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# Shippers' transport efficiency: An approach for measuring load factor

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## ABSTRACT

One key aspect of efficient transport is load factor: the load carried compared to the maximum load that could be carried in a load unit (e.g. a vehicle). The purpose of this study is to develop an approach that will clarify and describe ways in which shippers can measure load factor. Drawing on existing literature and understanding gained from empirical data the proposed approach uses the load factor model, which structures measurement of load factor overall and at several levels (packaging, shipping, vehicle, fleet) as the ratio of required to available capacity. Shipping level includes utilization of purchased capacity, which is of special interest to shippers. For applying the model in practice, calculation methods linked to availability of data are presented. Calculations of volumetric load factor from two cases illustrate the methods. This paper's detailed descriptions of how shippers can measure load factor provide calculation structure as well as transparency. Measuring load factor is of interest to evaluate efficiency, particularly since load factor is related to transport costs and environmental performance.

**KEYWORDS:** capacity · green logistics · load factor · measurement · shipper · transport efficiency

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## 1 INTRODUCTION

Various political entities have long-term targets for a considerable reduction of greenhouse gas emissions within the transport sector; in the European Union, for example, the goal is a 60 percent reduction of greenhouse gases by 2050 [1]. Having a more efficient transport system in place has been identified as one important strategy to meet such targets [1]. Several studies have found that increasing "load factor" is a promising way to reduce the environmental impact of transport-related activities through a more efficient use of transport resources [2-5]. McKinnon [6] states that "raising vehicle load factors is one of the most attractive sustainable distribution measures to companies because it yields substantial economic as well as environmental benefits" (p. 243). Load factor may be described as the load that is actually carried compared to the maximum load that could have been carried in a load unit, such as a vehicle [7-8].

Measuring performance is generally known to be necessary for a company: for example, in order for the company to support decision-making [9] and to evaluate the progress of particular operations [10-12]. In particular, load factor (which may be classified as an input/output measure) can be used to evaluate goal attainment in specific areas of logistics efficiency [13]. Detailed descriptions of ways to measure load factor performance are currently limited, however. In the previous literature, load factor is often one of several aspects that are measured in a larger performance-measurement system, such as the measuring of $CO_2$ emissions [3, 14], transport efficiency [7, 15], or overall vehicle effectiveness [16]. Because previous studies have generally covered load factor as only one among several aspects within transport operations, such studies have offered few details about measuring load factor.

A standardized way to measure load factor is also currently lacking. Different interpretations of the load factor concept have been put forth regarding the dimension that is measured (measuring weight, deck area, or volume, for instance) as well as how to measure that dimension (whether the load unit should be included in the figure, for example). These differing interpretations make it difficult to compare results between studies. In addition, previous studies have provided limited information about how full vehicles are. Only measuring weight says nothing about the volume utilization, for example, while measuring deck area says nothing about the utilization of height. If a vehicle is fully loaded with boxes but those boxes are half empty, does that mean that the load factor is 100 percent? These challenges will be further examined based on the previous literature in chapter 2 of this paper.

Both transport providers and shippers have a major incentive to assess their load factor, since this factor is related to transport costs. For shippers, measuring load factor involves other challenges beyond simply measuring vehicle utilization, as has been done in the literature to date [e.g. 3, 5, 7]. When a shipper purchases transport services from a transport provider, it is important for the shipper to know that the purchased capacity will be utilized well; in other words, they should not purchase more space than they require. Shippers may contract different types of services from their transport providers, including dedicated service, truckload service, and less-than-truck-load service [17]. When a less-than-truck-load service is contracted, for example, it is important to know the load factor for that capacity.

A structured way to describe the various components of load factor is needed. In particular, it is crucial to understand a shipper's perspective, because shippers are generally interested in getting the most from their purchased capacity. As a step towards addressing the challenges associated with measuring load factor, this study thus aims to develop an approach that will describe ways in which shippers can measure load factor. This model will facilitate calculations and will lead to an increased understanding of shippers' load factor performance.

The remainder of this paper is structured as follows. Chapter 2 reviews the existing literature so that the challenges involved in load factor measurements may be described; chapter 3 then describes the study's methodological choices. Chapter 4 presents the load factor model. Chapter 5 describes how to calculate load factor, and finally, chapters 6 and 7 discuss the results and conclude the study, respectively.

## 2 LITERATURE REVIEW OF LOAD FACTOR MEASUREMENTS

In order to address the challenges involved in load factor measurement that were briefly mentioned in the introduction, this chapter will describe the challenges in more detail by drawing on the existing literature. While the term *load factor* that is used in this paper is commonly used in earlier studies, these studies also use other terminology for the same concept, including vehicle utilization, capacity utilization, fill rate, and vehicle fill.

This paper describes the following three challenges related to load factor measurement: first, a standardized way to measure load factor is currently lacking; second, collecting load factor data often involves numerous uncertainties; and third, only measuring load factor at the vehicle level is insufficient for providing a comprehensive understanding of the utilization of space.

### 2.1 No standardized way to measure load factor

Earlier studies have not consistently measured load factor performance, because they have interpreted the load factor concept in several ways and because a standardized way to measure load factor is currently lacking.

Different dimensions are generally used to measure load factor – including weight, deck area, height, empty running, or volume – and each dimension has several definitions. Weight is the most common dimension for measuring load factor. Examples of load factor definitions related to weight from the literature include "the ratio of the actual weight of goods carried to the maximum weight that could have been carried on a laden trip" [5], "revenue tonne-km / revenue tonne-km available" [18], "tonnes/vehicle" [19], "kg/day" [20], and "payload weight" [21]. For the dimension deck area, one previous study has defined load factor as the percentage of occupied floor space [22]. For the *volume* dimension, previous studies have defined load factor as the "volume of product actually despatched against the transport capacity deployed for the movement" [23] and as the "internal volume/ external volume with lid" [24]. Other definitions for volume have been put forth, such as "unutilised capacity (number of units)" [25].

What constitutes a load factor of 100 percent will be different depending on the dimension that is measured; as an example, the occupied floor space could result in a 100 percent load factor even if the pallets are empty [22]. In addition, a weight-based load factor might be high but not take the utilization of the deck area into account [26]. Measuring load factor in terms of payload weight, as shown in Pahlén and Börjesson's study [21], makes it possible to achieve a load factor of more than 100 percent when in reality a great deal of unutilized space exists. Several studies have used more than one dimension to measure load factor, which provides a better picture of the utilization of the maximum capacity: McKinnon and Ge [7] measure weight, deck area, and height, for example, while Léonardi and Baumgartner [3] measure weight, volume, and empty running. Still, because previous studies have primarily used weight-based load factor measures, the volumetric measure of the load is often missing. This is problematic, since volumetric figures provide a better understanding of the space that is required for a given load [8]. Gudehus and Kotzab [27] take into account that capacity may be weight determined, volume determined or a mix of these. Because loads are often constrained by volume, for example – as stated by truck operators in national surveys [8] – measuring load factor in terms of volume is of interest.

The lack of standards and the different interpretations made when calculating load factor means that it is difficult to understand the load factor figures or to compare results between studies. Before load factor figures may be interpreted, the details on dimensions and definitions must be transparent so that the meaning of the different figures will be clear. Considering both weight and volume provides a more complete picture of load factor in terms of the utilization of both maximum space and maximum weight.

### 2.2 Challenges in collecting load factor data

Various challenges are also to be found in collecting data to measure load factor. Weight-based data may be reported in a company's system, for instance, but the data may be incorrect, as Pahlén and Börjesson [21] found, or it may be inconsistent, as McKinnon [8] discussed. McKinnon [8] pointed out several problems involved in the compilation and interpretation of EU freight-transport statistics. As a result, the load factor figures that are available for the European Union and its individual countries must be interpreted with caution; for example, the data from different countries have not been measured in a consistent manner [8]. Various inconsistencies in measuring the weight of the goods in freight-transport data exist: for example, whether or not the weight of the unit load device is included. Due to difficulties in collecting accurate load factor data based on weight, Giannouli et al. [28] utilized assumptions of load factor in their emissions calculations. Further, volumetric data on loads (which would be of interest for loads that are constrained by volume) are often unavailable in a company's system; instead, volumetric data are often collected based on estimations or observations [21, 29]. Previous studies rarely describe how these estimates have been made, however. Increased transparency about what data are used and how the data are used would be useful for interpreting the results. In general, transparency is encouraged by providing details about a study's data-collection methods; guidelines would be useful for achieving this kind of transparency, since previous studies have used different approaches to arrive at their load factor numbers.

### 2.3 Measuring load factor at the vehicle level only

Load factor should be measured at several system levels to show the efficient use of transport resources. Many earlier studies have measured load factor at the vehicle level, such as those conducted by McKinnon and Ge [7], Kellner and Igl [30], and Leach, Savage, and Maden [31]. While measuring load factor in vehicles is useful for determining vehicle utilization, the measure does not reflect the efficient use of the units that are transported inside the vehicles: for example, doing so does not show how fully loaded the containers on a ship or the boxes on a truck are. Gudehus and Kotzab [27], on the other hand, focus on load factor and packing strategies for one level at a time. In order to capture the efficient use of units inside units, Samuelsson and Tilanus [32] included lower levels than the vehicle level in their capacity-efficiency measure, including floor occupancy, height utilization, pallet and box characteristics, net product, and loading-execution efficiency. Also, Santén [33] included lower level measures; packaging, loading and booking efficiency. Comparing load with a fleet's capacity is another system-level approach that is previous research exemplified in the context of container liner shipping [34].

For shippers, measuring load factor involves challenges beyond simply measuring vehicle utilization between terminals. The utilization of the purchased capacity is an important consideration for those shippers that purchase transport services from transport providers; as such, shippers should not purchase more space than is necessary. For shippers that send less-than-full truckloads, the efficient use of the purchased capacity may be more directly influenced than the utilization of the whole vehicle (which the transport provider fills with goods from other shippers). In such situations, it would be useful for shippers to measure their capacity utilization related to their purchased capacity [33]. As a result, measuring load factor has to account for more levels than simply the vehicle and take into account the perspective of the shipper. Shippers should also measure the efficient use of packaging, as shown in Pålsson, Finnsgård, and Wänström's study [24]. From a shipper's perspective, the efficient use of resources should thus encompass both packaging and the shipper's purchased capacity.

### 2.4 Requirements on a structured way to measure load factor

A clarification and description of how shippers can measure load factor is necessary because of the many problems described above. The challenges identified in previous studies, leads to the following requirements on a structured way to measure load factor:

- enable shippers to measure load factor;
- provide a transparent method of measuring;
- allow historical comparisons to be made between transport flows and between companies;
- be comprehensive (that is, be able to express load factor at several system levels so that situations may be avoided in which empty boxes in a vehicle result in a high load factor);
- be able to handle both volume and weight, since both dimensions can restrict the maximum load;

- clarify what "100 percent capacity" means; and
- allow applications that are independent of the characteristics of the goods flow (for example, different load units).

## 3. METHOD

This study developed an approach for measuring load factor, in which the challenges mentioned above were considered so that ways in which shippers can measure their load factor performance could be clarified. The approach in this paper further details the load factor model briefly presented in Rogerson and Santén [41] and proposes methods for calculations when applying the load factor model in practice. New knowledge is generated by the development of small-scale theories [35], where the various components of measuring load factor is structured. A high level of practical relevance is aimed for and for that reason illustrations of load factor calculations are provided from two cases.

The challenges involved in load factor measurements were derived from a structured literature review conducted during the initial phase of this study, described in part in Santén and Rogerson [36]. Thereafter, the study progressed in three main steps. The first step built on the existing literature on logistics, transportation, and capacity management; during this step, a conceptual model was developed that outlined required versus available capacity as well as several load factor levels (see Fig. 1 in chapter 3). In the second step, details were elaborated in the load factor model showing which aspects determine the volume and weight of the required and available capacity (see Fig. 2 in chapter 3). These insights were drawn from systematically combining empirical data from two cases with existing literature in line with Dubois and Gadde [37]. The two cases offered an excellent opportunity for depth of observation [38], and provided a deep and detailed understanding regarding measuring load factor and descriptions of ways in which load factor may be calculated. Finally, an approach for how to calculate the load factor was proposed, drawing on the practical problems involved when conducting load factor calculations in the two cases (see Fig. 3 in chapter 5).

### 3.1 Case selection

The cases included two specific goods flows in two companies, which were selected according to purposeful sampling criteria; to feature the particular aspects of interest as a way of providing in-depth understanding and insight [39] about the shippers' load factor measurements. Case Food Distribution was a wholesaler that distributes frozen food, chilled food and groceries to Swedish supermarkets several times per week. Case Energy Equipment was a manufacturer of large, heavy energy equipment for international construction sites. The two cases showed key components of the load factor model in terms of several load factor levels, such as packaging and shipping, and the use of different load units (boxes vs. pallets). Selecting cases that represent the common situation that shippers purchase their transports from a third party [40], allowed measuring efficient use of purchased capacity.

The cases were part of a larger research project focusing on load factor performance. That larger research project had a wider scope than measuring shippers' load factor, also studying how shippers could improve their load factor. While this paper uses the cases to illustrate how load factor can be measured, Rogerson and Santén [41] structure shippers' opportunities to increase load factor. The load factor figures stated in Rogerson and Santén [41] as the starting point before changes to improve load factor in case Energy Equipment are used in this paper. The specific case described for Food Distribution consists of data for a transport to different recipients and a different point in time compared to case Food Distribution in Rogerson and Santén [41]. The data collection and analysis described below focus on the method applied for the purpose of this paper.

### 3.2 Data collection

The data were collected through semi-structured interviews, internal company documents, and observations of the packing and loading processes. For a summary of the data collected from the two cases see Appendix A.

Over a period of one year several rounds of interviews were conducted with the respondents (Table 1). The interview guides included questions that were important for (1) the details in the load factor model (Fig. 2) and (2) calculating the load factor based on the load factor model (Fig. 1). The interviews were also used for presenting the ongoing work and give the respondents possibility to provide input from their practical experience on the applicability of the model and approach to measuring load factor.

*Table 1: Respondents in the two cases*

| Case | Respondents |
|---|---|
| Food Distribution | Transport-planning manager, logistics manager, transport-order manager, transport-operating manager |
| Energy Equipment | Project manager; supplier manager; transportation and logistics manager, Northern Europe; global packaging category manager; transport planner |

Further, internal company documents on the transport and load data were collected and observations also served a major role. In both cases, an initial observation provided an overview of the situation of the company's packing and loading activities. For the Food Distribution case, a second observation showed more details and examined specific aspects that had been identified from interviews to determine required and available capacity for the specific goods flow to be measured. The investigators used an observation protocol and took photos of the activities that they examined in the study. In both cases load factor was measured at the point of departure of a specific outbound goods flow, for case Food Distribution from the central warehouse and in case Energy Equipment from the manufacturing site.

### 3.3 Data analysis

To describe how load factor could be measured, those aspects that determine load factor were identified in an iterative process combining (1) calculations of load factor performance according to the structure in Fig. 1, and (2) reflections on how to derive the load factor figures.

The aspects were derived from the data collected in the two cases as well as previous literature, and were sorted according to whether the aspects determined required and available capacity resulting in the more detailed model (Fig. 2).

The load factor was calculated in the two cases for two load factor levels (packaging and shipping) as well as the overall level (see Fig. 1). The required and available capacity were calculated in volumetric terms, since volume was identified as constraining the maximum load in both cases. Quantitative data based on internal documentation, interviews, and observations were used for the calculations. The applied methods for deriving required and available capacity in the two cases illustrate necessary estimations and simplifications when calculating load factor in practice.

### 3.4 Research quality

Tables and figures showing the calculations, load factor performance, and the load factor model for each case were discussed with three respondents from each case for verification. The quantitative data as well as method used for calculating the load factor was also discussed on more than two occasions with the two respondents who had provided the quantitative data used for the calculations. The framework was presented at several workshops with industry participants, which allowed the researchers to acquire feedback on the usefulness of the model and the method for calculating load factor. The responses from these workshops indicated that the model was indeed transferable to contexts beyond the two cases that were examined in this study.

## 4. THE LOAD FACTOR MODEL

In response to the challenges addressed in chapter 2, a first step is to be able to describe shippers' load factor at several system levels in volume and weight. To do so, this chapter presents a load factor model (Fig. 1), drawing on a model briefly presented in Rogerson and Santén [41]. This chapter elaborates on the model, providing more details and also placing it in the context of logistics and transport systems. It further explains the details with regards to aspects determining required and available capacity (Fig. 2). The model and its components are described in this chapter with the literature underpinning the descriptions. Illustrations of various aspects of measuring load factor in accordance with this model are provided from the studied cases (Table 2).

The definition of load factor used in this paper, which builds on the definition of vehicle loading proposed by McKinnon and Ge [7], is the ratio of the load carried (required capacity) to the maximum load that could have been carried (available capacity). The model structures the load factor on different levels (packaging, shipping, vehicle and fleet) based on the balance between required and available capacity (see Fig. 1). The model's logic focuses on balancing the capacity required for the goods to be transported with the capacity available to transport the goods. The model distinguishes between logistics and transportation systems, as described by Woxenius and Sjöstedt [42], such that the logistics system is the shipper's system when outsourcing transport and the transport system concerns the shipper's management of its own transport operations or those of transport providers. The scope of this paper is to translate the general definition of load factor into a definition from a shipper's operational perspective when outsourcing transport, i.e. the logistics system in the model. Since all load factor levels will influence the efficiency of the transport operations as a whole it is also important for shippers to be aware of the load factor in the larger system levels, i.e. the transport system. Therefore, the logic of the different load factor levels in both the logistics and the transport system is described in this chapter, while the cases focus on shippers measuring their load factor (in the logistics system). A detailed approach regarding the transport system is addressed as an issue for further research, see Ch. 7.

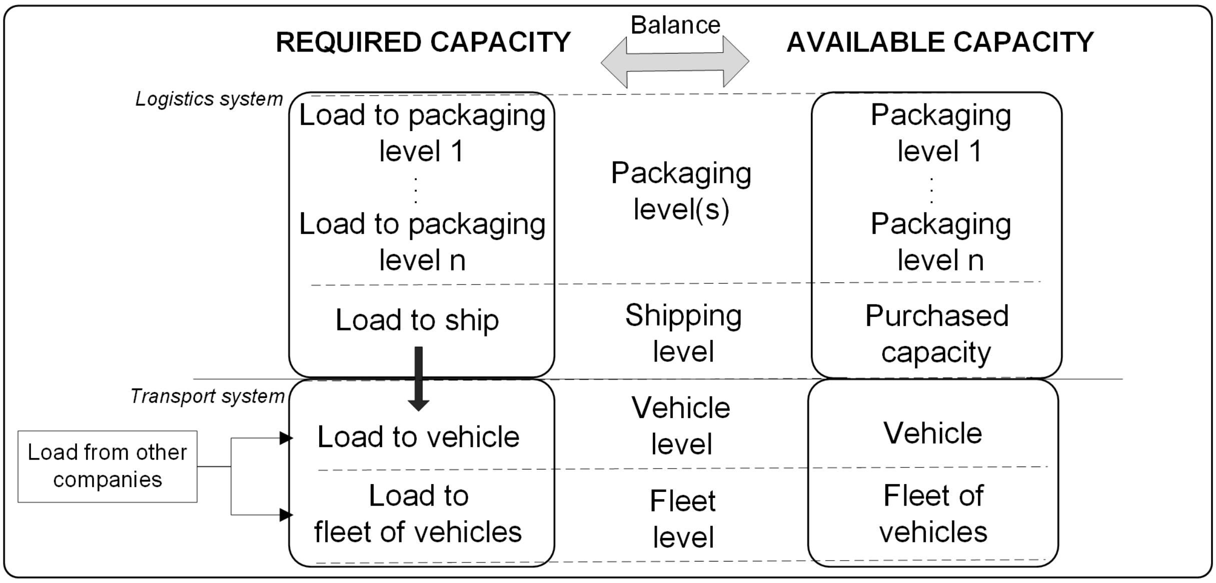


*Figure 1: The load factor model*

### 4.1 Balancing required and available capacity

Required and available capacity can be measured using volume and/or weight to calculate a ratio of how well the available capacity is utilised. Often, it is useful to measure the dimension (i.e. weight or volume) that constrains the maximum load [cf. 16]. However, to achieve a perspective on the load factor that encompasses both weight and volume, the load factor model can be used to calculate both individually. A high load factor is achieved when the required and available capacities are balanced in terms of volume (length * width * height) and/or weight.

The model can be used to compare both actual required capacity and available capacity in a specific time period and estimated required and available capacity for a future period. The period can be short (e.g. a particular delivery or deliveries during a day) or long (e.g. deliveries over the course of a month). It is important for the time period being measured to be clear.

### 4.2 The load factor levels

A number of different load factor levels exist: packaging level (1, 2, …, n), shipping level, vehicle level and fleet level. To achieve a comprehensive understanding of the load factor performance, it is important to consider the balance between the required and the available capacity on all load factor levels. For example, measuring only the vehicle level could give an impression of high performance, even if the vehicle is loaded with nearly empty boxes. The number and types of levels that exist in a given shipper's system may vary depending on the situation and the type of contract. For example, a manufacturing company will have different packaging levels than a distributor, and the shipping level can either be a share of a vehicle (if purchasing LTL) or one or several vehicles (if purchasing FTL).

At a packaging level, the required capacity is the load to be packed, and the available capacity is the load unit into which the load will be packed. Several packaging levels are possible, which previous literature has described as primary, secondary and tertiary [43] or in terms of containers, roll cages, pallets, boxes and similar items. For example, Samuelsson and Tilanus [32] include a box load factor and a pallet load factor as partial-capacity efficiencies in a less-than-truckload (LTL) distribution system. In our model, we denote packaging levels using the numbers 1 to n; therefore, Samuelsson and Tilanus' [32] example translates as products loaded in a box at packaging level 1 and boxes loaded at a pallet at packaging level 2. Individual shippers can decide which load factor levels are relevant to measure in their systems. For example, if products are delivered to a shipper from their supplier in their primary packaging, and the packaging is never broken before packing the items on pallets to prepare for shipments to the shipper's customers, level 1 packaging (products in their primary packaging) is outside the shipper's own responsibility. Instead, the load factor at the second (and larger) packaging level(s) can be influenced more directly by that particular shipper, and thereby their primary focus.

At the shipping level, the required capacity is the load to be shipped (i.e., goods leaving the shipper), and the available capacity is the purchased capacity for the load. The shipping level is more aggregated than the packaging levels. The load to ship is the sum of packaging level n and can also include the load resulting from other packaging levels. For example, a wholesaler with a large product range can ship

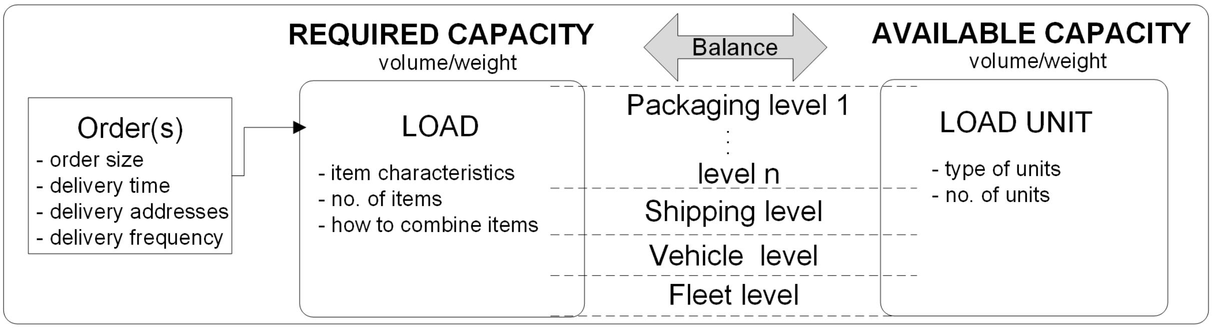


*Figure 2: Determining required and available capacity*

items comprising both products packed on pallets (level 2) and other (bigger) products packed in their own packaging (level 1) and loaded directly onto the purchased capacity. The purchased capacity is of interest to a shipper outsourcing freight transport. In the model, purchased capacity can be smaller than a vehicle (less than a truckload), a vehicle (a full truckload) or several vehicles, depending on what is purchased. Available capacity for shippers purchasing full truckload services is the capacity of the whole vehicle, while available capacity for shippers purchasing less than a truckload of services is the purchased share of the vehicle (e.g. a specific number of pallets). When purchasing less than a truckload of service, the shipper measures its share at the shipping level, not at the vehicle level. The load from one shipper may be consolidated with goods from other companies in the case of less than a truckload of services, and such consolidation is organised by the transport provider [44]. In such situations, the vehicle- and fleet-level load factors are considered to fall outside the scope of the shipper's load factor measurements.

At the vehicle and fleet levels, the required capacity is the load to be shipped on one or several vehicles, and the available capacity is the vehicle(s) available for the load. This level is included in the shipper's system if the shipper manages the transport (i.e. owns his or her own vehicle) or if the shipper coordinates its goods with goods from other shippers (i.e. without help from transport providers).

## 4.3 Determining required and available capacity

This section describes the aspects that determine required capacity and available capacity, which must be considered when calculating load factor. See Fig. 2 for the aspects determining required and available capacity. The studied cases illustrate aspects determining required and available capacity (Table 2).

### 4.3.1 Determining required capacity

Required capacity is the volume or weight of the load at each load factor level (packaging levels 1 to n, shipping level, vehicle level, and fleet level). The volume and weight of the load are determined by order details, item characteristics, number of items, and possibilities for combining items (where an item is a product or packed load unit). The load (at each load factor level) comprises one or more items. An item at a higher load factor level can be a load unit used at a lower load factor level (e.g. a box). This unit is the available capacity at the packaging level, but an item to load at the next level.

Items can be combined in different ways [e.g. 45]. Which items can be combined is determined by the order details (e.g. order size, delivery time, delivery address, delivery frequency and shipment consolidation) [46], meaning for example that a specific load unit can only contain items to the same delivery address [27]. Further, how items can be combined depends on their characteristics in terms of shape [e.g. 45], sensitivity [e.g. 44], stackability (i.e. if items can be stacked on top of one another) [e.g. 45, 47] and density [e.g. 48]. For examples, see case descriptions in Table 2.

### 4.3.2 Determining available capacity

Available capacity is the volume or weight available in load units (at each load factor level) for a given load. The available capacity in terms of volume is the inner dimensions of the load units at each load factor level (packaging, shipping, vehicle and fleet) for the number of load units. Similarly, the available capacity in terms of weight is the weight available for the load. The volume and weight available for a load unit are determined by the type of the load unit: which load unit is used (the size), what equipment exists in the load unit (e.g. cooling equipment), and the material of the load unit. The equipment may use up space or weight thus reducing the available capacity for packing or loading items and resulting in less available capacity. The material of the load unit may determine the weight it can carry. The material of the load unit protects the contents, for example, during packaging [49]. A protective packaging material may reduce the need to protect the product inside the packaging. In case Energy Equipment boxes were designed to protect the goods well, see Table 2.

*Table 2: Aspects determining load factor, examples from cases*

| | |
|---|---|
| **Packaging level** | |
| *Required capacity* | Food Distribution: 3,450 products to 3 shops were packed in layers on standardised EUR-pallets. Item characteristics of particular relevance for how the items could be positioned and oriented were shape and sensitivity to damage and temperature. Some products had irregular shapes, resulting in packing loss (air). Items sensitive to damage (e.g. crisps) could not support heavy products on top. Items were allocated to different pallets depending on temperature regimes (e.g. frozen food, chilled food and groceries).<br>Energy Equipment: 530 items (18 large) were combined, taking into account sequence of unpacking, shape and risk of damage. The sequence of unpacking determined which products could be packed in which boxes. Many products had irregular shapes (e.g. legs protruding in one direction), resulting in packing loss (air). Risk of damage resulted in extra packaging material inside the boxes. |
| *Available capacity* | Food Distribution: 69 standardised EUR-pallets were used. Volume possible to load was determined by the length, width and height of the pallets. The height limit (1.25 m excl. pallet) allowed double stacking and unloading at the recipients.<br>Energy Equipment: 21 customized boxes were available for loading goods. The size of each customized box was adapted to the size of the items to be packed inside. The boxes were designed to protect the goods, i.e. through stiff and strong material, which also made it possible to double stack large boxes on the shipping level. |
| **Shipping level** | |
| *Required capacity* | Food Distribution: 69 packed pallets were loaded onto a large truck combination (vehicle and trailer). Some pallets were easy to stack (level); other pallets were uneven and could not support stacking. To avoid products being crushed (e.g. crisps) certain pallets could only be loaded as a top layer. Pallets were allocated to different zones in the truck depending on temperature regimes (e.g. frozen food, chilled food and groceries).<br>Energy Equipment: 21 boxes of varying size were loaded onto vehicles. Large boxes were not always possible to stack or position in one direction, e.g. if the height of two boxes stacked on top of one another was greater than the space available inside the vehicle. |
| *Available capacity* | Food Distribution: A large truck and trailer combination with capacity for loading 96 double stacked pallets (48+48). The equipment in the vehicle (i.e. the cooling equipment, internal walls to separate different temperature zones and a fork lift for unloading goods) reduced the available capacity by 2 $m^3$ to 94 pallets (135 $m^3$).<br>Energy Equipment: 8 vehicles were available, each capable of loading 65 $m^3$ of goods. |

Different types of load units exist, and these have different available capacities in terms of load volume and weight (e.g. type of truck [50] or pallets [47]). Load units that are customised (specialised) to a specific purpose may be adjusted to the dimensions of the planned content (required capacity), in [27] called a dimension adjustment strategy. Standardised load units, on the other hand, can be used for many purposes and have specific dimensions. The number of load units is related to the type of load unit selected: one unit with a large capacity or several units with smaller individual capacities. The different type of load units and their respective capacity are exemplified in cases, see Table 2.

### 4.4 Interaction between various levels in the load factor model

Load factor measurements must consider all levels. Measuring the load factor of only one level, says nothing about the load factors on the other levels and may, therefore, be misleading. For example, the box on the first packaging level may have a high load factor, while the next packaging level has a low load factor due to difficulties in combining units on the pallet. Furthermore, on the second packaging level, the pallet can be fully loaded with boxes, even if the boxes themselves have a low load factor (unoccupied capacity).

The interactions among load factor levels reflect the connections among load factor levels and how available capacity at a lower level affects required capacity at a higher level. The packed load unit at a lower level becomes an item in the load at the next level, but at the next level, the required capacity (in volume) is based on the outer dimensions of the packaging, rather than the inner volume of packaging that is the basis for the available capacity.

Further, measuring load factor at each load factor level must be complemented with an overall measure of load factor. This overall measure compares the required capacity at the lowest load factor level with the available capacity at the highest load factor level. The overall measure indicates how much of the volume or weight is used by the smallest loading units (often products) and unused capacity refers to both the volume and weight of the load unit and the space left unused when packing and loading items on each level.

In addition to the overall load factor measure and the measures at each load factor level mentioned above, a complementing measure is the ratio between the available capacity at one packaging level and the required capacity at one higher load factor level [cf 24]. This measure facilitates an understanding of how much of the packaging is available for packing/loading goods, such that a high number means that the packaging material takes up little space.

## 5. APPROACH FOR CALCULATING THE LOAD FACTOR

In this chapter, an approach for calculating load factors from the perspective of a shipper is presented. The approach is a stepwise guide for how to use the load factor model and the aspects determining required and available capacity when calculating load factor in practice. The calculation method needs to be adapted to the specific situation in the company, e.g. regarding availability of data, and thereby it is important to measure in a structured way and to be transparent about the basis of the calculations (so the load factor numbers are not misinterpreted). Calculating load factor in the two studied cases illustrates the use of the approach and the calculation methods proposed . The approach is summarised in Fig. 3.

First, the system in which the load factor should be measured is defined. To facilitate a complete evaluation of the load factor, both weight and volume (or, alternatively, the dimension[s] constraining the load) are calculated. Furthermore, the time period for measuring the load factor is decided. For example, the load factor can be calculated for each departure, each day, each week or each month. Further, the load factor levels in the measured system must be identified.

As a second step, for each load factor level, required and available capacity, respectively, are calculated.

| | |
|---|---|
| 1 | Define the system in which to measure load factor |
| | (a) Calculate both weight and volume or identify the measure (weight or volume) that constrains the load factor and calculate that measure. |
| | (b) Decide the time period for which to measure load factor, for example one departure, one day, one week, five days. |
| | (c) Identify load factor levels. |
| 2 | For each load factor level, calculate required and available capacity respectively. |
| 3 | Calculate the load factor for each load factor level (the ratio between required and available capacities) and the overall load factor (the ratio between the smallest required capacity and the largest available capacity). |

*Fig. 3 Approach for calculating load factors*

Calculation difficulties stem from what data is available. As pointed out in Gudehus and Kotzab [27] many companies do not register or update such data. Two different calculation methods for required and available capacity are described in Table 3.

The two methods to calculate required capacity are: (a) summarising the weight or volume of all individual items and (b) measuring the weight or volume of the items after they have been combined. The most appropriate method depends on the availability of data. As explained earlier the required capacity is the volume or weight of the load to be packed/loaded. In an ideal world calculation of required capacity would involve summarising the weight or volume of individual items (method a). However, data regarding individual weight or volume may not be available in the company's system. As the load to be packed/loaded may consist of various items, it could involve much work to measure each individual item. Simplifications may therefore be necessary. As an example, in case Energy Equipment odd-sized items at the packaging level were calculated as a box (the maximum width multiplied by the maximum length of each item) since this was the volume information available in the company's systems. Further, when method a (summarising the weight or volume of all individual items) is used, volume calculations must consider how the items are combined. Item combinations may be limited by item characteristics, such as shape, size, weight, stackability and sensitivity. Odd-shaped items may be impossible to combine on a load unit without some air between the items. Simplifications may be necessary when there are difficulties obtaining data on these characteristics.

*Table 3: Examples of calculation methods*

| Calculation | Method | Notes |
|---|---|---|
| Required capacity | (a) Summarise the weight or volume of individual items | Possible simplification: Calculate odd-sized items as a box (maximum width multiplied by maximum length of the item). |
| | (b) Measure weight or volume after items have been combined | Possible simplification: Subtract empty space after items have been packed/loaded |
| Available capacity | (a) Use maximum weight/volume the load unit can carry | Possible simplification: Regarding maximum packing height on pallets, use for example average height to which pallets are packed in the specific situation. |
| | (b) Use inner dimensions | Note that weight/volume taken up by equipment has to be deducted. |

If data on individual items are not available and difficult to obtain, an alternative method (method b) is to measure the weight or volume after items have been combined. For volume, required capacity is calculated using the outer dimensions (i.e. length, height and width). For weight, total required capacity is measured, meaning that everything that is loaded into the load unit at the load factor level must be measured. For example, when measuring load factor at the shipping level, a load unit (e.g. a pallet) at the packaging level must be included. However, at the packaging level, if measuring after the items have been combined, the load units (e.g. the pallet) weight or volume must be deducted, since the required capacity comprises the items to be put onto the pallet. When using method b, the unused space between the items on the load unit must be included in the required capacity. Further, it may be simpler to measure the volume not utilised inside a load unit. In case Food Distribution the required capacity at the shipping level was calculated by subtracting empty space in the truck after goods had been loaded inside the truck. Method b (measuring the weight or volume of the items after they have been combined) may also be necessary when data regarding packing and loading patterns are missing.

To evaluate the results of the packing and loading operation (i.e., the amount of unused space), data on both individual items (method a) and combined items (method b) can be compared. To be even more detailed, it would be possible to specify the weight/volume of the load units as part of required capacity on each load factor level (except the first level, which consists only of products). Such details would allow evaluating how much of required capacity consist of load units in relation to unused space and loaded items.

The two methods to calculate available capacity are: (a) use maximum weight or volume the load unit can carry and (b) use inner dimensions. The available capacity is the volume or weight that a load unit can carry. Volume can be calculated based on the inner dimensions (i.e. length, height and width) of, for example, a box (method b), or based on the volume (i.e. length, height and width) that can be put on, for example, a pallet (method a). For weight, the available capacity is the maximum weight that can be put on the load unit, excluding the weight of the load unit itself. For example, the maximum load of a pallet is commonly 1,200 kilograms (although some variations exist), and the maximum volume is the size of the base of the pallet (e.g. 0.8 by 1.2 meters) multiplied by the height to which the pallet can be loaded (e.g. 1.5 meters, where the height may vary due to health and safety regulations). The maximum height of a closed load unit, such as a box, depends on its construction [27]. The maximum height to which a flat load unit can be packed or loaded is a design parameter, but restrictions regarding safety and stacking need to be considered [27]. Therefore data regarding the height to which a pallet can be loaded may differ between companies. It may also be difficult to obtain exact information regarding maximum pallet height. For example, the available capacity on a pallet in case Food Distribution was calculated based on the average height of the loaded pallets, excluding the height of the actual pallet. Further, the volume or weight of any equipment in the vehicle (e.g. bars for double stacking or walls for separating temperature regimes) reduces the available capacity and therefore needs to be deducted in the calculations. Such deductions should be transparent in order to be able to follow up space used by necessary equipment on board the vehicle. For example, for calculations in case Food Distribution the volume of inner walls in the vehicle separating temperature zones, and the volume of the fork-lift needed to unload the goods upon delivery, were deducted from available capacity in the truck.

It is important to note that the load factor levels are connected. For example, at the packaging level, the inner dimension of a box is the available capacity. At the next load factor level, the outer dimension of the

*Table 4: Calculating load factor, examples from two cases*

| **Results of load factor calculations** | |
|---|---|
| *Case Food Distribution* | Overall: 52% (70 m³/135 m³)<br>Packaging level: 84% (70 m³/83 m³)<br>Shipping level: 87% (117 m³/135 m³) |
| *Case Energy Equipment* | Overall: 49% (256 m³/520 m³)<br>Packaging level: 74% (256 m³/347 m³)<br>Shipping level: 84% (435 m³/520 m³) |
| **Packaging level** | |
| *Required capacity* | In case Food Distribution it was measured after the items had been combined on pallets. The number was calculated based on the number of pallets (69) needed for the packed items. The volume per pallet was based on the length (1.2 m) and width (0.8 m) of each pallet multiplied by the estimated average height of a packed pallet (1.05 m excl. pallet). The height to which pallets were packed was based on average figures from the shipper's internal documentation and further validated with the transport planning manager and through on-site observations of the specific goods flow. Estimations of packed pallets were used since volume data were not available for individual items in the shipper's database. In case Energy Equipment it was calculated by summarising the outer volumes of the 530 individual items. The volume data was the simplified calculation of the items as a square box (available in CAD from the shipper's internal documentation). |
| *Available capacity* | In case Food Distribution the maximum volume of the pallets was calculated based on the number of pallets (69), the dimensions of each pallet and the maximum allowed height of 1.25 m (excl. pallet). In case Energy Equipment the volume of the boxes was calculated by summarizing the inner volume of all individual boxes. |
| **Shipping level** | |
| *Required capacity* | In case Food Distribution it was calculated by subtracting empty space from the available capacity inside the truck after pallets were loaded. Empty space was estimated during observation. In case Energy Equipment it was calculated by summarising outer volumes of the boxes to load. |
| *Available capacity* | In case Food Distribution the volume inside the truck was calculated by multiplying the inner dimensions of the vehicle and subtracting the volume taken up by equipment (internal walls and a fork lift for unloading goods). In case Energy Equipment the volume available for loading goods was calculated by multiplying the inner dimensions of the vehicle. |

same box is the required capacity as the length, height and width of the item. In weight calculations, available capacity at the packaging level is the maximum weight that can be loaded onto the load unit. At the next load factor level, the actual weight of the load unit, including its load, is used to calculate the required capacity. For example, at the packaging level, the available capacity is the weight that can be put onto a pallet, excluding the weight of the pallet. Meanwhile, when calculating the required capacity on the shipping level, the weight of the pallet has to be included.

As a third step, the load factor at each load factor level and the overall load factor are calculated. The load factor at each load factor level is calculated by dividing the required capacity by the available capacity. To calculate the overall load factor, the smallest required capacity is divided by the largest available capacity, resulting in a figure of how much weight/volume is occupied by the smallest items. For the overall load factor, unused capacity consists of both the volume/weight of the load units and air between items when combining them, which can be derived from detailed figures of required capacity. This unused capacity can be divided into necessary (e.g. load unit) or unnecessary (e.g. air), using detailed figures from the calculations.

The result from the load factor calculations in the two cases as well as the details from the calculation methods are described in Table 4.

## 6. DISCUSSION

This paper focuses on load factor measurements from a shipper's operational perspective. Previous research has described load factor measures in general terms, while this paper takes a detailed approach. Building on the load factor definition used by McKinnon and Ge [7], compared to previous research, the approach for measuring load factor presented in this paper uses a load factor model that includes several load factor levels. Using several levels broadens the load factor concept (which, in much of the previous research, has focused on vehicle utilisation [e.g. 5, 8, 51] or one level at a time [e.g. 27]). The main argument for measuring load factors at several levels is that measuring only one level can be misleading, since such an approach does not offer information on the performance of other levels. There are interactions between the levels, for example, how items are packed on the pallet (packaging level) influences the possibilities to stack them on the vehicle (shipping level). Thereby, in order to avoid sub optimisations, several load factor levels need to be taken into account. Compared to Samuelsson and Tilanus' [32] capacity efficiency framework (including both pallet and box levels) and Santén's [33] packaging, loading and booking efficiency, the load factor model in this paper can be adapted to different shippers' systems with regards to how many levels to include, what constitutes required and available capacity at each load factor level and has a clear distinction between required and available capacity at each level. Further, the load factor model pinpoints which levels are included in the shipper's system as well as the transport system. Further, an overall load factor measure is included in this paper, which facilitates an understanding of how much of the volume or weight is used by the smallest loaded units (often products) in relation to purchased capacity.

The proposed approach to calculate load factor outlines specific steps for calculating load factor and, in particular, describes methods to calculate required and available capacity. The approach is valuable since a standardised method of measuring load factors is lacking, where earlier studies have followed different interpretations of what aspects should be included. The presented approach to calculate load factor provides additional suggestions regarding necessary simplifications and the need to account for equipment, compared to Gudehus and Kotzab [27]. Furthermore, where most previous literature tends to consider only weight (e.g. [5]) and, occasionally, volume (e.g. [24]) in load factor measurements, our approach includes both.

The two methods described for calculating required and available capacity clarify the required data, including decisions regarding the level of detail in the data. To avoid inconsistencies in the calculations, such as whether the load unit is included in the load or not [8], the proposed method for calculating the load factor provides details regarding how to conduct consistent calculations. In particular, this clarification is supported by the illustration of volumetric load factor calculations in the cases, since the volume of goods is generally more difficult to measure than their weight [8]. The level of detail depends on access to data and the time available to collect data, and estimations may be necessary. However, calculating load factors for many shipments may require greater simplifications than the examples provided in this paper. Such applications and simplifications should be studied in more detail. Furthermore, when interpreting the results, there should be an awareness of the potential uncertainties of the calculations (e.g. subjective judgements when estimating a load). Therefore, to achieve consistency in the measurement of load factors, details need to be transparent. Such consistency is necessary when evaluating current performance to identify potential for improvement, update the load factor after possible changes, and to benchmark.

Several avenues for further research open up related to the load factor model. The model structures load factor from a shipper's perspective, to be measured at the point of departure from the shipper. The cases show the use of the load factor model in two situations, which differed with regards to, for example, (a) type of products, (b) type of packaging and (c) purchased capacity. Further research could test the model in other situations, such as detailing measurement on smaller packaging levels and in different contract situations. Also, the application of the model to shippers using other modes of transport, such as sea, air and rail is relevant to study further.

Moreover, in order to achieve macro-level goals (e.g. environmental performance) it is important to widen the scope of the measurement, so that suboptimal solutions are not identified. First, the applicability of the load factor model for transport providers is of interest in order to understand efficiencies with regards to vehicle and fleet levels (when these are managed by the transport provider). Second, in a distribution round, the load factor will vary at each delivery point [52]; thus, the order of delivery and the transport distance must be taken into account. Therefore, future research would benefit from broadening the scope to include a vehicle's entire trip. Third, further studies into combining volumetric and weight-based load factor measures are of interest so that the most optimal load factor across fleets can be identified.

Measuring load factor is a step towards making improvements, for example improving packing strategies, as detailed in Gudehus and Kotzab [27], and having calculated the load factor, areas that are relevant to change can be identified [41]. In Rogerson and Santén [41] the idea of balancing required and available capacities is used to structure means for shippers to improve load factor according to changes to aspects determining respective capacities. Further research could study the application of the approach to measure load factor in different shipper's contexts to evaluate how it could be used for following up on improvements.

## 7. CONCLUSIONS

This paper presents an approach for calculating load factor: (1) define the system in which load factor should be measured; (2) calculate required and available capacity for each load factor level; and (3) calculate the load factor on each load factor level as the ratio of required to available capacity.

Taking a shipper's perspective, measuring load factor includes several levels (e.g. packaging and shipping). Measuring load factor at only one load factor level, such as the vehicle level, can significantly overestimate capacity utilisation, particularly if the load factors at other levels are low. To fully understand load factor performance, therefore, it is important to calculate both the overall load factor and the constituent load factor levels.

Methods for calculating required and available capacity are suggested, and offer guidance depending on what data that is available. Consistent and transparent calculations are important.

By using the approach for calculating load factors shippers can measure their load factor, and understand imbalances that exist, including at which levels their required and available capacities are imbalanced.

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Conflicts of interest: The authors declare that they have no conflicts of interest.

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## APPENDIX

*Appendix A: Data collection in the two cases*

| Data-collection method | Case: Food Distribution | Case: Energy Equipment |
|---|---|---|
| Interviews | Descriptions of transport and loading activities; what influences load factor (required and available capacity), how items were combined on pallets; maximum pallet height; how pallets were combined on vehicles, how transport was ordered, how to derive required and available capacity on each load factor level, difficulties in measuring load factor. | Description of transport and loading activities; what influences load factor (required and available capacity), how items were combined in boxes; how boxes were combined on trucks, how transport was ordered, how to derive required and available capacity on each load factor level, difficulties in measuring load factor. |
| Internal documents | Transport plans (order sizes, number of pallets to be shipped on each vehicle, delivery addresses, and delivery times); loading plans (placement of pallets on vehicles); vehicle data (length, width, and height). | Item sizes (from CAD); sizes of boxes; vehicle data (size of purchased capacity). |
| Observation | Pallet height; how items were combined on pallets; how pallets were positioned in the truck when loaded; equipment transported inside the trucks; the use of double stacking of pallets. | Characteristics of boxes; how items were packed in boxes; boxes awaiting loading on vehicles; how boxes were loaded onto vehicles. |