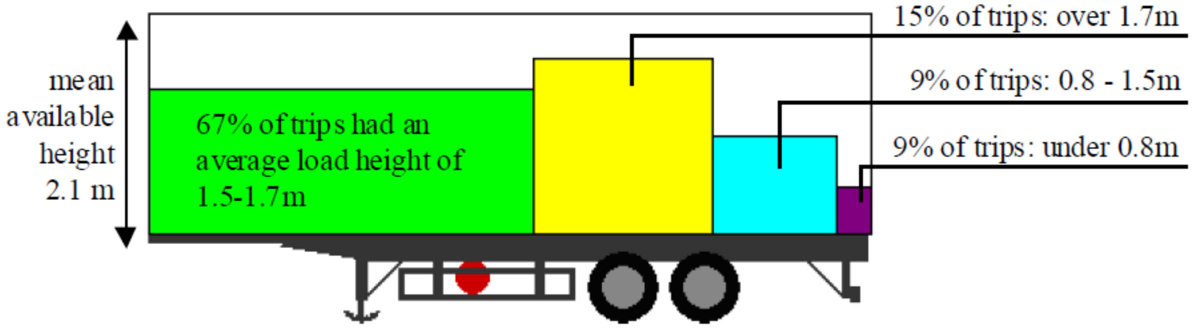


Figure 13: Distribution of average pallet height range in laden trips (McKinnon et al., 2003)

Baumgartner *et al.* (2008) claimed that computerized routing and scheduling and vehicle telematics offer a great potential to improve loading factor, and consequently the environmental performance of the freight transport.

Besides them, McKinnon (2010b) introduced two other ways for improving vehicle loading that are stated as "the adoption of more transport-efficient order cycles" (e.g. encouraging customers to choose an ordering pattern and delivery table which helps in this regard) and necessity for companies to collaborate and share vehicle capacity. The later one is also emphasized by Pan *et al.* (2009) who have treated the effects of merging supply chains in order to reduce CO2 emissions.

Morabito *et al.* (2000) examined an optimization model for loading of pallets on a truck and the selection of pallets and the result was that by using more appropriate pallets, the truck area can be utilized more efficiently.

Also some instructions are given for increasing fill rate by Jordan (2011) as:

- Load the vehicle in a way that allow for more freight to be carried per trip and maximize every last inch of space. If the vehicle loading started from the largest pieces to the smallest ones, the amount of weight being carried can be increased. It even suggests using the driver's compartment, if no passenger is being taken.
- By reorganizing the way in which the cargo is boxed/packed, the space can be maximized. Thus superfluous packing materials should be eliminated to increase the number of items can be fitted into the vehicle. Of course, safety considerations must be taken into consideration too.
- Reduce the frequency of deliveries to the minimum number possible by rescheduling, thus it will result in larger freights being carried by each vehicle and waste from unused space will be reduced.

5 Empirical findings

In this part the findings from the interviews are covered. The aim of interviews was to get the first-hand information about how transport companies are dealing with fill rate issues. As discussed in section 3.4.3, several interviewees were chosen among scholars and practitioners. The interview questions were designed in a way that could give a complete picture about fill rate situation in the transport industry. The questions can be divided into several categories, in which each category covers a part of the mentioned complete picture. These categories are: perception of fill rate, measuring fill rate, application of fill rate, and the factors influencing fill rate.

5.1 Forwarder1's business model in land transport:

Forwarder1 is the largest logistics operator in land transport within Europe and one of the leading ones in other parts of the world. Forwarder1 offers freight transport services for palletized goods, and all products that could be placed on the pallets. Forwarder1 plays as an intermediary between its customers and hauliers, it means the company does not own resources like trucks and the drivers are not employed by the company. The company has agreement with many independent hauliers that offer transport services to Forwarder1's customers. These hauliers have agreement with Forwarder1 to work just for it and not for other logistics operators. Besides, every single relation between two nodes (e.g. Gothenburg-Stockholm and vice versa) is assigned to only one haulier. The size of haulier companies varies, as it could be a company with more than 100 trucks, or even one driver with one truck. Forwarder1 receives order from customers to transport certain amount of goods in a certain time schedule with the price that both parties are agreed upon, and then gives this order to the haulier to perform the operation in a fixed time and cost. The relationship between the company and its hauleirs are mostly long term relationship and they act as a partner.

Forwarder1 owns its terminals also people who work at them for receiving, handling, sorting and delivering of goods are employed by Forwarder1. The hauliers are responsible for picking goods up and transport them to the terminals and unload them, and then terminals' staffs handle goods to different destination area and sort them according to customers' requirement. Haulier's driver loads the consignment into the truck and transports it to the final destination. Forwarder1 is responsible for all sorting activities and performing of consolidation within terminals, beside route planning and deciding on which nodes should be included in one transport trip. On the other hand, the hauliers make decision about the size of vehicle to be used and how fill the truck. The haulier also can choose transport route within the cities and prioritize the places for loading and unloading of goods.

5.2 Forwarder2's business model in land transport

Forwarder2 is the one of the leading companies in land freight transportation. It offers logistics services for different kind of products in different categories as parcels, pallet, and heavy weight. Parcels and pallets shipment are performed through hub and spoke systems and terminals for sorting and consolidation, but heavy products are transported directly from customers to customers without passing through terminals. Heavy products are mostly full truck load and does not need for consolidation to fill remained capacity.

Forwarder2 has a centralized decision-making organization, and acts as an intermediary between customers and hauliers. The company owns its terminals and all activities within terminals are performed by Forwarder2's employees. Whereas, Transport operation is outsourced to hauliers and Forwarder2 does not own any of trucks and drivers. Its hauliers could also work with other transport companies, and Forwarder2 can select other hauliers to perform certain shipment in a lane. In this respect Forwarder2's hauliers have more freedom to choose their partner and perform their transport operations.

The other difference between Forwarder2 and Forwarder1 is that Forwarder2 has two kinds of contract with their hauliers according to type of goods. In pallet and parcel category, the company buys traffic work form subcontractors (hauliers), they pay to hauliers based on transport costs of moving a specific amount of goods form origin to destination. In heavy product category, the company buys transport work form hauliers to transport goods between customers without passing through terminals (direct shipment).

5.3 Perception of fill rate:

The first question is that if companies are using fill rate as a KPI at all. It is important to see how fill rate is treated in practice and what is the perception of different companies about fill rate, how do they define it, and moreover, if there is discrepancy on the perception of fill rate in different organizations. It was also a goal to find out if there is a logical description for any possible difference in the level of importance of fill rate among various companies.

The scholars' impression about the transport companies' perception of fill rate was that they do not have a clear understanding and even definition of fill rate, due to the fact that they are mostly interested in economic resource utilization, rather than physical resource utilization. Thus the focus is more on the financial KPI's, and not on KPI's like fill rate.

The first thing that observed from interviews of transport companies was that fill rate is not well-understood in some of the cases or it was not of interest for the company and therefore was not applied in practice. At Forwarder1, they believe that it is the haulier that should be responsible for the filling rate, so practically, they do not regularly do any action about measuring, monitoring, and improving it in daily operations. Forwarder1's business model is very unique and the payment to the haulier is based on the amount of freight, in terms of weight, that is carried. It means that they are not buying vehicle-km from the haulier, and besides the haulier is responsible for loading the truck. Thus they think that it is the haulier that should be trying to improve fill rate, as the haulier gets more if loads more freight on the truck. Forwarder1's pricing method is cost plus method, meaning that Forwarder1 gets the transport costs from the haulier and adds a few percent to that as the company's profit and invoices the total number as the price to the customer. Consequently, they believe that if the haulier improves fill rate, then the haulier can lower the cost and consequently the price, thus more customers and more profit can be gained. This perception might be partly correct, but it should be considered that it is Forwarder1 that provides the freight to be carried by the haulier.

In contrast to Forwarder1, at Forwarder2 there is a well-defined system for measuring fill rate, use it for different purposes and in their decision making process. Fill rate, which is called “filling ratio” at Forwarder2, is a very important KPI in their performance measurement system, thus it is systematically measured, monitored, and controlled. Forwarder2 believes that it is their responsibility to assure that trucks are as full as possible, and do corrective actions if problems are discovered.

In general, it can be said that interviewed companies are aware of the importance of fill rate and even believe that it is a key factor for the company’s profitability, but the way that they act and react regarding this awareness might be far from the importance it deserves, but of course Forwarder2 is an exception. Since the company’s business model might impact their perception about fill rate, the relation between business model and fill rate needs to be further assessed.

5.4 Measuring fill rate:

The second category of questions is about the ways which are used by companies for measuring fill rate. If the answer of first question was that the company is using fill rate, then the next question would be in which way it is being measured and weather it is based on weight, volume, number of pallets, etc.

Again the scholar interviewees believed that transport companies usually do not measure fill rate, but if they measure it, it should be weight based fill rate. The mentioned reason behind that was that it is the easiest way of measuring fill rate and it has a direct relation with the common pricing and billing method used by transport companies. When the shipper issues an order, the first parameter which determines the price is the weight of the consignment. Forwarder1 pays the hauliers based on the weight of the freight, alongside with the distance travelled; meaning that they are buying ton-km. in contrast; Forwarder 2 buys vehicle-km from the hauliers, and pays for the cost of a truck driving between two nodes. When the consignment is palletized, then it is possible to use the number of pallets as the measurement method for fill rate, by dividing the actual number of loaded pallets to the maximum capacity of the vehicle. Volume is not usually used, due to the difficulty in measurement, but when the consignment is too bulky, then the volume is measured in order to determine whether the actual weight should be used as the chargeable weight or not. The only mentioned exception was for transporting liquid, such as diesel and gasoline. In such a case the actual volume of the consignment is usually known, due to the nature of the consignment, however it needs to be calculated in terms of weight to avoid exceeding the maximum allowed weight of the truck.

At Forwarder1, fill rate is not measured regularly, as they believe it is the haulier that must do it. Since trucks in Gothenburg are allowed to drive in bus lanes if their fill rate is high enough, Forwarder1 measures it once a while in order to show it to the authorities that the trucks are full enough to be allowed to drive in bus lanes. This measurement is done just for a limited time and a given number of trucks, as sampling. If the truck is a distributing truck, the measurement is done when it leaves the terminal and if it is the pick-up truck, the fill rate is measured at the last leg of the journey. In all the cases the measurement is based on weight. If the consignment is bulky, then the chargeable weight is considered in measuring fill rate. If the consignment density is more than 750 kg/m^3, then the actual weight is considered, and if the density is less than 750 kg/m^3, the weight is considered as 750 kg per cubic meter. It seems that Forwarder1 has the necessary data for calculating fill rate (the amount of loads on each truck and the maximum capacity of each truck), but they do not calculate and follow the figures, unless it is needed. In an aggregate level, for taking strategic decisions regarding capacity planning, the historical data about amount of goods transported and the available capacity are analyzed to adjust the capacity to the demand. Then Forwarder1 request the capacity needed for the future from the corresponding haulier. Although Forwarder1 believes that hauliers are responsible for fill rate and it might affect the profitability of the company, they do not have any information about whether hauliers are measuring it or not.

Fill rate is measured regularly at Forwarder2 based on kg/loading meter. The capacity unit is loading meter and they try to put as much freight as possible in one loading meter. Fill rate is usually measured for line haul transport, e.g. between terminals, and not for pick-up and delivery operations. They have also another product which is full load transport from one customer to another customer, but Forwarder2 is not interested in filling rate in this operation, due to the fact that Forwarder2 devolves all the responsibilities to the subcontractor.

Forwarder2 usually use the provided data by the customer, such as weight and volume, as the basis for calculating fill rate. The actual measurement at Forwarder2's terminals is done only for a part of all loads, in randomly basis or by referring to the history of a particular customer providing incorrect data. In these cases, the weight and volume of the consignment is measured at the terminal. For the bulky goods, the chargeable weight is considered instead of the actual weight of the consignment. For example, for a euro pallet, if the weight is higher than 1000 kg per loading meter then the weight is used, otherwise the chargeable weight will be 1000 kg for those with the weight of less than 1000 kg.

The arguments for using kg/loading meter and not using for example volume were first, this is the data that exists in their system, and second, volume is somehow incorporated by considering chargeable weight for bulky consignments. Finally, the legislation is based on the maximum weight of the truck, so they need to have such a data to follow the rules.

Forwarder2 calculate fill rate in an aggregate level, for example for the lane of Gothenburg to Stockholm for a given period of time, instead of focusing on every individual truck. They know how much freight has been transported, in terms of weight, from one terminal to another in a specific period, and how much capacity, in terms of loading meter, was available at the same period. By dividing the amount of freight to the amount of capacity, the fill rate will be determined. The goal for Forwarder2 is to reach to the filling rate of 940 kg/loading meter, with consideration to the fact that it depends on the type of commodities and Forwarder2's types of products. The average filling rate during July 2011 was 714 kg/loading meter.

The difficulties that Forwarder2 is facing are first the validity of provided data by customers. This data is the basis for all calculations, from pricing to calculating fill rate, but the data is not always accurate. Thus Forwarder2, and even Forwarder1, sometimes need to measure the weight or the volume of the shipment to assure that the data is correct. The second problem is in defining the "good" fill rate. It is difficult to determine the target fill rate as a goal, since it varies a lot depending on the type of shipments. The existing target of 940 kg/loading meter at Forwarder2 is just based on experience and there is no strong reasoning behind it.

5.5 Application of fill rate:

Fill rate can be used for different purposes and its application may vary from a company to another. Therefore, here the application of fill rate is categorized based on the interviewed companies, e.g. Forwarder1 and Forwarder2.

5.5.1 Fill rate usage at Forwarder1:

Forwarder1 is using fill rate for several purposes, as:

For capacity planning:

Forwarder1 has the required data about the amount of goods transported in every specific lane. The available capacity for that lane is also known. By comparing these two figures, Forwarder1 can plan for the required amount of capacity in the future and demand it from the corresponding haulier. However, it must be mentioned that there exists no measure calling filling rate when doing this capacity planning, but the actual analysis is based on fill rate concept. One interesting thing about Forwarder1 is that the capacity planning is done based on actual weight, volume, and chargeable weight. In some cases, depending on the situation, volume might be the basis for capacity planning, but in general, chargeable weight is used the most.

In calculating emissions:

For calculating emissions of transportation, filling rate must be considered, since there is a direct relation between fuel consumptions and the weight of the vehicle. Referring to Equation 6, fill rate must be known to be able to calculate emissions. Here, the fill rate based on actual weight must be considered and not chargeable weight, which Forwarder1 is doing it correctly. When allocating emissions to the each customer's share, chargeable weight is considered.

To get permission for driving in bus lanes in Gothenburg:

Forwarder1 measures fill rate to prove to the government that they have a certain level of fill rate. It is a very limited and seldom measurement for Forwarder1 and its purpose is to get the permission for driving in bus lanes. Thus it just facilitates the pick-up and delivery operations in the cities.

5.5.2 Fill rate usage at Forwarder2:

Fill rate is being used by Forwarder2 for following purposes:

As an efficiency measure:

Forwarder2 uses fill rate as an efficiency indicator which shows how well they are performing. A target is also defined, as the fill rate of 940 kg/loading meter, and they are trying to reach to this level of fill rate. It obviously shows that with higher fill rate, Forwarder2 decreases the cost and makes more profit. Fill rate is monitoring regularly, and corrective actions are being implemented if it is relatively low.

Fill rate in calculating costs and pricing:

As fill rate impacts the cost of transportation, it affects the pricing indirectly. At Forwarder2, the costs of producing different types of products, e.g. parcels and groupage, are monitored for different periods. One thing that observed was that the cost of producing, for example 1000 kg of groupage, during July in Sweden was relatively higher compared to other months in Sweden. The reason behind it is that filling rate is usually low during July, due to the excess capacity compared to the lower levels of customer orders. Thus this cost needs to be incorporated into the price, either by having higher prices during July or distributing the extra cost on the prices for the whole year. It means that the impact of fill rate on the cost is influencing the price, especially considering the fact that in transport industry the cost plus method is the normal way of pricing.

Fill rate in capacity planning:

This has been successfully implemented at Forwarder2, by reviewing the fill rate history of different lanes and adjusting the capacity for the future, accordingly. In order to do this, fill rate is monitored regularly. If fill rate is between 0-800 kg/loading meter, then decreasing the capacity for upcoming periods is considered. If fill rate is between 800-1200 kg/loading meter, no changes in capacity is desired. For fill rate above 1200 kg/loading meter, then it would be logical to increase the capacity. It must be mentioned that another KPI plays an important role in such situations, and it is the amount of goods which is left at the terminal after the truck leaves the terminal. For example, having a high fill rate and at the same time high amount of goods left in the terminal might be a clear sign of capacity shortage. Forwarder2 usually books a fixed capacity from hauliers with taking the historical demand fluctuation trend such as seasonal fluctuation, into account. Then there will be a continuous negotiation with hauliers to decrease or increase the booked capacity according to the real amount of goods available to be transported.

Fill rate in calculating emissions:

At Forwarder2, fill rate is used when the amount of emissions are calculated for each journey. The basic idea is that the amount of emissions for transporting a certain amount of goods can be calculated, by knowing the truck specification, fill rate, distance and so on. At the end Forwarder2 can tell the customer that how much his/her consignment, e.g. a certain parcel, is contributed in producing the total emissions.

5.6 Strategies for increasing fill rate

At Forwarder2 recently a responsible person is assigned in terminals for making sure that trucks are full enough, and if they are not, he/she is supposed to start actions such as reducing capacity. Training employees, especially forklift drivers, is another way that is helping to increase fill rate. Forwarder2 has also invested in trucks with double floors which give better opportunities to utilize the available space.

Despite the fact that Forwarder1 has a very close relation with hauliers, still it was emphasized that even more cooperative relationship would increase the chance of reaching to higher fill rate levels. Since Forwarder1 is using a decentralization strategy and regional branches are more or less independent, it would have helped to gain a higher efficiency regarding the entire Forwarder1's system if some of the decisions could have been taken centrally. It was also highlighted that flexibility is rather low in Forwarder1 due to the specific existed business model, which only allows Forwarder1 to work with one haulier in a given lane and subcontractors, in return, have to work exclusively for Forwarder1. It might reduce the possibility of utilizing the available capacity.

The scholars emphasized on information as the most important factor which can lead to higher levels of fill rate. if the transport company has the right information as early as possible, the possibility of better planning for increasing efficiency and resource utilization will increase remarkably. Transport companies need to put more effort into consolidation by better planning, getting more consignments, and adjusting the capacity to the demand. Taking the resource utilization considerations into account in the stage of product and packaging design, might help to better fit the consignment into the truck space and consequently increase the vehicle utilization.

5.7 Summarizing the empirical findings:

To make it simpler for the reader, the empirical findings are summarized in the Table 6. It is done by highlighting some key questions and the received answers from the corresponding interviewee.

Table 6: Summarized empirical findings

Question \ Interviewee	Researcher Consultant	Researcher	Forwarder1	Forwarder2
Is fill rate measured?	No, economic utilization is more concerned	No, economic utilization is more concerned	Yes	Yes
How frequent?	-----	-----	When it is needed	Regularly
Fill rate parameter	Weight (kg)	Weight (kg)	Weight (kg)	Kg/loading meter
Reason for using that specific unit	- Measuring weight is easier - Everything is based on weight	- Measuring weight is easier - Everything is based on weight	- They charge customers based on weight - Measuring weight is easier	- Required data exists - Volume is somehow incorporated by considering chargeable weight - Legislation is based on weight
Measuring approach	Top-down	-----	Sampling	Top-down
Type of data	Chargeable weight	Chargeable weight	Chargeable weight	Chargeable weight
Application of fill rate	-----	-----	- Capacity planning - Calculating emissions - To get the permission for driving in bus lanes (Gothenburg)	- Efficiency measure - Pricing - Capacity planning - Calculating emissions
Strategies to improve fill rate	- Get right information as early as possible - Training - Product and packaging design	- Get right information as early as possible - Consolidation - Get more volume - Decreasing frequency	- More cooperation with hauliers - Centralization - Flexibility	- Training - Using trucks with double floors - Adjusting the capacity

6 Analysis

In this chapter, the analysis which has been done based on theoretical framework and empirical findings, is presented. Thus it has been tried to connect empirical findings to the concepts introduced in the theoretical framework.

6.1 Perception of fill rate:

It might be perceived from the empirical findings that transport companies are not always interested in fill rate, which to some extent is true, as the economic resource utilization has higher priority in the transport business. Although, it does not mean that companies do not care about how full their trucks are, but it means that fill rate is not usually treated in a systematic matter. Transport companies have a common sense that the fuller the trucks, the better for economic situation of the company, but having a method to measure it, control it, and set targets for improvement needs a well-defined system that is the basis of these operations. Thus, in the analysis about perception of fill rate two subjects are discussed. First, it is discussed that who should be responsible for or interested in fill rate. Second, it is discussed that what fill rate implies about transport efficiency and if it can be a stand-alone KPI.

One interesting topic is that who should be interested in fill rate. This question arises because in freight transportation, usually more than one actor are involved, then the question can be answered by looking at the company's business model and its cost and revenue structure. The relation between fill rate and company's business model is discussed in detail in section 6.5. It also discussed earlier in section 4.5.1 that economic resource utilization is usually more interesting for transport companies than physical resource utilization. Thus if a company involved in freight transport gains a certain level of the economic resource utilization then it might not be interesting for the company to increase its efficiency by focusing more on physical resource utilization. Thus the degree of importance of fill rate in a company is to great extent related to this.

To simplify the discussion, it is assumed that in the freight transport there are three actors. The haulier that owns the vehicles, the transport company that rents vehicles from the haulier, and the customer that owns the flow or the freight. Thus transport companies are actually middlemen between customers and hauliers. Transport companies, in general, buy traffic work (measured in vehicle-km) from hauliers and sell transport work (measured in ton-km) to customers.

To see how important the fill rate can be for one actor, it must be analyzed that by changing the amount of fill rate how the cost or revenue is changed for a specific actor. Another point is that if the company in focus is aware of this influence of fill rate on the cost or revenue. The last point that should be addressed is that which actor has the ability to increase fill rate in practice in a way that gives some benefits to the actor. All these aspects might vary from case to case but here it is tried to generalize them as much as possible.

The haulier as sells traffic work is naturally interested in economic fill rate and does not care if the vehicle is full or not, as long as his economic interests are fulfilled. The transport company buys traffic work, which simply can be said that buys some amount of vehicle capacity as a whole, and tries to fill it by selling it in smaller portions to individual customers. Customer just buys the transport service and put some requirement such as the time and place of delivery and does not care about how it is actually handled.

With this explanation of roles, assuming that the transportation price is unchanging, if fill rate increases, the transport company is the first actor that gets benefits out of it. On the other hand, if fill rate decreases, the transport company suffers first, as the operational costs will be increased. Thus, it can be concluded that the transport company is the one that is responsible for fill rate and must be interested in increasing it. Another way to justify it can be done by Equation 14. It means that the aim is to maximize the Ton-km per vehicle-km, which consequently makes the transportation efficient, because more transport work can be done by less number of vehicles. Vehicle-km and ton-km are independent but fill rate connects them together, since maximizing that equation can be done by increasing fill rate. The actor in the transportation chain that owns this equation is responsible or seems to be interested in fill rate.

$$\left[\frac{Ton - km}{Vehicle - km}\right]_{Max}$$

Equation 14

According to the actors' role, the transport company is the one who buys vehicle-km and sells ton-km, thus it is the company that by maximizing the equation can achieve higher profits. Hence, in this case it is the transport company that is responsible for fill rate.

This explanation of responsible actor for fill rate might not be true if the roles are not according to the assumed case. For example in the case of Forwarder1, they are not buying vehicle-km from the haulier, but ton-km. Then it seems that it is the haulier that owns the Equation 14. But in reality, it is both Forwarder1 and the haulier that get benefit of maximizing the Equation 14. Then it would be logical to assume both of them should be responsible for fill rate. The second point that discussed earlier was that if the companies are aware of their responsibilities about fill rate. Forwarder1's case shows that at least Forwarder1 is not aware of that, maybe due to the fact that Equation 14 at the first glimpse indicates the haulier as the responsible one. Then the third point, that was which actor has the ability of improving fill rate, will arise. In theory most of the actors can influence fill rate. Even customers with their ordering pattern can impact the ability of increasing fill rate for the transport company. Referring to the Forwarder1's case, haulier does not have many options for improving fill rate, except by choosing the smaller vehicle and loading as much freight as possible into the truck. When it comes to consolidation, it is Forwarder1 that plans for it not the haulier; therefore Forwarder1 must be responsible for fill rate as well.

It must be mentioned that fill rate as an efficiency measure might lead to wrong conclusion about efficiency if it is used just alone by itself. It usually occurs in macro level when government wants to indicate the transport efficiency and refers to fill rate as the KPI of transport efficiency. In a company level, a truck can be 100% full and still inefficient, due to for example, poor route planning. It means that other parameters must be taken into account to get the full picture of transport efficiency. This has been proven by Samuelsson *et al.* (2002) and Lumsden (2007) by considering time, speed, and distance efficiency, besides capacity efficiency (see Equation 3 and Equation 4). In other words, it is the system efficiency that should be tried to improve, not only capacity efficiency.

It is also true in a macro level, which needs fill rate to be considered even more carefully. Fill rate, for example, can be very high, but still having a high level of congestion, due to using lots of small trucks instead of using fewer but bigger trucks. Therefore, it might be necessary to use fill rate along with other measures depending on the purpose of each case. It also should be considered by governments that fill rate cannot technically be 100%, especially due to imbalances in flow of goods. For example, a truck carrying timber is usually designed exclusively for carrying timbers, thus it can be naturally predicted that it would be empty on return journey. However, regardless of this technical problem, there would not be many customers on the origin, thus not enough demand for carrying goods to there. Another point is that in a national scale, if a company improves its fill rate by attracting more customers, the fill rate of its competitor which used to have those customers will drop. It means that in total no changes in fill rate will occur. All these considerations imply that fill rate might do more harm than good if it is not understood well and it is not well-defined that how and for what purpose it is going to be used for.

6.2 Application of fill rate:

As mentioned in previous section, one consideration about fill rate is that it should be designed carefully according to its application. In a transport company, fill rate can be used for number of purposes, such as measuring efficiency, pricing, capacity planning, following regulations, and calculating emissions, as were observed in empirical findings (see section 5.5). Besides, in the section 4.6.2, two contexts were defined for the usage of fill rate, efficiency context and environmental context. In the following section, each of the observed application types of fill rate in the transport industry is discussed by relating them to the defined contexts.

6.2.1 Fill rate applications in the efficiency context:

From the efficiency perspective, the aim is to decrease the costs and improve the profitability of the company. In the data collection process, three kinds of application for fill rate were observed that can be put under the umbrella of efficiency context. These applications are fill rate as an efficiency measure, in pricing, and in capacity planning.

Fill rate as an efficiency measure:

Fill rate can be used as an efficiency indicator which shows how well the vehicles are used in transportation activities. It can show the current situation of freight transport activities regarding how well they are performing. It does not only indicate the efficiency of loading operations, but also planning and consolidation operations. Thus it can help to understand and identify the necessary improvements. Consequently, a level of fill rate can be defined as the target for improvement. These specifications of fill rate are in compliance with the characteristics mentioned for a well-defined measure by Franceschini *et al.* (2007) in section 4.2.

Fill rate in pricing:

Since there is a direct relation between cost and the price, fill rate can be used for calculating costs and through that for the price. One direct influence of fill rate on the price is for bulky freight, as discussed by Lumsden (2009) and Noonan *et al.* (2006), which is mentioned in section 4.6.3. Considering the fact that transport companies are using weight for pricing, if the consignment is occupying a large part of the capacity but the weight is not accordingly high, then the chargeable weight is used for pricing. The optimal density defined by the companies varies among different companies and also for different products in a single company. Nevertheless, chargeable weight is a concept that is used by all the transport companies to be assured that their operations are profitable.

This application might be more tangible when the customer is a big company with frequent and large amount of shipments. Since the customer is buying ton-km from the transport service provider, if the consignment has a minimum level of filling rate, then a lower price can be quoted by the transport company.

Fill rate in capacity planning:

This application can be explained by the following example. Assuming that a bus is travelling between several stops in a city, if there are lots of standing passengers, then either the bus is not big enough or it is not travelling frequent enough. Therefore, the action can be to assign a bigger bus or plan a more frequent schedule for the bus. On the other hand, if many of the bus seats are unoccupied, then it can be concluded that either the bus is too big or it is travelling too frequent. In this case the capacity can be adjusted by assigning a smaller bus or making the bus travels less frequent. This example shows that how the capacity can be calibrated according to the level of fill rate in which somehow shows the actual demand. Although this example was for passenger transport but the basic idea can be expanded to freight transport as well.

Obviously, if the capacity is higher than the demand, fill rate will be low, thus the costs will be high. Adjusting the capacity to the demand is a very important factor for the company's profitability. Here, fill rate plays an essential role by indicating whether the capacity coincides with the demand or not. As mentioned in the empirical findings Forwarder2 is a good sample of implementing this application of fill rate.

6.2.2 Fill rate applications in environmental context:

As discussed in the section 4.6.2, fill rate can be used in the environmental context. The aim is that by increasing fill rate, the number of vehicles can be reduced, thus less negative environmental impacts will be produced. Two types of fill rate applications mentioned in the empirical findings can be put under this category, which are for calculating emissions and following the regulations.

Fill rate in calculating emissions:

The basic idea is to consider filling rate in the emission calculation in a way that shows how much goods are transported in which incurred a specific level of emissions. It means that the environmental performance of a truck would be better if its available capacity is being used more, or in other words more goods are carried by the truck. As it has been shown in the Equation 6, there is a direct relation between fill rate and the fuel consumption. Since the emissions are the result of burning fuels in the truck engine, consequently the amount of emissions will relate to the filling rate.

Both interviewed companies are using this concept when calculating emissions. They report to the customer that how much of the total emissions of a given transportation belong to the customer's consignment. It is calculated in relation to the contribution of the given consignment in the total cargo transported by the truck, and then the extent to which the total cargo occupies the available capacity of the truck. By communicating the level of emissions with the customers, they might change their ordering pattern in a way that helps to reduce their emissions footprint.

Fill rate in following regulations:

If there are any rules or regulations for fill rate, it can be said the reason behind their existence is due to environmental issues. Government and policy makers may set some regulations regarding fill rate in order to decrease negative impacts of transportations, such as emissions and congestion. One example of such regulations was observed for one of the interviewed companies which needs to prove to the authorities that they have a certain level of fill rate to be allowed to drive in bus lanes in Gothenburg city.

No regulations were found in national or regional level for filling rate but it is possible to have such regulations in the future, as the environmental issues of transportation is in focus by policy makers. Currently, there are other rules which do not directly set limitations on the filling rate levels, but have been stated to help increasing fill rate. An example of this kind of rules is cabotage in EU (European Environment Agency, 2010), which is mentioned in the section 4.6.2.

6.3 Measuring fill rate:

As discussed in section 4.6.4, some ways for measuring fill rate are mentioned in the literature. What was observed from interviews was that most of the companies are using weight-based measure to determine the fill rate, which is supporting what claimed by McKinnon & Leonardi (2008). Forwarder1 is measuring fill rate based on weight, once a while, just to show that they have a higher fill rate than the minimum level which by regulation allows them to drive in bus lanes, and Forwarder2 uses kg/loading meter as the fill rate measure.

This diversity in how companies are dealing with fill rate refers to their perception and awareness of the fill rate concept. So first a specific company must have a clear understanding about fill rate and then the decision about monitoring it can be taken. In this stage, the question about what should be measured as an indicator for fill rate should be answered. Here, it might be weight, volume, etc, that is chosen. Then, it must be clearly defined that how it should be measured. At the end, it must be clear what the measured indicator is really implying.

When it comes to what should be measured, some considerations must be taken into account. Every individual method of measuring has its advantages and drawbacks. In special situations, only some of them might be applicable. In the Table 7 the advantages and disadvantages of using each of the available measures for fill rate are presented. Since the kg/loading meter measure is more or less like weight-based fill rate, and deck-area is not much used in practice, they have been excluded from the analysis.

Table 7: Advantages and drawbacks of different fill rate measures

Fill rate based on	Advantages	Drawbacks
Ton-km	- Easy to measure - Can be used for all kind of cargo - Some historical data might be available - Compatible with pricing system	- Needs measurement equipment - Fill rate might be influenced by distance - Does not provide a reliable data if the cargo is bulky - Chargeable weight might be considered instead of actual weight
Weight	- Easy to measure - Can be used for all kind of cargo - Some historical data might be available - Compatible with pricing system - Compatible with regulated restrictions	- Needs measurement equipment - Does not provide a reliable data if the cargo is bulky - Depends on the vehicle specification (weight and size) - Chargeable weight might be considered instead of actual weight - Time-consuming
Volume	- Can be used for all kind of cargo - Consistent with the average density of goods	- Difficult to measure - Might need tools - Does not provide a reliable data if the cargo is too dense - Depends on vehicle sizes - Time-consuming
Number of pallets	- Easy to measure - Takes less time for measurement compared to others	- Not applicable for ununitized cargo - Highly dependent on stackability and stowability

As discussed by Lichiello (1999), which is mentioned in section 4.2, a well-defined measure must have some attributes to be effective. These attributes are validity, reliability, functionality, credibility, understandability, availability, and abuse-proof. Characteristics of each fill rate measure regarding these attributes are shown in Table 8. It can be seen that fill rat measurement based on number of pallets gets the highest score, and based on ton-km the lowest score. Since number of pallets cannot be used for measuring fill rate of non-utilized goods, it seems that using weight-based measurement is inevitable.

Table 8: Characteristics of fill rate measures

	Ton-km	Weight	Volume	No. of pallets
Validity	Moderate	High	High	High
Reliability	Moderate	Moderate	Moderate	High
Functionality	Moderate	Moderate	High	High
Credibility	Low	High	Low	High
Understandability	Moderate	High	High	High
Availability	High	High	Low	High
Abuse-proof	Moderate	Moderate	Moderate	Moderate

To see how measuring fill rate of a vehicle based on weight and volume can give totally different numbers, the following example can be helpful. Assuming that there is a semitrailer with the normal dimensions, which is carrying freight with the characteristics of sand or cereal in which that can be shaped as the container's shape. This assumption is due to prevent creating unoccupied space of the trailer because of the shape of freight. According to NTM (2008), the trailer has maximum 26 tons of weight capacity and 92 m^3 of volume capacity (see Figure 14). In practice, the actual weight and volume capacity can be calculated considering the real dimensions of the truck and trailer, in regard with the maximum weight and dimensions allowed by regulations.

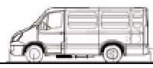
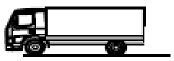
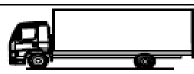
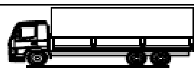
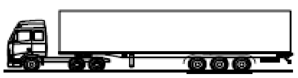
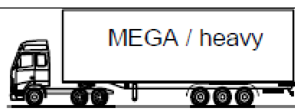
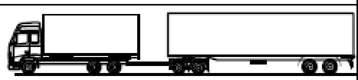
No	Illustration	Nomenclature	Max **weight**[1]	Vehicle **length** (approx.)	**Cargo capacity** (typical values, inner dimensions)				
			[tonne]	[m]	[tonne]	pallets	[m]	[m3]	TEU
1	(no picture)	(LCV) Pick-up	< 2,5	5	0,6	1	1,8	3 - 6	0
2		(LCV) Van	< 3,5	7	1,5	3 - 5	3 - 4	10	0
3		(MDV) Light lorry/truck	3,5–7	8	5	14	4 - 6	35	0
4		(MDV) Medium lorry/truck	7-18	12	7	24	7,7	44	0
5		(MDV) Heavy lorry/truck	16–26	12	15	24	7,7	44	1
6		(HDV) Tractor + 'city-trailer'	16 - 26	12 - 15	15 - 16,5	20-28	8 - 12	50-64	1
7		(HDV) Lorry/truck + trailer	≤ 40	18,75	22	36	7,75 + 7,75	104	2
8		(HDV) Tractor + semi-trailer	≤ 40	16,5	26	33	13,6	92	2
9		(HDV) Tractor + MEGA-trailer	40 ≤ 50	16,5	33	33	13,6	110	2
10		(HDV) Lorry/truck + trailer or semi-trailer on dolly	≤ 60	24 - 25,25	40	51	7,7 + 13,5	140	3

Figure 14: Vehicle types and cargo capacity (NTM, 2008)

Using Equation 12, the optimal density will be:

$$\rho_{opt} = \frac{\bar{M}}{\bar{V}} = \frac{26}{92} = 0.28\ ton/m^3$$

This is the density in which the cargo with this density will completely fill the truck both regarding weight and volume, thus the weight and volume capacity utilization would be 100%. If the density of cargo is higher than 0.28, a 26 tons freight will reach the maximum weight capacity, while the volume capacity will be partly full. In the Table 9 the utilization of volume capacity for different amounts of density is calculated. It must be noted that the weight capacity utilization would be always 100%.

Table 9: Utilized volume capacity for cargo density of more than 0.28 ton/m³

density (ton/m³)	weight (ton)	volume (m³)	% of utilized volume capacity
0.28	26	92.00	100%
0.31	26	84.52	92%
0.33	26	78.17	85%
0.36	26	72.71	79%
0.38	26	67.95	74%
0.41	26	63.79	69%
0.43	26	60.10	65%
0.46	26	56.82	62%

On the other hand, if the density is lower than 0.28 ton/m³, then volume will be the constraint in capacity utilization. It means the freight with the volume of 92 m³, just partially utilize the weight capacity, depending on the density of the cargo, although the volume capacity utilization would be always 100%. The weight capacity utilization for different amounts of density is shown in the Table 10.

Table 10: Utilized weight capacity for cargo density of less than 0.28 ton/m³

density (ton/m³)	volume (m³)	weight (ton)	% of utilized weight capacity
0.11	92.00	9.90	38%
0.13	92.00	12.20	47%
0.16	92.00	14.50	56%
0.18	92.00	16.80	65%
0.21	92.00	19.10	73%
0.23	92.00	21.40	82%
0.26	92.00	23.70	91%
0.28	92.00	26.00	100%

Combining all the data in the Table 9 and Table 10 will give a better view of the situation, which is shown in the Table 11.

Table 11: The level of weight and volume capacity utilization for different amount of density

Density (ton/m³)	% of utilized weight capacity	% of utilized volume capacity
0.11	38%	100%
0.13	47%	100%
0.16	56%	100%
0.18	65%	100%
0.21	73%	100%
0.23	82%	100%
0.26	91%	100%
0.28	100%	100%
0.31	100%	92%
0.33	100%	85%
0.36	100%	79%
0.38	100%	74%
0.41	100%	69%
0.43	100%	65%
0.46	100%	62%

The corresponding graph of Table 11, shows how weight and volume utilization are falling apart from each other, except for the density of 0.28 ton/m³. The two graphs are completely divergent, but the interesting point is that the weight utilization would have worse situation compared to volume by density changes (see Figure 15). It also can be seen that AB is a straight line, while BC is a curve. That can be a reason why with the same amount of variation from B, the utilization would be less for weight compared to volume.

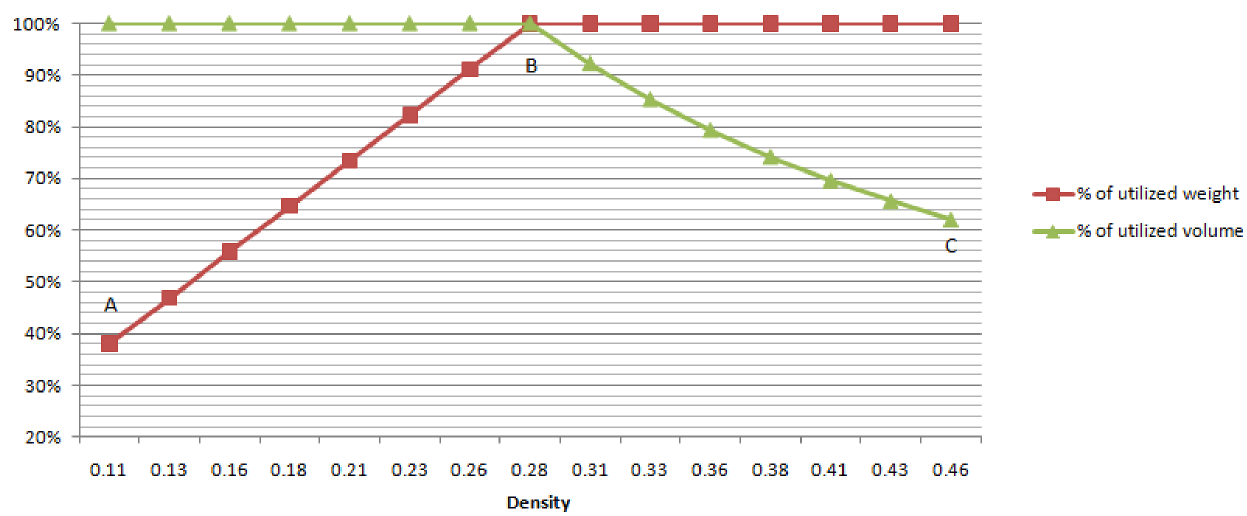


Figure 15: Weight and volume capacity utilization for different amounts of density

It shows that why transport companies have to consider bulky cargo not only by weight but also a further charge to compensate for the corresponding weight that could have been charged if the cargo would not have been bulky, as discussed in section 4.6.3.

When a company selects one of the measures as fill rate indicator, considering all the aspects mentioned about the characteristics of each measure, then it should be clearly defined how the actual measurement should be performed. Here the decisions about approaches for practical measuring should be taken. For example, if weight is selected as the fill rate measure, it should be decided if top-down approach is applied instead of measuring every single truck and then calculating the average for a given period. It must be clarified whether the provided data by customers are going to be used or the transport company must weigh the consignment by itself. Also the chargeable weight should be used or the actual weight of the consignment. The measurement approach for different services must also be defined properly, as for pickup-distribution and long haul.

The last step is to notice what the measured fill rate implies. Lots of considerations must be taken when interpreting the numbers. Some of these considerations were mentioned in section 6.1, when talking about perception of fill rate. For example, it should be considered that fill rate does not show the system efficiency of transport operations. When the data is based on customer declaration, or the chargeable weight is used, then the reliability of data must be questioned. Obviously, when chargeable weight is used as the basic data, then the weight-based fill rate measure should not be interpreted as a number that shows the actual vehicle utilization of weight capacity. Or when weight is used as the measure, and the consignments are not homogeneous, then it should be noted that the measure cannot be valid for evaluating the utilization of volume capacity.

6.4 How to increase fill rate:

Obviously increasing fill rate is among the major goals in logistics operation, and transportation companies tend to use their maximum capacity as much as they can. As it is stated in the theoretical part of this study, there are different ways to increase fill rate suggested by researchers (McKinnon *et al.* (2003), Baumgartner *et al.* (2008), Pan *et al.* (2009), Morabito *et al.* (2000), and Jordan (2011)).

Their suggestions for increasing fill rate can be categorized in three major groups, as described in the following sections:

6.4.1 Increasing the degree of load consolidation:

McKinnon et al. (2003) believes that by increasing the load consolidation, we can reach to higher degree of vehicle utilization. In the logistics operation, companies need to get more volume to be able to increase vehicle fill rate. This consolidation can take place in terminals owned by logistics companies or their partner companies. According to scholar interviewee of this study the more goods the company gets, the better will be the consolidation. Because the transporter has more ability to fill the truck for final destination and also more ability to stack goods in appropriate way to use all space of capacity.

According to Baumgartner *et al.* (2008) computerized route planning and vehicle telematics offer a great potential to improve loading factor, and consequently the environmental performance of the freight transport. Obviously if transport operators have more data on arrival goods and different parts of destination delivery, they can consolidate goods in a more efficient way, further they can use the vehicle in the way back by picking up goods in other areas close to their destination. Using the computerized route planning also leads to less truck running by finding the best way for picking up goods and closest way for running to destination.

However, in the interview by transport companies, it became clear that many logistics companies even the large one like Forwarder1 do not use computerized routing. The route planning is performed usually manually and in less frequent manner. For instance in Forwarder1 they have route planning once or twice a year, using meeting and brain storming with company's specialists and their hauliers partners. The main reason for not using software for routing is huge investment in installing and performing of program.

The other ways for increasing consolidation as introduced by McKinnon (2010b) are "the adoption of more transport-efficient order cycles". One example could be offering different transport services based on delivery time and frequency, like express delivery or usual delivery. The first method is also mentioned by Jordan (2011) as reducing the frequency of deliveries to the minimum number possible by rescheduling, thus it will result in larger freights being carried by each vehicle and waste from unused space will be reduced.

According to the interviewees, logistics operators' first priority is customer satisfaction and delivery performance. Therefore, being on time and availability in offering service is fundamental in logistics business. The operators could not postpone the delivery time in order to get more goods for consolidation, even if it leads to more efficient operation. High competition in the market and increasing the need for fast and on-time transportation, lead transport companies to focus on offering more frequent and appropriate services. However, customers may be willing to wait or postpone their delivery time, if the operators charge them with fewer prices. Therefore, operators can offer fewer prices to encourage customers for waiting and there would be more opportunity for more efficient consolidation. In some companies this method is used by introducing different services as more frequent (fast) with high price, and less frequent with lower price. This kind of service is more used in postal companies and parcel transport operators. It is also usual in practice that operators postpone the delivery by negotiation with customers and offering less charge for their service, which is more common with larger customers and long term partners.

Specially in case of structural imbalance in transportation due to an uneven transport demand in a two-directional transport relationship as mentioned in section 4.5, consolidation of goods can play a fundamental role. Imbalance in transport creates low fill rate, thus consolidation and decreasing the frequency of transport can improve fill rate. For instance, many trucks go to Stockholm from Gothenburg, but some of them would not be full in the way back. Because Gothenburg is a production node and Stockholm is a consumption node. Therefore, if transport operator could decrease transport frequency and increase the consolidation in this route, number of trucks that go to Stockholm would be less and thus number of empty trucks turn back to Goteborg will be less.

On the other hand, the barrier against performing consolidation is lack of information in the early step of decision making. According to experts at Forwarder1 and Forwarder2, the information about weight, volume and destination of goods that is given by customers is not on time and accurate. For instance, the dimension of goods reported by customers is not what it actually is and staff in terminal has to measure them again, or there are rescheduling in time and size of carrying goods by customers.

Other issue in information is related to information sharing within the company. The operator needs to have accurate and on time data of available goods in its terminals and distribution centers, in order to plan appropriate routing and consolidation. According to Forwarder1, the decision making is more decentralized and information between different regions is not shared in a systematic way. Therefore, the need for centralized IT application within organization is obvious, to get data as early as possible.

Another barrier for companies that outsource their transport operation to their hauliers like Forwarder1 is the flexibility in selection of hauliers to transport in a specific lane. Forwarder1 has the agreement with hauliers to operate in a certain lane thus if the truck is not full, the halulier could not go to other lane for consolidation and fill the truck. Therefore it would be an issue for better resource utilization and increasing filling rate.

6.4.2 Change packaging and sorting of goods

One of the methods for increasing consolidation and using the maximum capacity of vehicle is increasing the stackablity of consignment. Changing the packaging and pallet-wrapping systems, in order to use as much as available capacity, are mentioned by McKinnon *et al.* (2003). Jordan (2011) also believes that by reorganizing the way in which the cargo is boxed/packed, the space can be maximized. Thus superfluous packing materials should be eliminated to increase the number of items can be fitted into the vehicle.

The capacity utilization can be increased, if consignments that are composing the load are geometrically compatible to put in one package, and stacked on each other. Some non-palletized goods, such as furniture, that are difficult to handle and stack on other goods, can be sorted and put in standard packages and then place these packages on the truck to use maximum available capacity.

Changing the packaging in the terminals of logistics operators is another solution to make them in more standard shape for handling and stacking in the truck. Many packages are not in standard dimensions to fit pallet size or make it difficult to be stacked in the truck. In these cases changing the package would affect capacity utilization besides protecting goods form damages during handling and stacking in the truck.

But the issue here is the time and cost for operation in changing and wrapping the package, handling and transporting them and again re-wrapping them in final destination. Transporters need to have lots of information about each individual package and its composed goods, but even it is not nearly enough. Optimizing can be very complicated for example which goods are the best suited to be put together for loading or stackability. The operator needs to have information, but then there is the mathematical issue, when trying to optimize the loading and capacity utilization.

The companies that have been interviewed in this study (Forwarder1, Forwarder2), had separate services and operations for palletized goods and non-palletized consignments. For instance Forwarder2 has different operation in these two categories and Forwarder1 act only on palletized goods and the goods that can be placed in containers. According to the scholar interviewee adaptation in packaging size, pallet size, and container could have huge effect on transport efficiency, however it is more appropriate in long term relationship with larger customers. As their resources are more adapted to each other, they can reduce more costs.

To increase fill rate volume and area cannot be exceeded, but weight can. Normally the operator fills up the area first as much as possible and then fills up volume and at last weight. For trucking companies weight barrier is not a big issue because they hit volume and area barrier first. Especially in parcels and palletized goods the volume limitation is more tangible, so it is necessary that load the vehicle in a way that allows for more freight to be carried per trip and maximize every last inch of space. As mentioned in section 4.6.7 if the vehicle loading started from the largest pieces to the smallest ones, the amount of weight being carried can be increased. Other suggestion would be composing heavy goods with light goods in one truck to reach the optimal point in maximizing volume and weight capacity.

6.4.3 Changing in vehicle and handling equipment:

One of the effective ways to increase fill rate is making change in vehicle, handling equipment and product itself. As mentioned in section 4.6.7 of theoretical part of study, these changes can be as follow:

1. Modifying the design and dimensions of handling equipments. This equipment could be the pallet that products are stacked on it, rolling rack or shelf that is more common in dairy products, or other kinds of containers like baskets.
By modifying and adapting the handling equipment with the size and dimensions of carrier, the maximum use of capacity would be achieved. To shed more light on it, Gadde & Håkansson (2001) discussed a case about how changing the dimension of rolling rack increases the efficiency and resource utilization of logistics. Rolling rack is moveable shelves that used for dairy products at supermarkets; it can be moved to the truck without loading and unloading of products. By adapting the size of products with rolling rack and dimensions of the truck, more resource utilization and less transportation have been achieved. However, making these adaptations cost for the companies and increase dependency between operator and customer, and demands for long term and partnership relationship between these two parties.
2. Make greater use of double-deck vehicles that can accommodate two layers of pallets/roll cages. As mentioned by McKinnon (2010a) vehicle utilization is usually limited more by the available deck-area than by the volume capacity, where the height to which products can be stacked is tightly constrained. In case of increasing volume in the truck, when there is not weight limitation, double-deck vehicle would be effective. By putting a surface layer in the carrier part, one can increase the surface area by two times. It also could be useful when goods could not stack on each other due to products characteristics (such as their weight, or shape).
3. Reduce the carrying capacity of the vehicle in order to match it to the typical size and weight of loads could increase filling rate. Reducing the vehicle height is helping in this regard. According to

scholar interviewee, if the goal is to maximize weight utilization then the transporter could use trailer with lower empty weight then more load can be carried on. At Forwarder1, one way for improving fill rate is choosing the suitable vehicle in size and dimension that could carry the goods with higher capacity utilization. The hauliers use different size of vehicles at Forwarder1 terminals, according to volume and weight of consignment but this adaptation is not a systematic method and usually is performed by practical people at terminals.

6.5 Relation with company's business model:

One of the factors that influence filling rate is the company's business model. The way that transport operator perform its activities, their relation with customers and other parties involved, and the way company do the business and make money, to a large degree affect filling rate measurement and efficiency improvement. Logistics companies offer their services in three different approaches:

- The company performs transportation activities by its own trucks and drivers, like hauliers.
- They act as an intermediary between customers and hauliers. The company usually owns terminals and does the terminal activities by its own personnel, but outsources transportation work to hauliers. Mostly large transport operators like Forwarder2 and Forwarder1 work within this category. However, there are some minor differences between their operations. These differences consist of ownership of terminals, performance of logistics operation within terminals, and their relationship with subcontractors and hauliers.
- The company acts as a TPL, buying transport services form logistics operators and selling it to customers. They buy transport services from large operators like Forwarder2 and sell it to their own customers.

Depending on whether the company is buying traffic work or transport work, the fill rate could have different view and level of importance for the company and its customers. For instance, when the customers need to transport home furniture to a new place, and rent a truck depending on working hours, the customer tries to increase fill rate as much as possible. In this case the customer is buying the traffic work. On the other hand, when the customer is paying to the company to transport specific amount of goods from location A to B, increasing fill rate is not interesting for customer but for transport operator. In this case the customer is buying transport work.

Buying traffic work or transport work modifies the relation between transport companies and their subcontractors. When the transport company buys transport work from hauliers, it is not interested in measuring and increasing fill rate and it is the haulier that is usually interested in filling rate improvement. If the company buys traffic work from hauliers, it tends to fill the truck as much as possible, and decrease transport charge by reducing number of used vehicles.

Another factor that is related to business model of the company is the company's priority between service and cost. There is a direct relationship between capital, cost, and service from company's perspective. By increasing capital like ownership of terminals, trucks and other resources, the costs will increase and company will be able to offer better services to its customers. When the transport company owns more trucks than it is usually needed, it can increase the transport frequency and customers will get better service, however, it has more capital costs and variable costs for the company.

In most transport companies the first priority is customer satisfaction and improving services to the customers. It is due to market condition and high competition between transport operators to offer fast, reliable and affordable transport services. Reduction of costs is important as long as it does not affect company's services and does not lead to lose market share. Looking into filling rate improvement in this vision, would be an interesting topic for companies, when it does not influence their services. For instance, if the transport company reduces transport frequency in order to increase vehicle filling rate, it may lead to lose some customers who need faster transport and this is not beneficial for the company. Companies try to make a balance between their costs and services, and tend to decrease their expenses without hurting their offered services.

In the following sections, the relation of business models of interviewed companies to filling rate concept is discussed.

6.5.1 Relation of Forwarder1 business model and fill rate

As discussed in section 5.1 the performance of logistics activities is shared between Forwarder1 and hauliers. All operations within the terminal like handling, sorting, and packaging of goods, are the responsibility of Forwarder1. Also route planning, time scheduling and determining the transport journey between cities and countries are performed by the company's specialists. Decisions about which haulier should take which customers' goods, and which trucks should go to the terminals for consolidation and how this consolidation is performed, are taken by Forwarder1. Therefore, the company can play fundamental role on filling rate and have great opportunity to increase the filling degree. On the other hand haulier has the power to influence fill rate to some degree. The haulier can decide on size of the vehicle, and by matching the size of goods and the capacity of the truck, can increase the fill rate. The haulier's driver is also responsible for loading the goods into the truck, and by appropriate stacking of goods and selection of optimal places for loading and unloading within the city can increase the fill rate.

In total, measurement of fill rate could be beneficial for both Forwarder1 and haulier, because by better utilization of capacity they can reduce the transport costs and get more market share in the business. Therefore, it is the responsibility of both to measure and increase the filling degree to achieve more benefit.

6.5.2 Relation of Forwarder2's Business model and fill rate:

Forwarder2 can influence filling rate to large extent. In parcels and pallets shipment, Forwarder2 receives money from customers and buys traffic work from hauliers, thus the company cares about increasing fill rate. All activities related to route planning and scheduling is performed by specialists at Forwarder2, and they have the opportunity to increase the filling degree by efficient consolidation of goods in the terminals and setting appropriate transport loop for loading and unloading consignments. Besides, all sorting, arranging, and packaging of goods take place at Forwarder2's terminals, and company's staff can increase the filling rate by accurate packaging of consignments, increasing stackability and sorting of goods for maximum capacity utilization. Also the company chooses size and kind of the hauleir's truck, and in this respect it can affect increasing fill rate by adapting capacity requirement with dimension of carriers.

The only part of shipments that Forwarder2 has less influence on its fill rate is full truck load in heavy products. In this kind of goods the company buys transport work and therefore it is the haulier that tends to fill the truck as much as possible. Forwarder2 pays the hauliers to transport certain amount of goods, in a schedule time frame from one customer to another, without passing through terminals. Therefore, number of used trucks and their utilized capacity are not interested by Forwarder2, but it would be important for hauleirs to use their truck as efficient as possible. In this case hauliers can impact capacity utilization by selecting appropriate truck size and efficient sorting of goods in the vehicle.

6.6 Relation with government policies:

By introducing new needs in transportation system due to changes in production and consumption systems, globalization, and increasing demand for fast, reliable and affordable transport; policy makers have paid special attention to transport efficiency. For instance, in Sweden, the government instructed the Transport Styrelsen, Trafikverket, & Trafik analys to propose action to increase fill rates of goods in different modes. According to report the by Transport Styrelsen, Trafikverket, & Trafik analys (2011) low filling rate increases transport costs, and it has negative effects on safety, environment and accessibility through increased congestion. Increase in filling rate leads to more sustainable resource utilization, and has impacts on society and economy, and demands for special consideration of people in authority.

In discussion of increasing fill rate, the infrastructure plays an important role. Capacity limitation due to infrastructure barriers, like roads condition, road safety, congestion, information sharing can impact filling rate, and the government by investing on new infrastructures and maintenance can affect resource utilization. The positive impact of investment in infrastructures must be weighed against the negative effect of inefficient freight. It is about involvement in environmental and climate impact, air pollution, noise and accident. Changes in infrastructures and the rules could overcome the issues for longer and heavier carriers, and it has a potential to increase fill rate and reduce number of vehicles to transport the same amount of goods. (Transport Styrelsen; Trafikverket; Trafik analys, 2011)

Other role of government could be on collaboration within and between countries. Many issues due to different rules among countries could be solved by collaboration and more centralized decision making. As many countries have different rules for dimensions and weights of the vehicles, transport across the borders would have some problems. This problem is less in EU, due to EU standard that allows trucks up to 18.75 meters and weight up to 40 tons to drive within member countries, with the exception of Finland and Sweden that are allowed to run vehicle up to 25.25 meters and 60 tones weight. (Transport Styrelsen; Trafikverket; Trafik analys, 2011)

Cabotage is another factor that can influence filling rate. Empty running on return journey is a major problem in transport efficiency, and the issue is more serious in longer distance especially between countries. Cabotage refers to domestic's transportation in a host state that is a state other than the one transporter is established. By cabotage the foreign carrier which is performing international road haulage can perform domestic transport in another EU country for certain period of time. The condition of cabotage is determined by negotiation between member countries and allows for more resource utilization among all members.

Research interviewees agreed upon that forcing the companies to improve their filling rate by increasing tax or other charges, is not useful because it causes an increase in transportation costs and finally the customers have to pay more price for transport services. However, government can have positive impact on increasing fill rate by removing the issues against better resource utilization. Issues like infrastructures restriction, size and weight limitation of vehicles, geographical diversity in rules and regulation, are some to mention. Furthermore, encouraging companies for investment in IT systems and vehicle telematics can have great impact on better resource utilization. This supporting can be through tax reduction policy for companies that invest in such capitals as well as paying loans and financial support for this kind of investment.

However, it should be noticed that filling rate is only an indicator and does not show transport efficiency by itself. To shed more light on it, Kalantari (2009) simulated a condition of sending trucks that are not 100% full to the hub instead of direct shipment. In this model all trucks that are not full are sending to hub for consolidation of shipments and becoming 100% full. At the end filling rate improved but traffic work would not changed, and trucks were driving around as much as before, therefore the transport efficiency did not change. Filling rate can be useful as a KPI if we use it with other transport efficiency measurement, and it would not be sufficient to use it alone. In this regard, if the government policy is to improve transport efficiency through better resource utilization, it is important to consider other KPIs as well.

7 Discussion

In this chapter, the general discussion about fill rate is presented. It is tried to explore areas which are not touched in analysis part, with having future improvements and developments in mind. Also some related areas for further research are introduced in this chapter.

Awareness raising about fill rate:

The knowledge about fill rate is very little compared to its importance. This subject just recently has absorbed the attention among scholars, and just a few number of transport companies are using it. This has led to a very little documented knowledge among scholars and practitioners. Many of the efforts done in this area, are dispersal and focusing on a limited scope. Moreover, the actors such as transport companies, hauliers, customers, government, etc., have their own perception and concerns about fill rate. Considering all these, no uniformity and consensus regarding fill rate can be seen.

Transportation activities are connected to each other as a network, regardless of company, national, and regional borders. They impact each other, to a great extent, which makes integration and cooperation inevitable. Fill rate in this manner needs a remarkable attention. All actors involved in a transportation chain needs to share their requirements and consideration to gain a consensus about fill rate. Training plays a great role in making first the company's personnel and second the partners aware of the importance of fill rate and existing ways of improving it.

Customers have a great influence on the fill rate, which is not emphasized enough. Transport service providers are performing according to the customer requirements, and if these requirements are in contrast with high utilization of vehicles, in most of the cases fill rate will be sacrificed. Thus there is a great potential for improvement if customers broaden their time requirements, use larger shipments, and provide accurate data earlier. This will increase the possibility of utilizing vehicles more efficiently by the transport company.

What should be measured?

Regarding the measure used for fill rate measurement, it can be said that no single measure seems to be appropriate in all situations. All the existing measures might be appropriate, as far as they are chosen carefully for the specific purpose, and what the measure implies is what it is actually designed for. Weight-based fill rate is the most common measure right now, although it has some drawbacks. However, other existing measures have drawbacks as well, making the weight-based one still a good choice among them. The only exception seems to be in the case of stackable pallets. Using number of pallets in such situations would be the best choice. This discussion directs us to the suggestion of using several measures instead of looking for a universal one which can be applicable in all situations. It can be arranged in a way that the density range of commodities is divided into three groups, too bulky, moderate, and too dense. For the commodity groups of too dense and moderate, weight and for the too bulky group volume can be used. Still it can be argued that this method might not give the correct picture of fill rate and comparisons might not give a valid answer. Another problem with this method would be to determine the border for too bulky and too dense groups, besides the problem of measuring volume of consignments with unusual shape. Another suggestion can be to use weight- and volume-based fill rate simultaneously, and refer to the one which is highr.

Fill rate shows to what extent the capacity is utilized, thus it seems to be reasonable that the same parameter which is being used as the capacity unit, should be used for fill rate measurement. In other words, it might be contradictory to measure the capacity with a parameter and the fill rate with another parameter. Therefore, it can be argued that defining a universal parameter for measuring vehicle capacity can help to ascertain it for filling rate too.

Economy of scale and cooperation:

Having access to sufficient amount of goods seems to be one of the most important issues for increasing filling rate, and there is a direct relationship between scales of available goods for transport and efficient capacity utilization in trucks. The more the transport company has goods for transport, the higher fill rate can be achieved, and in this regard larger transport companies can benefit from their economy of scales. Even more, the frequency of transport would increase when there are more goods available, and waiting time for consolidation of goods for the same destination would decrease. Having more goods on hand, makes consolidation of consignees easier and further brings more opportunity for increasing stackability in the truck, because terminal staff can sort consignments according to their dimension and fit the truck by matching available goods to available capacity.

Therefore, economy of scale seems to have great impact on increasing filling rate, and that would be an issue for smaller companies that have less resources and goods to be transported. Cooperation between smaller companies in transportation and merge in logistics operation seems to be helpful to overcome this issue. This cooperation could be in terms of having common transport organization that acts as an independent organization among member companies, or partnership between logistics departments of all companies involved. By this cooperation, economy of scale and better utilization of resources can be achieved. Besides, by resource combination of involved partners the efficiency of transport would increase as well as vehicles' filling rate. This resource combination can include using uniform packaging, pallets and handling equipments. Moreover, the same terminals with standard managerial system that leads to more centralized decision making process would be effective in increasing filling rate.

To be concluded, it must be emphasized again that there is a need for all parties to cooperate for improving fill rate. One actor can only improve it to a limited level. To reach to the potential efficiency it might even be necessary that competitors cooperate with each other.

Reliability of data:

The reliability of existing data for calculating weight-based fill rate can be criticized for two reasons. First, transport companies are usually using the data which is declared by customers, since they do not have enough resources to collect data by themselves. Second, chargeable weight is used instead of the actual weight of the consignment, when its density is lower than optimal density. All these make the data unreliable that might give incorrect conclusion when interpreting and analyzing fill rate. Thus, this problem needs to be solved for the future to get a valid picture of fill rate situation.

Role of IT and telematics:

The next issue for better resource utilization seems to be, having access to on-time and accurate data. These data could vary between information on received goods, destination of consignees, available capacity on hand, and amount of goods available at the terminals. Furthermore, having data about incoming goods, time delivery and all kind of rescheduling in transport operation, is essential for decision making and better utilization of resources. The most important factor in data collection would be its accuracy and on-time accessibility of data. Due to large amount of information in transport operation and diversity of locations in which transport activities are performed, having correct information when it is needed plays fundamental role in decision making process.

To overcome this issue, having centralized IT and telematics system seems to be necessary. This IT system can connect all transportation nodes for loading and unloading of goods like terminals and distribution centers, with central office for decision making process. Also equipping vehicles with telematics system and connecting them directly to centralized IT system, leads to have on-time and accurate data about available loading capacity, vehicle location and better route planning. However, access to accurate data would not be sufficient without systematic approach for analyzing data and using them in decision making process.

Logistics and transport planning could not be performed without information about different transportation nodes in different geographical locations, and running vehicles. By expanding the logistics operation even more in near future, due to globalization and longer distance between production and consumption areas, it seems to be necessary to use IT solutions for all planning and managerial processes.

Contribution of policy makers:

It seems that policy makers will enter to fill rate area in the future and will introduce some regulations due to environmental issues. In such a situation, it can be predicted this external force on involved parties in transportation will result in improvements in fill rate levels. Transport service providers are more interested in economic resource utilization rather than physical fill rate, thus other incentives are needed to encourage them to strive for achieving higher fill rates. At now, there is an opinion among transport companies that they are already trying their best in achieving high levels of fill rate and it cannot be increased remarkably. Of course the regulations must be designed in cooperation with all parties, to avoid putting impossible burdens on the shoulder of a particular party.

The other role of people in authority for improving fill rate in freight road transport is more cooperation within and between countries. Having more uniform rules for transportation, like weight and dimension of vehicles and loading units, driving rules, picking up and delivery rules between countries and so on would help transport companies to use their vehicle as efficient as possible and remove the barrier against cooperation between logistics companies in different countries.

As mentioned earlier IT can play fundamental role in increasing filling rate but huge investment and lack of financial resources seem to be the most important barriers against utilization of IT solution within the companies. Government can help companies to tackle these barriers, by helping them with different kinds of support. This can be in terms of financial support like paying loan for investment in IT systems or offering tax reduction for companies that invest in such a system. This kind of support by government indirectly affects increasing filling rate and resource utilization, as well as reduction in environmental emission which is one of the major concerns for policy makers in recent years.

7.1 Areas for further research:

Due to limitation in time and also the scope of this study, not all the related areas could be analyzed. Here some areas related to fill rate which might be interesting for future studies are introduced.

Full truck load vs. less than truck load:

One area that needs to be studied further is the relation of fill rate with different type of goods loads and transport services. It seems that fill rate is being influenced by having full truck load (FTL) and less than truck load (LTL), or by having pickup-delivery and long haul operations. Long haul transportation which is between terminals has normally higher levels of fill rate compared to pickup-delivery. Besides, fill rate is not constant in pickup-delivery, which makes the measurement complicated. FTL loads are directly shipped from the shipper to the receiver, which makes having empty running inevitable on the return journey. The border which is determined for defining FTL and LTL impacts the volume of each of these services. For example, if the current FTL limit is defined as a load of larger than 1000 kg and it is decided to increase it to 2000 kg, then less direct shipment (FTL) will occur but more pickup-delivery and long haul shipment. Consequently, the total fill rate of the system might change. All these considerations make it worthwhile to investigate the relation of fill rate with the defined FTL and LTL operations. It is also useful to investigate which part of the transportation operations has lower fill rate, or has more potential to be increased, to prioritize and focus the efforts on that sector.

Small vs. big transport companies:

It must be considered that in this study only a few number of big transport companies were interviewed. In the future, it is recommended that larger number of companies must be studied to get more reliable data, especially among small companies. One can argue that small transport companies should be more interested in fill rate, since efficiency is more important for them to survive in the competitive market with lots of competitors. Therefore fill rate in small companies must be higher compared to large companies that more or less have a guaranteed amount of customers with fewer large companies as competitors. On the other hand, it can be said that small transport companies are more focused on customer service and providing customized services for the customers. The more a company is service-oriented, the less it seems to be interested in fill rate. Also another argument is that big companies are usually more concerned about the image of the company, and thus might concentrate on efficiency more. Therefore, a further study is needed to be done to explore such areas based on the actual situation of big and small transport companies.

8 Conclusion

In this part the conclusion, consisting of a summary of steps taken in this project, findings and results of the study, reviewing the research questions and their answers are presented.

The purpose of this study was to assess fill rate in road freight transport and investigating the ways that are existed in the literature and practice for measuring it. The purpose was divided to some research questions, consisting of the concept and perception of fill rate, applications of fill rate, fill rate measuring methods, and comparing the available methods of fill rate measurement. To answer these questions, data collection through literature study and interviewing experts, and then analysis of the subject were done.

It was found that there exist various perceptions of fill rate in practice and it is the economic resource utilization that is more interesting for the transport companies than physical resource utilization. However, fill rate is applicable in the contexts of efficiency and environment. It can be used for different purposes, for example, as an efficiency measure, for calculating costs and price, for capacity planning, and for calculating emissions. Weight, volume, deck-area, number of pallets, and ton-km were explained as measures for fill rate. Weight has been the most common measure so far, but the reliability of existing data can be questioned, as in many cases the chargeable weight has been used instead of the actual weight. The advantages and disadvantages of each of these measures were discussed and it was concluded that no single measure can be suited in all situations.

To improve fill rate it is recommended that more research should be done about fill rate, as lack of academic studies is tangible. Moreover, all parties involved in the transportation activity should cooperate closely to increase fill rate in the whole transport chain. Customers are very important in this regard, since it is their service requirements that oblige transport companies to perform in a way that is not efficient. Therefore, it is very important that all parties have the same perception of fill rate. Some practical ways to improve fill rate were introduced, such as, increasing consolidation, changing the packaging in order to increase stackability and stowability, and changing in vehicle and handling equipments.

No remarkable change in the fill rate levels can be foreseen in the close future, unless an external force outside the company, such as regulations, makes new incentives for all parties involved in transportation, to review their operational strategies. Increasing fuel prices and making the share of transportation cost higher in the total price of products, might help in this regard to encourage all parties to perform more efficiently.

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10 Appendix I

1. How do you define fill rate? What is your perception? Do you use other terms to call it?
2. Do you measure it? How important is it as a KPI in your organization? Why do you measure it?
3. What are the other ways (or KPIs) you are using for measuring resource utilization?
4. How do you measure it? Not only the formula, but also the way the actual measuring activity is done, for example the way occupied volume is measured. Is it dependent on the type of commodities?
5. Why do you measure it in this way? What are the difficulties or simplicities?
6. What parameters are included in it or affecting it? For example time utilization.
7. What are your strategies, in general, to improve fill rate? How can this KPI be improved in respect to the way it is being measured?
8. What are the costs of improving fill rate?
9. How do you measure your capacity? Is there any relation between the unit which is used for capacity measurement and the way fill rate is measured?
10. Do you use it as a KPI for internal usage or you report it to outside the organization?
11. How do you decide when higher fill rate is in contrast with customer requirement? Which one has higher priority in your company?
12. Are your customers willing to compromise their expectation in favor of achieving higher fill rate?
13. What is the connection of fill rate with your company's business model?
14. What can be the role of government in increasing fill rate?