Measuring resource efficiency in long haul road freight transport

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ABSTRACT

Purpose of this paper

The purpose of this paper is to present a methodology for measuring filling rate and resource utilisation of vehicles and load units for road freight transport.

The proposed methodology is based on comprehendible and easily accessible data. The proposed methodology is used in a multiple case study, analysing freight transport solutions provided by the major actors of the Scandinavian transport scene.

Design/methodology/approach

The paper is based on a literature review of existing research, covering filling rate and resource utilisation in freight transport. Based on the literature review, a methodology has been developed, taking into account the specific characteristics of the transport operators.

The methodology was then used in a case study, collecting empirical data from three leading operators on the Scandinavian transport market, and the handling of general cargo.

Findings

In the paper, filling rate is studied in the context of resource utilisation in road freight transport. Based on a literature review, four ways of measuring filling rate, payload weight, average height of the goods, deck-area coverage and average volume, loading level, have been selected and used in a multiple case study. The empirical study shows that none of the measures used, single-handedly fully reflect resource utilisation and the ability to allocate more goods to existing capacity. Instead, a composite measure is needed to understand the hidden capacity and the potential of using existing loading capacity more efficiently.

Practical implications

The methodology presented in the paper will enable transport service providers to measure transport efficiency using filling rate and to use this increased knowledge to improve the overall efficiency of the transportation system.

Originality/value

This paper combines empirical findings with existing theory. Based on this knowledge, the paper suggests actions to both academia and the transportation industry on how to measure resource efficiency based on physical capacity, improving the utilisation of physical resources in freight transport.

Keywords: *Road freight transport, Filling rate, Resource efficiency, Transport service provider, Case study*

1. Introduction

According to the EU, new technologies for vehicles and traffic management are expected to be a key to lower transport emissions in Europe and the rest of the world (EU, 2011). The increased focus on sustainability has meant that a large part of the research in the freight transport area has been focused on technology, including the use of alternative fuels. Engine and exhaust systems, aerodynamic profiling, improved tyre performance and reductions in tare weight are expected to contribute to a significant reduction of the environmental impact from freight transport, reducing both fuel consumption and CO2 emissions (McKinnon, 2010).

Despite the development of new technology, the underlying problem is the goods and the demand for transportation. The uncertainty experienced in the logistics triad (Sanchez-Rodrigues et al., 2010:1; Sanchez-Rodrigues et al., 2010:2) i.e. carrier, shipper and customer, and the lack of communication between the actors reduce the efficiency of the freight transport system. In general, customers and shippers are not penalised or charged for the volume forecast inaccuracy or late notification of additional volumes (ibid,). Furthermore, shippers and customers do not take responsibility for the additional handling of the goods required in freight transport. Actions increasing the filling rate and efficient use of transport resources are primarily not in the interest of neither the shippers, nor the customers.

Via the Green Logistics project, several studies have been made (McKinnon et al., 2010), raising the attention to the efficient use of resource and the importance of filling rate in road freight transport. In Sweden, the government has realised the problem of the under-utilisation of vehicles and load units in freight transport. As a consequence, the Swedish National Transport Administration (Transportstyrelsen) recently published a report on filling rate and the reduction of empty backhaul (Transportstyrelsen, 2011). An important conclusion of the report was that, despite the awareness of the problem, little was known on the actual situation and the actions needed to improve resource utilisation in road freight transport.

Depending on the type of the goods, the demand for transport or the kind of services available, different measures are being used, either on their own or in combination (Samuelsson and Tilanus, 1997). Primarily, resource utilisation is measured based on either volume or weight or a combination of the two. The length of haul is sometimes also included, using tonne-km as a loading factor. In the literature, Weight, Tonne-km, Volume and Deck-area coverage (load-area length) are often referred to measuring resource utilization in freight transport (e.g. McKinnon, 2007; McKinnon, 2008; McKinnon and Edwards 2010). Other factors can also be included in the analyses such as backloading (McKinnon and Ge, 2006; McKinnon and Edwards, 2010) and other combined measures related to the goods, transport distance or the population density of the geographical destinations involved.

The load factor is important also for the energy consumption and CO2 emissions (McKinnon, 2008). Increasing the load factor reduces the environmental impact from freight transport. Measures taken to improve the performance of the transport system often reduce the environmental impact from road transport and vice versa. Increasing the filling rate is therefore a significant contribution to the overall efficiency of the freight transport system.

In this paper, the role of the filling rate and resource utilisation will be discussed. Based on a literature study, a framework for measuring and analysing filling rate will be presented. This framework is then used to present a study of the filling rate in a terminal freight network and the chosen methodology for measuring the available capacity of the loading units. Finally, suggestions will be given on how different ways of measuring filling rate can improve the environmental and financial sustainability of the road-based freight transport system.

2. Literature review

Despite the increased focus on sustainability in freight transport during the last decade, comparatively little attention has been given resource utilisation in terms of filling rate. A possible explanation could be the nature of data and the complexity of this information, making gathering of data troublesome. From an academic point of view, there is only a very limited number scientific papers analysing road freight transport from a filling rate, suggesting that there seem to be a research gap in the literature.

Repeated literature searches were made on *fill*/*filling rate* and adjacent areas such as *resource utilisation, (freight) transport efficiency/effectiveness* and other search phrases using different databases such as Science Direct, Google Scholar, Emerald and Scopus. Several papers were found, however, very few of these papers primarily had a focus within the defined area. The papers that were found to be relevant are referred to later in this chapter. As a complement to the research papers, relevant projects have also been reviewed.

The presentation of the literature review has been divided into three parts: contextual factors influencing filling rate and resource utilisation, how to measure physical efficiency in goods handling and finally, different ways to define and measure filling rate used in previous studies. Specific results found in the literature are presented as a separate part of this chapter followed by a short summary.

2.1. Contextual factors influencing filling rate and resource utilisation

In the freight transport industry, it is well known that it is difficult to collect information on the physical properties of the goods. The problems related to collecting information concerns many kinds of information data, but especially volumetric data on road freight flows (McKinnon, 2000). The problems that occur are often due to technical reasons and the time available for processing the goods while being transported. Physical measuring of the goods is by many means a manual and time-consuming process. There is no systematic collection of volumetric data for road freight flows. Therefore assessing vehicle fill at an industry level is very problematic (McKinnon and Edwards, 2010). Limitations in time and handling capacity mean that little or no information at all related to filling rate will be recorded. Information is therefore often difficult to get hold of. The lack of data is probably one of the reasons why payable weight is the most common way to report on freight, as payable weight is the most common way to charge for freight transport.

A part of the problem, contributing to the complexity of freight transport, is that the demand for transportation cannot be isolated from other activities in the supply chain. The demand for freight transport is the result of a complex interaction between decisions made at different levels in the supply chain (McKinnon and Woodburn, 1996). Strategic and operational factors are influencing the interaction between transport users and transport service providers. Activities such as production, procurement, inventory management, warehousing and sales have a great impact on the efficiency of freight transport (McKinnon, 2008).

The most critical factors affecting resource utilisation in freight transport are the inter-functional relationship between transport and core activities of the shippers. Factors likely to influence road freight demand are: the total volume of sales, the nature of the product and logistical factors (Table 1; source: McKinnon and Woodburn, 1996).

Table 1 Logistical Decision Making (McKinnon and Woodburn, 1996; McKinnon, 1998)

Type of decision	**Choices made**
Structure of the logistical system	The number of locations, factories and warehouses, constituting the framework within which freight is being moved
Pattern of sourcing and distribution	Supplier and customer base of the freight customer. Changes in sourcing and distribution have a significant impact on the freight demand such as the trend towards outsourcing of production, centralised warehousing and new distribution strategies.
Scheduling of product flow	Scheduling of orders, defining the frequency and the size of the shipments leading to vehicle movements
Management of transport resources	Choice of transport modes, carriers and vehicles, the planning of loads and the routing of deliveries

For strategic decisions, e.g. the structure of the logistical system and the sourcing and distribution of products, the influence of the logistics manager is often quite limited compared to other functions within the organisation. Alternative distribution strategies are therefore often limited to operational decisions (McKinnon and Woodburn, 1996).

Drewes Nielsen et al. (2003, p.300) proposed a model indicating the relationship between the elements of freight transport and the hierarchical decisions leading to freight transport. In their model, Distance, Speed, Frequency, and Point in time were proposed to indicate the capabilities of transport logistics. These indicators are then used to evaluate the role of each of the four factors originally proposed by McKinnon and Woodburn (1996). Strong relationships were proposed to exist between several of the identified elements, implying a strong relation between certain factors whereas other connections were less strong or even absent. Commercial decisions and the pattern of trading links often decide the logistics structure. These decisions are the main driver for freight distance and the number of tonne-kilometres whereas scheduling, representing another hierarchical level, mainly impact the number of vehicle-kilometres required (Drewes Nielsen et al., 2003).

The only level in the proposed model, where decisions are taken based on logistical strategies is the Management of transport-level. All decisions taken on this level will influence resource utilisation. However, as concluded by the authors, the hierarchical structure of decisions affecting freight transport lead to a limited impact on transport efficiency. To show the essential development in freight transport and to meet the criteria of using simple indicators, four indicators can be defined: Transport mode, Transport content, Transport distance and Transport efficiency (

Table 2).

Table 2 Indicators showing the impact of changes in logistical organisations (Source: Drewes Nielsen et al., 2003)

Indicator	Definition
Transport mode	The choice of transport mode, either by the shipper or the forwarder
Transport content	The ratio between the average length of haul and the average payload measured in kilometres per tonne.
Transport distance	The average length of haul, computed as the ratio between tonne-kilometres and the payload weight
Transport efficiency	The ratio between the tonne-kilometres and the vehicle-kilometres.

In comparison to more commonly used indicators such as vehicle-kilometres and tonne-kilometres, these indicators relate transport to a specific product or production (Drewes Nielsen et al., 2003). The suggested indicators therefore provide a possibility to distinguish between transport distance and transport efficiency.

2.2. Physical efficiency in goods handling

An important part of the research on transport efficiency is how to measure transport efficiency and what methodology to be used. According to (Piecyk, 2010), primarily four factors are used measuring transport efficiency:

1. Filling rate - A measure on how the goods are being loaded on the loading unit and the use of the physically available space and weight in relation to the restrictions of that loading unit.
2. Vehicle/resource efficiency – the use of the individual vehicles such as empty running and positioning
3. Freight transport efficiency - the use of vehicles on the road network, i.e. efficient planning and routing of vehicles.
4. System efficiency/effectiveness – the layout and design of the transport system and the location of terminals as a way to fulfil the demands and requests of the customers.

Filling rate is of great importance for freight transport efficiency. There is however, a trade-off between filling rate and resource utilisation in terms of what measures that can be taken in terms of time and resources to fill the load unit. A balance has to be found on how to use both vehicles and personnel, i.e. how to use the time a truck or a trailer spend being loaded in the terminals compared to the operational driving time, referred to as vehicle efficiency.

Vehicle Efficiency is a measure of how the load units are used. This involves both idle time and the routing of vehicles. Vehicle routing and scheduling is closely related to the development of information systems in freight transport and the use of ICT, which is also the case for the next factor mentioned by Piecyk (2010), Freight transport efficiency. Freight transport efficiency is strongly related to the use of tools for planning and resource optimisation.

The fourth factor mentioned by Piecyk (2010), System efficiency, refers to the design of the transport network. As mentioned by McKinnon and Woodburn, the demand for freight transport is a complex interaction made at different levels in the supply chain. The strategic importance of individual terminals may change as key customers re-evaluate their sourcing or distribution strategies (McKinnon and Woodburn, 1996).

All four factors mentioned are representing different decision levels and planning horizons. Whereas filling rate and resource efficiency often are operational decisions, freight transport and system efficiency are on a strategic, often long-term, decision level.

2.3. Filling rate

Filling rate can be defined as the ratio of the actual goods moved to the maximum achievable if the vehicles, whenever loaded, were loaded to their maximum loading capacity (McKinnon, 1999). Based on that general definition, five common utilisation measures can be identified: *Weight-based loading factor, Tonne-km loading factor, Volumetric loading factor, Deck-area coverage and Level of empty running* (Table 3).

Table 3 Utilisation measures for describing the loading factor (McKinnon, 2010)

Loading factor	Definition
Weight-based loading factor	The ratio of the actual weight of goods carried to the maximum weight that could have been carried on a laden trip.
Tonne-km loading factor	The ratio of the actual tonne-kms moved to the maximum tonne-kms that could have been moved if the vehicle had been travelling at its maximum legal weight.
Volumetric loading factor	The proportion of cubic space in the vehicle occupied by a load.
Deck-area coverage (or 'load area length')	The proportion of the vehicle floor (or deck) area covered by a load, representing a 2-dimensional view of vehicle loading. Where the height to which products can be stacked is tightly constrained, loading is usually limited more by the available deck-area than by the cubic capacity.
Level of empty running	The proportion of truck-kms run empty.

Due to capacity restrictions the load units, cannot be fully used in all aspects, e.g. due to weight limitations or deck-area coverage. A load unit that is fully used, reaching 100 per cent volumetric fill rate can still be under-utilized in terms of weight or deck-area coverage. This is because many low-density products fill the available vehicle space before the maximum permitted weight is reached. In sectors characterized by low-density products, weight-based load factors tend to underestimate the true level of utilization. Tight limits on a product's stacking height often means that loading is usually constrained much more by the available deck area than by cubic capacity (McKinnon, 2010). According to McKinnon and Edwards (2010), the current decline in the average density of road freight, increases the proportion of loads that 'cube-out' before they 'weigh-out'. Therefore, for lower density products, space-related measures of lading are more appropriate (McKinnon and Edwards, 2010).

Stacking and physical consolidation of goods requires effort in time and resources loading and unloading the goods. If time and resources are scarce, filling rate will not be prioritized. The trade-off between space utilization and efficient loading and unloading of the goods, leads to a situation where load units may have lower fill rate due to the time and resources required to fill up the load unit. The filling rate should therefore always be analysed based on the context and purpose of the study.

2.4. Previous studies

Very few studies of filling rate have been presented, offering estimation on general freight transport. Although previous studies made by McKinnon and the *Green Logistics* project have discussed resource utilisation and filling rate, data on filling rates is hard to find. In a study by NEA from 2001 (Lumsden, 2006), filling rates were recorded based on nearly 150 departures. In the study, the filling rates were estimated to 92 %, 82 % and 57 % for deck-area coverage, weight and volume respectively. The average utilised volume capacity was estimated to 82%, the average utilised weight capacity was 57% and the average deck-area coverage was 92%.

In 1997, Samuelsson and Tilanus presented a four-dimensional physical efficiency model of goods transportation, expressed in the dimensions of time (T), distance (D), speed (S) and capacity (C) (Samuelsson and Tilanus, 1997). In the model, the four dimensions were further divided into 18 factors describing the partial efficiency of road freight transport. The partial efficiency factors were then used in a Delphi study, involving both Swedish and Belgian representatives from the freight transport industry. Based on the consensus of the group of representatives from the industry, values for the different measures on resource utilisation were estimated.

Samuelsson and Tilanus (1997, p133) also estimate the potential improvement on transport efficiency. Among the areas where the potential improvement is estimated to be largest the Time for driving was estimated to provide the largest potential saving, 3,5 on a five-grade scale. Other measures where the potential was high were Backhaul capabilities (3,4), Business time (3,2), Increasing the height of the loads, i.e. to increase the cube utilisation (3,1), Actual loading execution efficiency (2,8) and Floor space utilisation (2,6).

In the study, the participants of the Delphi were asked to estimate the utilisation of the trucks quantitatively. It was found that the cube utilization was very low, about 27 per cent. On average, 80 per cent of the deck area was occupied. The average load height of the goods was estimated to 47 per cent.

2.5. Discussion on the results of the literature study

To determine the way filling rate in freight transport has been treated in the literature, a literature study was made, focusing on resource utilisation in general and filling rate in particular. It was soon discovered that the number of articles to be found was very limited. *Filling rate in road freight transport appears to be more relevant to the practitioners in the transportation industry than to academics within the freight transport research community*.

Through the literature study it was discovered that filling rate in road freight transport above all is a matter for transport operators, optimising the use of physical resources and utilities. Filling rate also seems to reflect the business model and the competitive advantage of the actors involved. High fill rates often bring revenues that not necessarily will benefit the shipper, thus information to be found will be scarce. Depending on factors such as the type of goods, the charge for transport, business model and physical organisation of the haulier, the filling rate is of varying importance. Activities, such as production, procurement, inventory management and sales, most often are of greater importance to the shipper compared to transport efficiency (McKinnon, 2008).

Regarding the actual levels determined by the filling rate studies there are even less results to be found in the literature. Very few studies have taken interest in the utilisation of the space of the loading units used in freight transport. The fact that few results can be found might seem strange provided that there are many studies to be found on transport efficiency, information sharing and communication strategies to improve freight transport management. In this sense, the research within the Green Logistics project and the previous work of Alan McKinnon and his co-authors represents a lion's share of the sources to be found on the area, specifically referring to filling rates in road freight transport.

3. Empirical study

The aim of the study was to measure filling rate and resource utilisation in long haul road freight transport between terminals in a freight transport network. The goods transported in the freight transport network were shipments of general cargo with a weight between 35 kg and 1000 kg approximately. Information was collected through observations and visual inspection, following the loading of the goods and at the point of departure of the vehicles.

3.1. Methodology

The study was made as a multiple case study (Eisenhart, 1989, Yin, 2003). Information was provided base on visual observations and systematic analyses of the recorded data from customer orders for the time period studied. The same information was collected from each one of the studied companies.

To gain access the information required for the study, three of the leading forwarding companies on the Swedish freight transport market were contacted and asked to participate in a research study. The companies were asked to grant access to the researchers recording all departing load units, i.e. trucks and trailers, over a weeks time, Monday through Friday.

To gain knowledge on how a study can be made under the circumstances at each site, two pilot studies were made before the final design of the main study was completed. Background information, such as gate numbers and destinations, was provided on beforehand, just before the observations started. Notes on filling rate and estimated volume of goods on each loading unit were then continuously taken by the researchers. An approximation of the stacking height and the loading profile of the goods were also made.

As the study involved several researchers, instructions were written made to ensure that all observations were made in the same way, rendering the same quantitative measurements in terms of correct judgements on filling rate.

3.2. Variables

In the study, observations were made using Payload weight, Average height, Deck-area coverage and Average volume, i.e. the same factors as proposed by McKinnon (2010). Using well-defined factors, previously used by other researchers in earlier studies (Lumsden, 2006), will make it possible to compare data but also to verify whether the measured values are reasonable or not.

In the research study, volumetric data and deck-area coverage were gathered through observation. Information on weight and capacity has been derived from the administrative system and the booking. Due to potential errors in the data provided by the shippers, the goods have been weighed in the terminals, using scales.

Payload weight (%)

All three participating companies are using payable weight to record and analyse the weight of the goods. Therefore, payload weight has been used to calculate the weight load-factor and not actual weight.

Average height of the goods (%)

The stacking height of the goods has been estimated as the used height as a fraction of the total height. This measure is not the same as average volume below.

Deck-area coverage (m)

The deck-area coverage of the loading unit was measured both in terms of residual loading meters and residual pallet space after loading the vehicle.

Average volume, loading level (%)

The average volume was estimated based on total carrying capacity and the average height of the goods. Average volume is the volumetric use of the load unit.

3.3. Findings of the study

All in all about 450 individual observations were made in the study, representing about 260 departures (truck and trailer) covering about 30 unique destinations for three different transport operators in one weeks time at each operator. Due to confidentiality, destinations that are not being shared by the operators will not be published in detail. However, the information collected on these relations provide important input on a general level where the destination and the transport distance.

There are several reasons for using a composite measure or a combination of the different measures mentioned in

Table 3. The main reason being that each individual measure will not be sufficient to describe the potential of adding more cargo, i.e. a loading unit that is fully loaded in terms of payable weight might not be fully used volume-wise and or covering the whole deck area. A typical representation of the filling rate can be found in **Error! Reference source not found.** below, showing a representation of three different measures of filling rate, namely Volume, Payable weight and Deck area coverage as a percentage of the total capacity. The specific sample represents the average filling rate over a week's time. The destinations in the figure are geographical areas or cities in Sweden. The transport distance from the collecting terminal

ranges from 60 km to 1370 km. Intermodal transport services are used for three of the destinations where the distance exceeds 800 km.

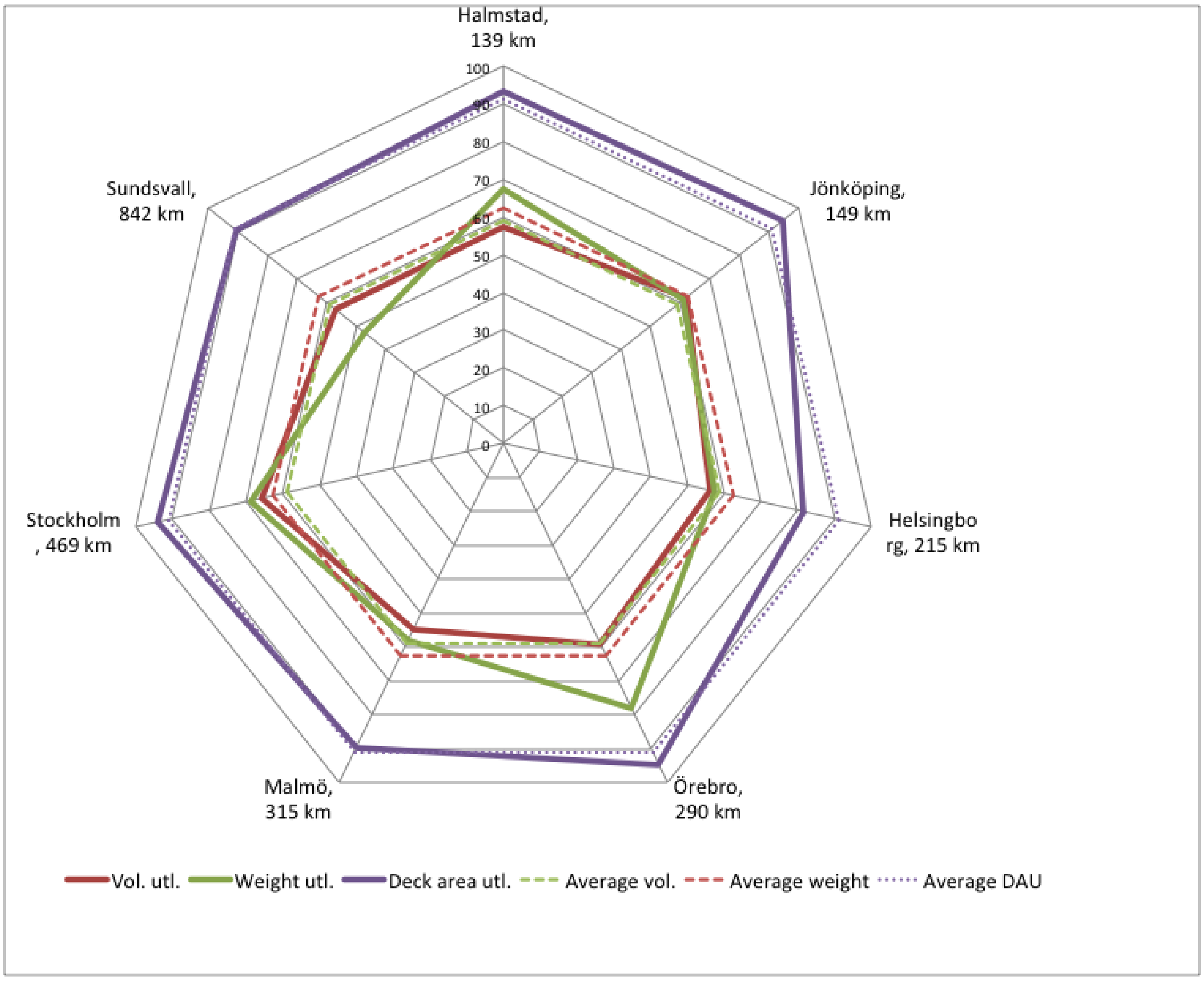


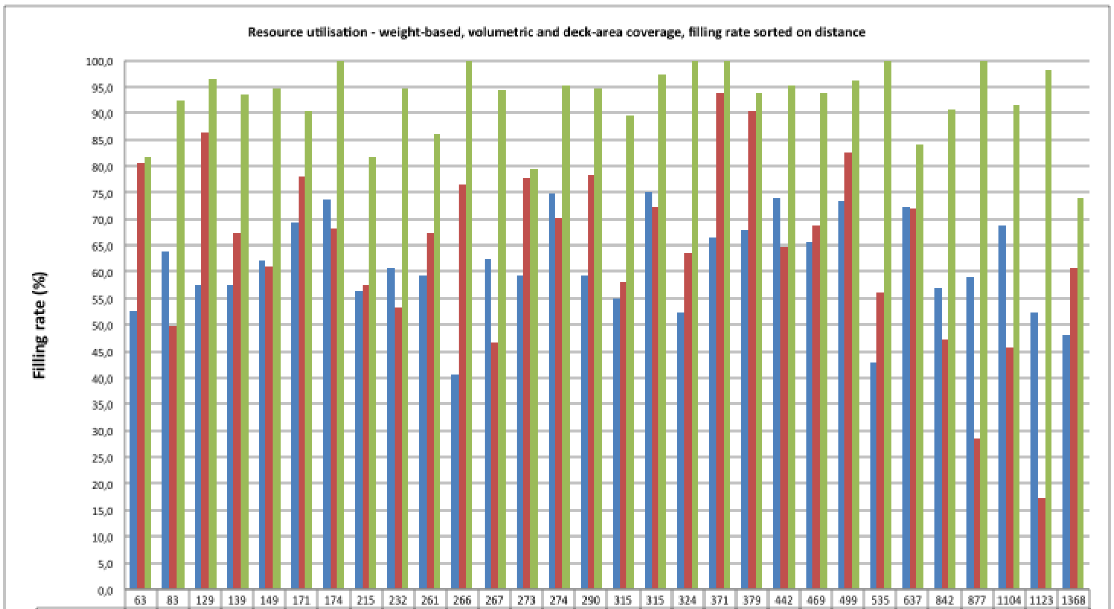
Figure 1 Average filling rate for general cargo, 7 destinations

Theoretically the volume utilisation of a loading unit can be 100 per cent but in reality, some space has to be available to enable fast and efficient loading and unloading of the goods. Payable weight is a combination of weight and volume. It is also the weight that forwarders use for transport planning, representing the information that is stored in the information systems of the transport service providers. Payable weight can be more than 100 per cent, without exceeding the weight limit of the vehicle.

Deck area utilisation reflects the residual capacity when the goods have been loaded on the load unit and the truck departs from the terminal. The floor space will in most cases be used to a maximum. As can be seen in Figure 1**Error! Reference source not found.**, the loading units are often close to fully used in terms of deck area coverage, however, both volume and payable weight is below 100 per cent. Subsequently, the loading units are not completely full capacity-wise.

A compilation of the results of the study reveals that, based on all 263 departures measured in the study, the average filling rates were 61,2 %, 64,3 % and 91,5 % for volume, payable weight and floor space respectively. No specific relationship between the different filling rate measures, implying that continuous analyses have to be made to distinguish potential relationships between the factors.

Introducing, freight distance and deck-area coverage (Figure 2), propose that for some freight distances, filling rates might be of strategic importance to the operators, i.e. despite low filling rates and low resource utilisation, daily departures are offered. Furthermore, the relationship between the different ways of measuring filling rates indicates that as the amount of goods increases, the more the volume of the goods reflects the resource utilisation. From a carrier perspective, the volumetric filling rate can be altered whereas the other two depend on the goods and the information provided by shipper.



	63	83	129	139	149	171	174	215	232	261	266	267	273	274	290
Vol. utl.	52,8	63,9	57,5	57,4	62,0	69,3	73,6	56,4	60,6	59,3	40,6	62,5	59,3	74,9	59,2
Weight utl.	80,7	49,8	86,3	67,3	61,1	78,0	68,1	57,4	53,2	67,4	76,5	46,6	77,7	70,3	78,1
Deck area utl.	81,7	92,3	96,4	93,5	94,7	90,4	100,0	81,7	94,8	86,2	100,0	94,3	79,5	95,3	94,7

	315	315	324	371	379	442	469	499	535	637	842	877	1104	1123	1368
Vol. utl.	54,9	75,0	52,2	66,6	67,8	73,9	65,7	73,4	42,7	72,3	56,9	59,0	68,8	52,5	48,1
Weight utl.	58,0	72,1	63,6	93,9	90,4	64,8	68,6	82,5	56,0	71,9	47,2	28,4	45,6	17,2	60,6
Deck area utl.	89,4	97,2	100,0	100,0	93,9	95,2	93,9	96,1	100,0	84,2	90,8	100,0	91,6	98,2	74,0

Figure 2 Utilisation of deck-area, payable weight and Volume, average filling rate of the three operators, sorted on destination

An analysis of the results based on transport distance (Figure 2) does not provide any direct suggestions for *if*, or *how*, these factors are interrelated. There are however reasons to believe that there are dependencies between resource utilisation and other factors related to freight demand. For these potential relationships to be evaluated, further studies are needed, e.g. based on the indicators presented by Drewes Nielsen et al., (2003), if possible, or a further analysis of the logistical decisions behind the demand for freight transport.

An important factor in freight transport is the transport distance. Transport distance often includes decisions on transport mode, transport frequency and the use of intermediate terminals for further consolidation of goods if the quantities are low. Another important part of the total economy within freight transport is return loads and the trade balance between to geographical areas. The balance between shipping terminal and the receiving terminal should be of interest for transport planning leading to better fill rates.

4. Discussion

Several measures are being discussed to reduce the environmental impact from freight transport, involving the development of engine technology, alternative fuels but also filling rates resource utilisation. A majority of the decisions that influence the environmental performance of freight transport are taken on a supply chain planning level, i.e. the location of production resources and sourcing of products. Therefore, it should be of great interest to the transport service providers to increase the filling rate on the resources leading to better resource utilisation. By monitoring the available loading capacity compared to the used capacity based on volumetric, weight-based and deck-area utilisation, a better correlation between the two should be possible.

As mentioned in the literature review, there are many factors concerning freight transport that cannot be influenced by the transport service provider. As freight transport for most shippers is a non-core process, it should be understood that full information on the goods and goods volumes should not be expected. Additional capacity has to be available to handle the variation in demand. From a filling rate perspective, this means that the optimal filling rate will always be lower compared to a transportation system with less variation in demand.

5. Conclusion

It is of great importance, not only to from an environmental perspective, but also from an operational perspective that available freight transport resources are used as optimal as possible. To ensure transport efficiency, filling rate, resource efficiency and better use of available resources are of great importance. Singlehandedly, increased filling rate will not lead to better transport efficiency, however, it is important to raise the attention to filling rate in order to increase resource utilisation and thereby increase transport efficiency and the sustainability of road freight transport.

A main purpose of the study was to develop a methodology for measuring filling rate and resource utilisation in road freight transport. Based on previous literature, a methodology was developed measuring filling rates based on goods volume, deck area coverage and payable weight. Results from the study indicate that filling rates and resource utilisation of the studied road freight transport operators were well in line with previous studies (Samuelsson and Tilanus, 1997; Lumsden, 2006). The results also show that there is a potential for improvements in all studies areas, especially concerning the volumetric utilisation of the load units and more efficient use of deck area, increasing the weight per meter of the load unit.

Many of the reasons to why resources are not fully used are related to the physical handling of goods. Transport operators have to be able to load and unload the goods efficiently reducing the handling time required in the terminal. When load units and packaging are compatible, the handling time can be reduced. For general cargo where the goods are varying in size and shape, it is important that the goods can be stacked in an efficient way, ensuring that the loading process become as fast and efficient as possible in terms of physical resources and personnel. Additional resources are needed for the loading to be efficient and for the load unit to be able to depart in time. Time restrictions will lead to a reduction in filling rates, which will make the utilisation of the loading unit less efficient.

A part of the problem leading to low filling rates is the lack of information considering the characteristics of the goods and the shippers' reluctance in providing correct information. Much of the information that is available on beforehand to the transport operators is incorrect or even absent. The lack of data limits the value of using decision support systems, ITS and advanced information systems are rarely used to increase resource utilisation from an operational point of view. Participation of both transport service providers and transport users are required to increase the value of information, providing better planning and use of resources.

5.1. Future research

The literature suggests that factors such as transport distance, freight balance between terminals and organisational structure of the transport operators, influence filling rate and the efficiency of the freight transport system. Future studies therefore involve analyses whether the different organisational structures of the studied companies, including market share, terminal structure and number of terminals, have any influence on the filling rates observed in the study.

Of specific interest are the following factors in relation to the observed filling rate:

Transport distance often includes decisions on transport mode, transport frequency and the use of intermediate terminals for further consolidation of goods if the quantities are low.

Trade balance and type of goods is a measure of the availability of goods. Return loads are an important part of the total economy within freight transport.

The destination's role as a source or sink for goods will influence both trade balance and the potential for physical consolidation of goods. Theoretically, there should be a difference in filling rate between the two destination that can be explained by the nature and characteristics of the goods.

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