Word count: 10,662

Packaging design, fill rate and road freight decarbonisation: A literature review and a future research agenda

Abstract

With growing concerns about freight transport emissions, it has become imperative to find ways to improve packaging fill rate that increases vehicle utilisation efficiency. The purpose of this review is to identify and evaluate interventions aimed to improve space utilisation at various levels of packaging in freight transport operations. A systematic literature review is conducted covering publications in peer-reviewed academic journals. A critical analysis explores each intervention, its application domain, along with economic, environmental and logistics implications. There is a lack of research focusing on interventions to improve the packaging fill rate in academic journals. The retail sector undertakes more packaging-related improvements compared to the industrial sector. Of the three packaging levels, more focus is given to the secondary (distribution) level design improvements in comparison to the other two. Primary (customer) level packaging is predisposed to marketing function whereas tertiary (transport) level is inclined towards the use of standardised packaging items. Our study presents a library of interventions that packaging practitioners could use to improve the packaging and vehicle fill efficiency. Our work is the first attempt to systematically identify, evaluate and categorise packaging intervention to improve fill rate that can reduce the economic and environmental impact of logistics operations. Also, this study provides recommendations for future research in the field of packaging design and logistics.

Keywords: Logistics; load factor; Packaging redesign; sustainable packaging; carbon emissions

Paper Type: Literature review

1. Introduction

Packaging is a primary requirement of any finished product. It offers product containment, protection, and preservation. It is also a source of information and influences product attractiveness and convenience for the customers (Lee and Lye, 2003). Besides, marketing and environmental functions, packaging also plays an important role in supply chains by fulfilling several logistical functions including transportation, storage, distribution and materials handling (Chakori et al., 2021). A strong interaction between packaging and logistic activities takes place at each stage of the product flow. For instance, filling, storing and handling at the manufacturers' site; striving for loading efficiency during transportation; influencing picking and storing at the warehouses; loading and unloading during distribution to stores, shelving and waste handling within retail stores and handling and unboxing at the customers' end (Pålsson and Sandberg, 2020). Due to the importance of packaging in logistics, concepts like, "packaging logistics" (Saghir, 2004 p.6) and more recently an expanded version incorporating sustainability, "sustainable packaging logistics" (García-Arca *et al.*, 2014, p. 330) have been coined. Both these concepts call for an integrated approach for packaging design in conjunction with supply chains for improvements and efficiency gains. The concepts incorporate the three functions of packaging: commercial, logistics and environmental (García-Arca and Prado, 2008), and point to the strategic role packaging can play in achieving organisational competitiveness.

The general supply chain management literature include topics on logistics, reverse logistics, operations and environmental considerations to name a few (de Oliveira et al., 2018). Patel and Desai (2019) reviewed the literature from a sustainability perspective, identifying the drivers and barriers for sustainable supply chain development. However, the contribution of packaging and logistics in attaining environmental and operational efficiency was not discussed. Bartolini *et al.* (2019) reviewed and synthesized the available knowledge on warehouse management and packaging. A warehouse is an important node in a supply chain where the activities are directly linked to packaging via material handling and re-packaging for distribution purposes. However, they did not discuss how the packaging fill rate improved warehouse operations in terms of material handling and re-unitisation of packages for distribution. Similarly, review by Meherishi *et al.* (2019) focused on the relationship between packaging with sustainability and supply chain management in circular economy context. They highlighted the selection of eco-friendly packaging design and materials, adoption of sustainable packaging practices and packaging waste management issues as the major trend of research efforts in the field. Likewise, Molina-Besch and Olsson (2022) and Otto et al. (2021) reviewed the food packaging materials innovations and their sustainability concerns. The former review focused on the packaging material innovations from the bioeconomy, the circular economy, and digitalization perspective while the latter one was directed on the consumer perception of packaging material innovations emphasising for more consumer information on these innovations. These reviews do not delve into the role of packaging fill rate and its requirement of meeting logistics functions. Recently, Mahmoudi and Parviziomran (2020) conducted a review on reusable packaging. Their review focused on the environmental, economic, and operational perspectives as well as the design of the reusable packaging logistics system. However, the reusable packaging and their fill rate and transportation are not covered. Finally, the state of art on packaging design presented by Azzi *et al.* (2012), following the content analysis approach, divides the literature into five categories: safety, ergonomics, sustainability, marketing perspective, and packaging design for logistics. The authors pointed to a lack of research of identifying factors that impede supply chain efficiency from a packaging perspective. They emphasised the complexities faced by multiple organisations relating to supply chain performance. Like other reviews mentioned above, the packaging influences on logistics is an under-researched area and lacks any exploration of interventions that improve packaging efficiency, in particular the fill rate.

Hence, our review fills the gaps such that: (i) we classify packaging fill rate related literature based on domain application; (ii) we consider literature discussing one or more packaging levels; (iii) we develop a library of measures taken and their impact, and (iv) we include both quantitative and qualitative studies on the packaging.

This review aims to identify and analyse interventions in packaging that would lead to higher space utilisation in packaging and transport vehicles. With increased fill rate efficiency economic and environmental savings are envisioned for material handling and freight transportation.

The rest of the paper is organized as follows. Section 2 presents our review methodology. Section 3 provides a research context. Section 4 presents the results. Section 5 covers discussion and various opportunities for future research while section 6 concludes the study.

2. Review methodology

The review of packaging and logistics literature is adapted from the Systematic Literature Review (SLR) methodology outlined by Tranfield et al. (2003). The process involves three stages, namely (i) planning the review, (ii) conducting the review and (iii) reporting the findings of the review. This section presents steps (i) and (ii) while (iii) is presented in section 4.

2.1. Planning the review

We used Scopus and Business Source Premier (EBSCO) databases to search for relevant literature. Following de Oliveira et al. (2018), Scopus was chosen due to its wider coverage and its extensive use in literature search tasks. Scopus also includes other databases, like Taylor & Francis and Science Direct. Likewise, EBSCO was chosen to extend the search net and include highest-quality business research databases. This ensured that all the pertinent literature is included.

Our keyword search was based on Azzi *et al.* (2012); Meherishi et al. (2019), and Rogerson (2017). These keywords were split into two groups as follows.

<u>Group A.</u> This group aims to collect literature related to packaging items and includes keywords such as: “packag*“, “pallet*”, “carton” and “packag* system”.

<u>Group B</u> keywords included terms linked to logistics i.e.: “logistics”, “fill* rate”, “truckload” and “load* factor”.

2.2. Conducting the review

Database queries were carried out using the search string formed of packaging and logistics keywords (Group A and Group B). Papers were considered relevant if they contain at least one search term from both groups in the title, abstract or keywords. The publication period was restricted to 2000-2021 with papers written in English and published in peer-reviewed academic journals and books.

All database queries, performed in July 2021, retrieved 377 papers in total from EBSCOhost, and 618 from Scopus. These papers were then imported to Mendeley, and duplicate records were removed. This resulted in 214 papers. We then applied the following inclusion and exclusion criteria to obtain the final sample:

> <u>Inclusion criteria</u>: Papers that address packaging and logistics management. The papers included those presenting empirical or conceptual original research, reviews, and perspectives.

Exclusion criteria. Papers that cover topics related to packaging in different areas (e.g., sustainable packaging or returnable packaging) were excluded from the review. The application of analytical methods to develop improved loading patterns, vehicle routing, and technical analysis of new packaging material were also excluded.

After applying the inclusion and exclusion criteria a working sample of 170 papers was obtained. These papers were read thoroughly, and 147 papers were further excluded due to a lack of relevance to our objective. For example, Tornese *et al.* (2016) investigation of pallet remanufacturing carbon footprint; using job analysis approach for redesigning the packing and loading by Korkmaz *et al.* (2020), and an evaluation of cost and worker fatigue in the packaging process by Glock *et al.* (2019). In the last step, the forward and backward citation approach was used in the working sample to identify papers that might be relevant for the review at hand and could not be found with the database search. However, this exercise did not lead to any relevant papers for this study. Our final sample consisted of 24 papers. Our data collection process is illustrated in Fig 1.

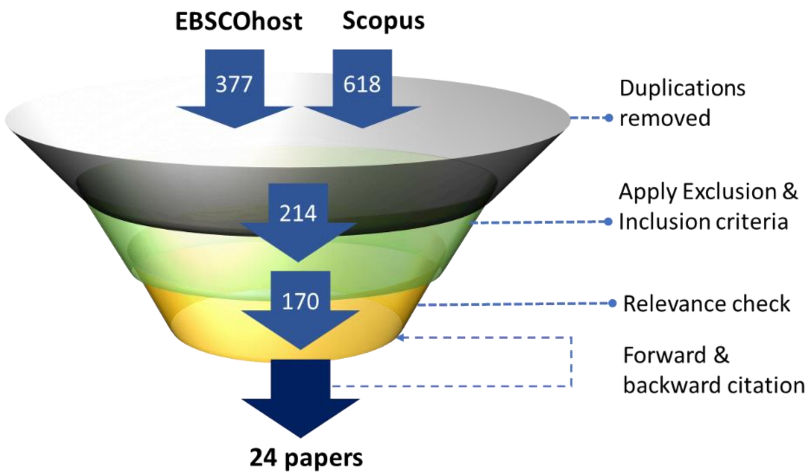

Fig. 1. Data collection process

3. Research context

3.1. Packaging and logistics operation

Along with the three primary functions of commercial, logistics and environmental protection packaging (García-Arca and Prado, 2008), the packaging system has been classified into three levels depending upon a specific position in the supply chain (Rundh, 2005). These three levels are primary; secondary and tertiary packaging levels (Mahmoudi and Parviziomran, 2020).

3.1.1. Primary level packaging

Primary level is the first level of packaging having direct contact with the product. This level of packaging is also known as 'sales' or 'consumer' packaging (Hellström and Saghir, 2007). Primary level packaging is the first protector of the product (Garcia-Arca et al., 2021). The other characteristic of primary level packaging is to satisfy consumer preferences, handling and apportionment of a product (Molina-Besch and Pålsson, 2016). Typical primary level packaging items include boxes, cups, cartons, trays, bottles, tubs, cans, sacks, drums, barrels.

3.1.2. Secondary level packaging

Secondary level packaging consolidates several primary packages together. The main characteristic of this level of packaging is to protect and ease handling, at a warehouse, during transportation and/or in retail (Hellström and Saghir, 2007). Cardboard boxes, totes, cages, cases are the main packaging items at this level. The handling cost of secondary level packaging throughout the distribution chain plays a vital role in the choice of secondary level packaging in terms of its type, size and number of primary products it carries (Saghir and Jönson, 2001).

3.1.3. Tertiary level packaging

Tertiary level packaging contains several secondary packages. However, depending on the product, primary level packaging can also be consolidated in tertiary level packaging (Hellström and Saghir, 2007), e.g., liquid detergent bottles on a pallet (García-Arca et al., 2016). Tertiary packaging is also known as 'transport' or 'distribution' packaging (Pålsson and Hellström, 2016). The main characteristic of the tertiary level of packaging is to facilitate the handling, storage, and transportation tasks of a larger volume of products. Pallets (full, half quarter), crates, roll cages, crates, bulk-bags, drums, barrels, shipping containers are the items used at this level.

3.2. Fill rate definition

This review's focus is to highlight the economic and environmental benefits to freight transport due to improved packaging. To achieve this, we used the measure of fill rate performance. In essence, fill rate defines resource utilisation. Fill rate is synonymous to filling rate, load or loading factor, or vehicle load (Liljestrand, 2016; Piecyk and McKinnon, 2010).

From a transport perspective, fill rate or load factor is the ratio of actual load carried to the maximum possible load carried for a particular vehicle (McKinnon and Ge, 2004). Various measures can be used to calculate the fill, for example, weight (Ülkü, 2012), tonne-kilometres (Piecyk and McKinnon, 2010), volume (Santén, 2017), and deck-area available (Liljestrand et al., 2015) to name a few. Furthermore, the weight-based measure is considered to underestimate the actual fill rate as low-density (low weight to volume ratio) goods form the larger share of freight being transported (McKinnon, 2009).

For packaging levels, in particular, Svanes et al. (2010) define the fill rate as the percentage of the total volume of the pallet filled with secondary packaging at tertiary level; the percentage of the total volume of primary packaging in secondary packaging; and the percentage of the total volume of the product in the primary packaging. Though their definition is limited to volume, it can also be applied to products that are weight restricted.

For this review, we are following the Svanes et al. (2010) definition as it aligns amicably with the role of packaging in improving the fill rate.

4. Finding of the literature review

4.1. Summary of papers collected

This section summarises studies on packaging improvements research that resulted in improved fill rate. Fig. 2, describes the fluctuation in publications during the period 2000-2020.

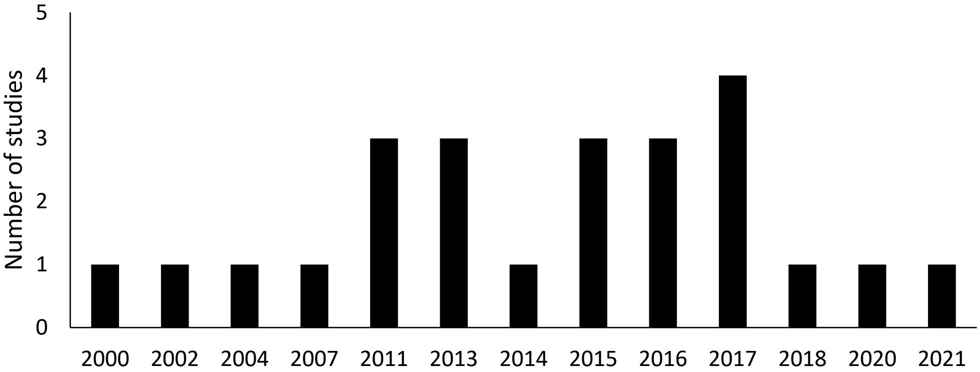

Fig.2. Packaging improvement publications trend

In terms of publication venues, studies have been published in a variety of journals. Eight studies are published in the Packaging Technology Science journal, three in the International Journal of Physical Distribution & Logistics Management and three in the Journal of Logistics Management. The remaining journals published one study each during the review period. The journals are in the fields of packaging technology, logistics, operational research, environmental science, and sustainability, pointing to the interdisciplinary nature of packaging.

A variety of research methods have been adopted to analyse packaging interventions and their impact. For classifying literature based on research methods we followed Bartolini *et al.* (2019) and Meherishi *et al.* (2019). Note that some studies adopted more than one research method. Our review found that the case study approach is widely adopted (e.g., (García-Arca et al., 2020; Rogerson and Sallnäs, 2017). The use of a case study seems appropriate as it provides an examination of packaging interventions within its real-life context. Case studies include numerical calculation to strengthen the case presented (e.g., Hellström and Nilsson, 2011; Liljestrand, 2016). Survey studies primarily engaged stakeholders to understand the perceived impact of packaging on the efficiency of freight transportation (Kye et al., 2013) and to collect quantitative data (e.g., Santén, 2017). Conceptual studies presented frameworks for evaluating packaging interventions (Liljestrand *et al.*, 2015), and interviews (Jahre and Hatteland, 2004). Finally, simulation method seemed to be the least preferred method by authors and had been adopted most often as a secondary method. In particular, García-Arca *et al.* (2020) used simulations to evaluate the impact of new secondary level boxes on container loading.

While studies reviewed followed both qualitative and quantitative research methods, case study methods dominate. This focus indicates that packaging interventions have been very problem focused. This is also a sign that companies are becoming more aware of packaging to improve their logistics functions. At the same time lack of studies using simulation, methodology presents an opportunity for future research. Simulation-based studies can enhance the understanding of how packaging improvements impact space, time, and effort from the end of assembly line packing to material handling in a warehouse to loading and shipping operations. As a result, the optimal packaging design can be identified without altering the existing setup.

4.2. Packaging interventions

Our literature review spans all three levels of packaging. In the following section, we have classified collected studies into two broad categories, retail and industrial sectors. Retail sector as the one dealing with commodities of daily use by public, such as foods items, drinks, consumer electronics or clothing. Industrial sector deals with fewer consumers with specific requirements such as automobiles, machinery, and parts. 81% of the studies in our review are from the retail while the remaining 19% are in the industrial sector.

4.2.1. Retail sector

To comprehensively identify packaging improvements in the retail sector, we further divided it into food (e.g., fish, milk, meat etc.) and non-food (e.g., mobile phones, perfumes, detergents etc.) categories. The distribution of studies in the food and non-food categories is 67% and 33% respectively.

4.2.1.1. Food packaging

Within the food packaging Singh *et al.* (2011), focused on primary packaging only. They evaluated original, cube and stackable primary level packaging designs for milk transport. For the same demand level, cube design gave 14.3% more milk units per pallet while ~12% and ~17% fewer pallets in comparison to the other two options. However, the tertiary packaging total weight for cube design increased by ~1.6% and ~43% in comparison to original and stackable designs, respectively. The stackable design had the most weight savings, 28.8% and 30%, per truck in comparison to original and cube designs, respectively. These weight improvements per truck for stackable design were possible as they eliminated the use of crates. However, the stackable design was not evaluated for stackable pallets which could have shown the possible reduction in the number of trips.

García-Arca *et al.* (2017) focused on secondary level packaging interventions. They introduced an Efficient Sustainable Box (ESB) concept. The approach focussed on combining both logistics and environmental efficiency in choosing a secondary package. Taking frozen food secondary packing as a case study they analysed two box options. The first option (Box 1) was based on modular dimensions approach while the option 2 (Box 2) was not. With new dimensions of Box 1 an increase in available volume by 14.3% resulted in a 20% increase of product bags per box while at the tertiary packaging level an increase of 5% (bags per pallet) was attained. However, cardboard use increased by 7.9%. For Box 2, changing dimensions gave 42.7% more space to place the product in. As a result, a 62.5% more product was packed at the secondary level while frozen food bags per pallet increased by 21.9%. Further calculation on option 2 pointed to an annual decrease of 315,000 boxes used corresponding to 77 cardboard tonnes less used than before. At the tertiary packaging level, for the same demand, 1,330 fewer pallets were stored and transported. However, they have not considered the truck-level volume savings.

García-Arca *et al.* (2020) continued their study in frozen food by evaluating three different box dimensions. In comparison to the original box, the new boxes increased the fill rate at secondary and tertiary levels. For box 1, with a reduced box volume, the number of primary packages in secondary level packaging remained unchanged (30 frozen food bags per box) while at the tertiary level frozen food bags per pallet increased by 6.67% in comparison to the original box dimensions. This increase occurred due to placing a greater number of boxes on the same pallet. For box 2, the volume of the box was increased by 14.3% such that greater height utilisation on a pallet could be achieved. This improvement led to 20% more products being packed in the secondary level packaging and 5% more products on a pallet in comparison to the original box. Finally, for box 3, the number of frozen food bags packed increased by 62.5% resulting in a 21.9% increase of primary packages on a pallet. This arrangement also achieved 5% less plastic being used for frozen food bags. All three new boxes recorded an increase in the number of primary level packages (food bags) on a pallet. Overall, with three new box designs, the packaging improvements resulted in having 300,000 fewer boxes in the supply chain and 1,500 fewer pallets handled per year. Likewise, cardboard material reduction resulted in a financial gain of 120,000 euros per year.

Most studies in food sector focused on tertiary level packaging interventions. The earliest study within this category was done by Jahre and Hatteland (2004). They showed that using standard packaging items improve supply chain efficiency and effectiveness through system integration. Taking roll-racks as the main transport package unit in the fresh milk distribution network, the authors confirmed that other resources (e.g., loading terminal, vehicles etc) in the case organisation developed to facilitate the use of roll-racks. However, roll racks may not be fit for transporting other similar products due to their specific packaging. This mismatch results in extra handling operations increasing the economic and environmental cost for the company.

Hellström and Saghir (2007) mapped the interactions between various logistics processes and packaging systems for the entire logistics chain for four food items. The authors posit that using standard packaging items (pallets and roll cages) lowers the handling cost in warehouses while varying secondary packaging size to fulfil customer demand results in improvements of the picking and replenishment processes. Finally, using half pallets to display products at the retail side helps reduce the handling cost for retailers. The authors did not mention any packaging interventions to improve fill rate and the corresponding impact on logistics operations rather highlight the benefits of using standard packaging items.

Liljestrand *et al.* (2015) proposed a framework for transport-level emission reduction. The proposed framework explored the complexity in transport operations by focusing on distance, shipment characteristics, and product characteristics handled. By applying the framework to the chilled and frozen food category, the authors suggested matching the shipment size to truck size to achieve high volume utilisation on a truck resulting in fewer truck trips, hence emission savings. However, no numeric evidence was provided.

Still using frozen food case study, Liljestrand (2016) proposed to use transport costs and impact on climate as means to compare packaging improvement interventions. The analyses showed that transporting frozen foods using high-capacity vehicles (HCVs)[1] reduces environmental impact between 7% to 15% while double-stacking[2] of pallets reduces the environmental impact by 5% to 23% as compared to the base case. Further, cost reductions by double-stacking pallets varied between 8% and 28% for two distinct routes considered, respectively in the study. Though double-stacking pallets reduce cost more, with the heavier truck more fuel is consumed resulting in higher emission, thus lowering environmental gains. This study considered homogeneous load and full truckload only. Relaxing the conditions may present a different climate and economic savings for the two options considered. For example, pallet height varies when different loads, packed in varying height boxes, are consolidated. Also, different laws and regulations among countries may limit the potential for improvements to be implemented. In addition, HCV and double stacking of pallets is a suitable option for low-density products only (Leach et al., 2013) along with safety and handling for loading and unloading for double-stacked pallets.

Finally, Rogerson and Santén (2017) hypothesised that efficient transport creates less traffic, which can reduce congestion on roads, distance travelled, fuel used and emissions. They investigated the order size, the delivery frequency, and the delivery time to evaluate the impact on fill rate at the truck level while considering tertiary level (unit load using a pallet) packaging. The overall strategy was to distribute the required truck capacity across the weekdays to achieve an even flow of goods. With the customer agreeing to one additional delivery per day, change in the order size and product composition the interventions were tested. This arrangement led to fewer products being transported on days that had been a high volume, while more products being transported on days that had been a low- volume while satisfying customer total demand. As a result, the weekly average pallet level fill rate remained unchanged (84%) while the transport level fill rate improved from 60% to 63%.

Some studies combined more than one level of packaging intervention. García-Arca *et al.* (2014) analyse the impact of primary and secondary packaging interventions. They presented the case of food packaging improvements by a retailer with its suppliers. Their research aimed to find the best packaging solution that would reduce the quantity and cost of packaging material used, increase pallet fill rate, improve transport use, and reduce handling, storage, and food loss. The analysis was performed for a combination of five primary level packaging options using a tray along with five secondary level packaging options using cardboard boxes (each box limited to 10 kg weight) to meet the weight requirement of 1,000kg tertiary packing using a EUR pallet. For the five options considered, an increase in the pallet utilisation, compared to the base case, varied between 5% and 16.7%. Further, analyses by the authors revealed four out of five box options were unsuitable for all products along with the technical changes to redesign the primary level packaging. Basing the final decision solely on cost (5%

[1] HCV considered is of length 25.25 metres and maximum gross vehicle weight of 60 tons.
[2] Double stacking was done in vehicle same as in the base case.

cost reduction) the company decided to retain old primary packaging with new dimensions of a secondary box-achieving a 10.8% pallet level efficiency. This study aligned itself with Jahre and Hatteland (2004) and Hellström and Saghir (2007) who argued that standardisation in packaging can increase logistical efficiencies. However, at the same time standardisation makes the system rigid and unadaptable to changing business environment.

García-Arca *et al.* (2015) continued their study by analysing the packaging operations of a company intending to gain cost and loading benefits within the frozen food sector. They suggested altering the orientation of the product in the primary packaging - a tray. As a result, tray resizing was possible which impacted carton resizing at the secondary packaging level. The overall impact of the changes was seen in an increased number of trays and weight of product per carton. At the tertiary packaging level, the pallet efficiency increased by 25%, from 240 trays per pallet to 300 trays per pallet. In other words, 25% fewer boxes required handling for the same level of product demand. Overall, the authors claimed that the company achieved 54% logistics and 46% material cost savings in a year amounting to 52,000 euros.

Olsson and Györei (2002), Kye et al. (2013) and Verghese et al. (2015) focused on the combination of interventions at secondary and tertiary packaging level. For making packing system better serve the requirements of storage and retail, Olsson and Györei (2002) evaluated the new secondary and tertiary level of packaging for 1 litre orange juice. At secondary level, a cardborad box is replaced by a cardboard sheet while at tertiary level, a new plastic pallet, quarter the size of a full standard wooden Euro pallet is propsoed. Though no fill rate evalaution is provided the authors claim that with new packaging system resulst in 65% reduction of cardboard material in the secondary packaging and an 85% improvemnet in handling time in retail and at the distribution centre. However, investments in new pallet design, new operational procedures to handle quarter pallets at warehouse, and risk of product damage, remain open questions to be explored further.

Kye *et al.* (2013) set out to explore the interaction and relationship between a packaging system and a logistical system on the efficiency of freight transportation (EOT). Based on a survey of logistics professionals in the beverage industry the study proved that box-modularity (the standardization of box dimensions for any identical pallet), palletization, developing a returnable system, and an information system make a statistically significant effect on EOT. In particular, box-modularity has positive effects on palletization as standardized boxes reduce a loading space loss on a pallet. Similarly, palletisation has positive effects on EOT, as palletisation helps in achieving economy of scale in freight transportation. Likewise, having an information system enables a company to develop a return system. The study proves very useful to companies that need to redesign their packaging system to improve EOT.

Verghese *et al.* (2015) identified improvements in the packaging in the fresh produce sector in Australia. It was a qualitative study using an interview approach with packaging-related stakeholders. The authors identified options for improvements at all three levels of packaging. At the tertiary level, the authors suggested using retail-ready packaging by using either full or fractional pallets. With the new packaging approach, it was expected not only the product waste would reduce but also intermediate handling while improving floor-ready retail sales. The second improvement suggested was to use shelf-ready packaging as this would result in less handling effort required in the retail stores. This arrangement has a disadvantage as shelf-ready packaging has fewer retail units in secondary packaging meaning more secondary packaging would be required increasing packaging material use and related environmental emissions. Also, using fractional pallets creates extra challenge for warehouse/distributor who primarily deal with storing products on full pallets. Physical handling is also more complicated due to inflexibility on the forklifts, i.e. the gap between the forks (Olsson and Györei, 2002). The study did not explore the unintended consequences of adopting each packaging strategy.

There is also a study that examined interventions at all packaging level. Through semi-structured interviews of logistics, environment, and packaging managers Molina-Besch and Pålsson (2016) highlighted the importance of packaging fill rate as a lever to achieve logistics efficiency. At the primary packaging level reducing air in packaging for small products and redesigning product dimensions may face organisational and technical barriers. However, operational improvements such as adapting primary packaging size to secondary and secondary to tertiary level packaging size can achieve high fill rates, that is, maximising fill rate at each packaging level. Also, the 'mixed pallets' approach, using modularized packaging for small product orders, and minimising packaging material volume and weight can increase fill rate. However, this approach has its constraints, for example, food and cleaning products cannot be combined in single load. This study also highlighted small order size and demand uncertainty as external barriers (as see in e-commerce packaging (Pålsson et al., 2017), while packaging technology lock-in and lack of unified organisational understating of packaging implications as internal barriers. This study did not prioritise any approach or barriers for any specific sector.

In summary, the studies reviewed in the food sector highlight the importance of packaging in improving logistic operations, saving packaging material and emissions from transportation. The packaging fill rate can be improved by designing new boxes, changing the orientation of products in their packaging and using standard packaging units (e.g., pallets and roll cages). Within the food retail category new box design for secondary level packaging seems to be the most attractive intervention (~42% of the total interventions) followed by tactical changes[3] (~31%) in this category, while use of standard packaging items at the tertiary level and primary level packaging intervention are found to be the least attractive interventions (~14% each).

Table 1 provides the packaging interventions and level of packaging considered for each study reviewed in the retail food category.

[3] For example, double stacking pallets, matching shipment, and truck size etc.

Table 1. Retail sector packaging interventions.

Category	References	Packaging level			Interventions
		Primary	Secondary	Tertiary	
Food packaging	Olsson and Györei (2002)	N	Y	Y	Use flat cardboard at secondary level and ¼ standard size connectable plastic pallet
	Jahre and Hatteland (2004)	N	N	Y	Use roll cage
	Hellström and Saghir (2007)	N	N	Y	Use standard pallets and roll cages
	Singh et al. (2011)	Y	N	N	New primary package design
	Kye *et al.* (2013)	N	Y	Y	Use modularised packaging and standardise
	García-Arca *et al.* (2014)	Y	Y	N	New box dimension
	García-Arca *et al.* (2015)	Y	Y	N	Resize tray and box; change product orientation
	Liljestrand *et al.* (2015)	N	N	Y	Match shipment and truck size
	Verghese et al. (2015)	N	Y	Y	Use fractional pallets for tertiary, and retail-ready secondary level packaging
	Liljestrand (2016)	N	N	Y	Use HCV and double stack pallets
	Molina-Besch and Pålsson (2016)	Y	Y	Y	Use modularised packaging
	García-Arca *et al.* (2017)	N	Y	N	New box dimension
	Rogerson and Santén (2017)	N	N	Y	adjustments to fulfilling the demand
	García-Arca *et al.* (2020)	N	Y	N	New box dimension
Non-food packaging	Twede *et al.* (2000)	N	Y	Y	Order postponement; use slip sheets
	Hellström and Nilsson (2011)	N	N	Y	New tertiary level packaging design (loading ledge)
	Wever (2011)	N	Y	N	Product placement in the packaging
	García-Arca *et al.* (2016)	Y	N	N	Improve primary level packaging design
	Santén (2017)	N	N	Y	Use steel racks and parcel cages for uneven good; use stacking
	Georgakoudis *et al.* (2018)	N	Y	N	New corrugated paper box dimensions
	García-Arca *et al.* (2020)	Y	Y	N	New product orientation and redesign of secondary level boxes

Y=yes, N=no

4.2.1.2. Non-food packaging

In this section, we review the non-food item packaging studies within the retail sector. As before we aim to examine packaging design improvements that result in a higher fill rate at a certain packaging level.

From our literature search, only one paper that focus on analysing the impact of interventions at primary packaging level. García-Arca *et al.* (2016) used a benchmarking approach for comparing the fill rate at the primary, secondary, and tertiary levels of liquid detergent packaging from 17 different vendors. An average of 12.5% of the unoccupied volume was found between the liquid detergent and the plastic bottle capacity. However, the unoccupied volume reached ~51% when the liquid detergent volume and the theoretical prism that fits the bottle was compared. At the tertiary packaging level, a comparison between the worst and the best packaging option for pallet loading was made. A difference of up to 377 litres of detergent per pallet and 3,248 litres of detergent per truck between the best and the worst primary packaging was observed. This study showed that the primary packaging inefficiency can cascade into tertiary packaging level along with ramifications in the material handling and storage. By comparing similar product packaging businesses can achieve economic and environmental benefits.

Most of the studies within non-food packaging category focused on either secondary or tertiary level of packaging only. Those who focused on interventions at secondary level of packaging are Wever (2011) and Georgakoudis et al. (2018). Wever (2011) used product densities for consumer electronic goods packaging. Based on their analysis of 1,000 products they claimed that consumer electronic goods should consider cube-out (volume) restrictions as opposed to weight-out restrictions. For achieving higher volume efficiency authors suggest: (i) better product placement in a package; (ii) use volume efficient cushioning; (iii) product redesign to reduce fragility, and (iv) incorporate cube utilization as the leading principle in product design. However, this study does not provide any case in which suggested improvements were implemented and their impact evaluated.

Georgakoudis *et al.* (2018) focused on redesigning the secondary packaging based on the premise that it offers handling and transportation benefits. The dimensions of paper corrugated boxes were changed and the fill rate at secondary and tertiary levels was calculated. In comparison to the base case, bottles carried per vehicle for box option 1 increased by 0.43% while 1.90% for box option 2. Box option 2 packed 4 extra bottles in comparison to the base case and box option 1. At the vehicle level, box option 2 resulted in adding more pallets per vehicle making the packaging weight per vehicle increase (1%) while box option 2 resulted in fewer pallets per vehicle with a marginal (0.33%) decrease of packaging weight per vehicle. However, for box option 2, the total cost of packaging was estimated to be increased ~45 euros per vehicle. The study showed that packaging redesign can result in improved space utilisation of a vehicle but with a cost trade-off to be considered in final decision making.

While Hellström and Nilsson (2011) and Santén (2017) only focused their attention to the interventions at tertiary packaging level. Hellström and Nilsson (2011) compared an innovative load carrier called a loading ledge (a load carrier can be adjusted to product dimension.) to a standardised unit load carrier, the EUR pallet. Using IKEA as a case, the authors demonstrated that the lightweight and modular design of the loading ledge outperforms the traditional wooden pallet. The authors found that for weight-restricted products using a loading ledge increased weight utilisation by 3%. Similarly, for volume restricted products, on average 26% improvements were achieved in comparison to pallets. The authors estimated a reduction in the use of 12m transport trailers by 10,000. Despite weight and volume utilisation gains, there are drawbacks to using a loading ledge. The most critical is that warehouses and material handling equipment are optimised for wooden pallets not loading ledges, hence usage may result in sub-optimal use of warehouse space and handling equipment.

Santén, (2017) investigated the role of product characteristics, order variation and lead time between orders on increasing fill rate for a freight company and a retail warehouse. Three fill rate measures, packaging efficiency, loading efficiency, and booking efficiency were used to gauge the impact of suggested interventions. By analysing historic data and observation for packaging efficiency, they suggested the following interventions: (i) place plastic boxes stacked with a pallet on top; (ii) parcel cages to be used for light, long or unevenly sized goods, and (iii) use steel racks for long items stacked on top of one another. For loading efficiency interventions, they added four extra employees to preload units at loading areas while for improving booking efficiency differentiated booking was adopted for the week such that full truckload (FTL) was booked for the beginning of the week and less than truckload (LTL) for later in the week. With the improvements suggested, the warehouse fill rate improved by 7% while for the freight company it was improved 16% for year-on-year monthly data. This study focused on volume-based fill rate calculations while excluded the weight-based ones. Also, order size uncertainty was not included which plays a major role in matching the load to a vehicle as highlighted by Piecyk and McKinnon (2010).

The remaining of the studies analysed the impacts of interventions at two packaging levels. Twede *et al.* (2000) analysed the impacts of secondary an tertiary level of packaging. They presented the case at Hewlet Packard (HP) printers in their study. Two interventions were highlighted: one packaging operation and the other packaging design related. In the former intervention, packaging activity was delayed till the very last minute before shipment while in the latter one improvement were made in secondary and tertiary level packaging design. With delaying the shipment HP was able to better manage its inventory to demand. With printers shipped in bulk, the secondary package was removed that resulted in 87.5% loading efficiency on a pallet (32 boxed printers per pallet to 60 printers per pallet). At the tertiary level, HP discontinued the use of wooden pallets to use slip sheets. This design intervention further increased space utilisation by adding a fifth layer of printers such that the number of printers transported increased to 75 from 32. Overall, a 25% increase in the total manufacturing, shipping, and inventory costs saving was achieved.

Finally, García-Arca *et al.* (2020) analysed the impacts of interventions at primary and secondary level packaging. They presented a case in which garment arrangement in a primary level packaging was improved. Also, new secondary level cardboard boxes were designed with less volume than the original. The box height was increased to allow more garments to be packed per box. A combination of new garment orientation and redesign of boxes resulted in better space utilisation. A 10% to 20% increase in the number of garments in improved secondary level boxes was found. At the tertiary level, the authors simulated the filling of three containers: 20-foot dry container, 40-foot dry container and 40-foot-high cube container. Their analysis showed that for the best box option, the number of boxes in tertiary level containers varies between 4% to 7%. Further, with the best box option, the number of garments per container varied from 25% to 28%. The authors claimed an average of 25% reduction in logistics cost while no emission savings calculations were provided resulting from less transport use.

Our review of non-food packaging points to fewer studies as compared to food sector packaging within the retail sector. In the non-food packaging category, emphasis again is on the secondary level packaging design to improve fill rate. Only one study, by Hellström and Nilsson (2011), presents a new tertiary level packaging design while others propose to use standard packaging items at this level.

Unlike the food packaging category, tactical interventions are the most attractive option (43%) followed by a new box design at secondary level packaging (29%) in this category. Use of standard packaging items and primary packaging equally the least attractive (14%) interventions. Furthermore, for food and non-food categories both report a lack of packaging interventions at the primary level.

Table 1 summarises the packaging interventions and level of packaging considered for each study reviewed in the non-food retail category.

4.2.2. Industrial sector packaging

In this section, we review the studies that present packaging improvements to increase the fill rate in the industrial sector. Within this sector there is no study that focus only on primary level of packaging. However, most of the studies focus on either analysing the impacts of secondary or tertiary level packaging.

Those who focused on secondary level packaging are Silva *et al.* (2013) and Pålsson *et al.* (2013). In the automobile industry, Silva *et al.* (2013) considered the case of the shipment of automobile engine heads in 20-foot containers from Brazil to the UK. The authors provided a comparison between current secondary level packaging and proposed improvements in the same by using a metal cage. Though the number of products in the secondary and tertiary level packaging did not change (16 engine heads in a metal cage and 416 in the shipping container), an 18% reduction in the use of cushion & wrapping material was achieved. This resulted in less waste and cost savings for the packaging material. One drawback of using a metal cage was weight increase (5.3%) in tertiary level packaging. This weight increase impacted the fuel consumption in the shipping and handling. However, the authors did not explore that line of inquiry but rather claimed that the long life (35 years) of a metal-cage and better volume utilisation of containers on return journey improves the logistical efficiency along with developing customer confidence in the packaging.

Contrary to Silva *et al.* (2013) within the automobile sector, Pålsson *et al.* (2013) suggested replacing returnable plastic box type secondary packaging with cardboard one. The premise of their suggestion was that the cardboard box provides more capacity to pack the product (from 33.8 to 41.98 cubic decimetres). As a result, 25% more items were packed per secondary container. The new cardboard box also resulted in more emission and cost-saving from the packaging supplier to point of use in the automobile plant- a performance measure not considered by Silva *et al.* (2013).

Rogerson and Santén (2017), and Rogerson and Sallnäs (2017) focused on interventions at tertiary level of packaging. Rogerson and Santén (2017) suggested two improvements for energy equipment packaging using data gathered through semi-structured interviews, company internal database exploration on orders and deliveries, and observations of the packing and loading processes. Firstly, to ensure the optimal combination of products in a box and finally to improving the placement of products within the box. The overall fill rate for the energy equipment's packaging and shipping stage combined increased from 49% to 56%. At the packaging level fill rate (volumetric) increased from 74% to 83%. This also resulted in fewer trucks required from eight to seven. Another case of technical wholesale considered by the authors suggested introducing three new load units (plastic boxes, parcel cages, and steel racks) for packaging at the secondary level, rather than continuing to use only pallets. Roll cages were also used to facilitate odd-shaped items for transport. Furthermore, the authors suggested adopting offline loading, which is, arranging goods in the loading area before the arrival of trucks.

While, Rogerson and Sallnäs (2017) surveyed to determine the role coordination of activities within shippers' organisations had in enabling fill rate efficiency. The two case companies included a manufacturer of customised paper reels for the electrical industry and a manufacturer of bathroom sanitary fittings. No quantification of fill rate was presented; however, several strategies were revealed that would enable efficiencies at the tertiary level of packaging. The strategies included: (i) match order size to vehicle/container; (ii) send pallets earlier to loading zone; (iii) leave pallets for a later delivery occasion; (iv) redesign product and packaging to allow for an efficient packing & loading of pallets; (v) devise accurate loading plans; (vi) add extra goods on pallets though not ordered but required at any time in a cycle, and (vii) route planning for delivery.

Most recently, Garcia-Arca *et al.* (2021) in their study identified the best packaging options at primary and tertiary levels for transporting combustion air ventilation tubes. This is the only study that combine more than one packaging levels in our sample. A total of 165 different shapes of ventilation tubes were analysed. The authors developed a heuristic that assigns a ventilation tube design to a specific box with an emphasis on reducing the empty space in a box. This led to the reduction in the number of primary packaging options from 73 to 34 cardboard boxes. It can be inferred from the reduction in the number of boxes required that the fill rate at primary level packaging improved. For the tertiary level packaging, the authors suggested using pallets with improved loading patterns instead of wooden boxes. As a result, a 12% increase in volumetric efficiency for unit load along with gaining an overall costs reduction of 18.5% including transport costs, and packaging purchases was found. Even though transportation cost reduction is often a proxy for fewer trips required, no details of truck loading and potential trips reduction was provided.

Our review of industrial sector packaging studies reveals that the automotive industry is seemingly more active in improving its packaging operations as compared to others. This trend can be attributed to the automotive industry's global sourcing of parts that have to travel long distances to the final assembly line (Itoh and Guerrero, 2020). Furthermore, contrary to the retail sector, the industrial sector is more inclined to improving tertiary level packing.

Table 2 summarises the packaging interventions and level of packaging considered for each study reviewed in the industrial sector.

Table 2. Industrial sector packaging interventions.

References	**Packaging level**			**Interventions**
	Primary	Secondary	Tertiary	
Silva *et al.* (2013)	N	Y	N	Use returnable metal cage
Pålsson *et al.* (2013)	N	Y	N	Use non-returnable carboard box
Rogerson and Santén (2017)	N	N	Y	Energy equipment: the optimal combination and orientation of products Wholesale: match product shape to packaging item
Rogerson and Sallnäs (2017)	N	N	Y	Improve coordination between various sub-units in the company
Garcia-Arca *et al.* (2021)	Y	N	Y	Use standard pallets; improved pallet loading pattern

Y= yes, N=no

5. Discussion

In this section, we present summary insights from our review. We begin with discussing the packaging improvements adopted in each sector followed by future research direction.

5.1. State of the art summary

Retail sector packaging has been researched more often than industrial sector packaging. This strong focus can be attributed to the size (volume) of the retail sector as well as packaging fulfilling the business-to-business and business-to-consumer needs. Within the retail sector, food packaging, frozen or chilled food, is most often the subject of packaging improvements as compared to non-food packaging. The industrial packaging studies however are more diverse in their focus as compared to the retail sector. Such that industrial packaging varies in its subject matter from automobile to energy to industrial level heat ventilation and air-conditioning equipment packaging. Unexpectedly, there are few studies in the automobile sector although the automobile sector transports, handles, and stores components bought all over the world and brought to the car assembly line.

Our review confirms poor fill rate in packaging. This poor performance is not limited to any single packaging level rather it exists throughout the packaging system and progresses into freight transportation. As a result of the low fill rate, it has been a challenge to reduce the need for transport journeys and the resultant CO_2 emissions.

At the primary packaging level, the interventions are more on the design and selection of more sustainable material. The foremost design consideration is protection, such that the chemical interaction of packaging and the product is minimised as well as the product and packaging waste. As expected, primary level packaging emphasis on consumer side functionality (fulfilling the promotion, information, and convenience requirements) of packaging as opposed to the logistics side including the fill rate.

At the secondary level, the literature focus is on using corrugated boxes. The interventions are in modifying the box's dimensions (either one or more) to reduce the unutilised space improving the fill rate. It is found that there can be more than one level of secondary level packaging depending on the type of product being packed.

In terms of comparing the number of interventions and packaging level, we found a pattern of improving secondary level packaging in contrast to the other two levels. Further, tertiary level packaging is not investigated as much as primary or secondary level. One possible explanation could be the standardisation of equipment (roll cages, pallets, containers) to achieve cost minimisation goal (Kye *et al.*, 2013) and the desire to develop a returnable tertiary packaging system (Meherishi *et al.*, 2019).

5.2. The gap in the packaging studies and transport

In this section, we highlight areas within the packaging design and logistics that have not yet been explored and thus represent opportunities for future research. We have grouped them into the following categories: packaging level; transportation; material handling, and organisational.

Packaging level: Studies focus on only one level of packaging interventions. Simultaneous or multi-level improvements, like primary and secondary or secondary or tertiarily level, are not considered. Likewise, reducing the number of packaging levels was not investigated. Eliminating a packaging level has strong cost and environmental implications (Rogerson and Santén, 2017). Within the packaging level, tertiary level packaging is addressed the least. There is, thus, a significant potential to improve fill rate by improving tertiary level packaging design. This becomes more relevant as the tertiary level packaging impacts truck space/weight utilisation. However, this lack of improvements explored can be attributed to the drive towards standardisation of tertiary level packaging as it minimises the cost of procuring transportation resources (Jahre and Hatteland, 2004).

Transportation: Linked to the previous gap identified, our review found that the impact of packaging interventions effect on vehicle journeys required is limited. The scope of studies needs to be widened to include vehicle journeys required. Also, adapting packaging design to vehicle dimensions needs to be explored further. By focusing on this key area underutilisation of a transport resource can be minimised resulting in economic and environmental gains.

Furthermore, there is a need to evaluate packaging improvement with operational strategies, like postponement and packing several products together on a single load carrier to find the impact on a vehicle fill rate and number of trips required (Brandt and Nickel, 2019; Qu et al., 2022). This evaluation become more important with significant increase in the e-commerce and e-grocery demand.

Materials handling: Packaging improvements can have a significant effect on material handling activities. Current literature in packaging improvements does not consider its effect on warehouse operations such as receiving, storing, retrieving, and loading and equipment used. There is a need to evaluate packaging improvements (e.g., size, weight, material used) on warehouse operations including its effect on handling equipment such as automatic palletisers, forklifts, and conveyers etc. The managerial implications and value of such an inquiry lies in time, space, and energy savings that can or cannot be achieved from packaging improvements.

Organisation: The present focus on packaging improvements to a single level indicates incremental innovation to be the dominant structure in the packaging design domain. This points to an organisational mind-set lock-in to product development ignoring the competitive advantage packaging design development can bring to whole supply chain. This inclination needs to be changed to adopting a systems perspective in packaging design development, including logistical considerations along with product and environmental safety (Qi et al., 2021), and product marketing (Panigrahi et al., 2019). Likewise, companies need to consider and value a dynamic approach to packaging improvement-periodically review their packaging and evolving business environment. Another area to explore in the context of new packaging with improved fill rate is how the relationships between packaging supplier and user change and how they should be managed. Finally, with the organisation context there is lack of studies that investigate the role of regulations or industry guidelines development governing the extent of empty space in a package.

6. Conclusion

Our aim in conducting this review was to identify interventions at all three-level of a packaging system that would lead to an increased packaging fill rate. The improved fill rate reduces the required number of freight transport journeys resulting in the decarbonisation of freight operations. The review revealed two distinct sectors that are engaged in packaging improvements. These sectors are (i) retail, and (ii) industrial sector. However, the retail sector is found to employ more packaging improvements in comparison to the latter one. Within the retail sector, food packaging is addressed more due to its size and stringent requirements against physical shock, contamination, and maintaining optimum temperature control. Packaging improvements are focussed more on the secondary level while primary and tertiary levels have seen limited innovative solutions. Furthermore, economic cost saving is the predominant metric for assessing improvement for all levels of packaging. Our review showed that packaging improvement is very product specific. Along with the design changes to packaging, the literature points to several operational strategies that can be leveraged to improve the packaging fill rate at the tertiary level.

Our contribution lies in identifying the sectors and specific application domains where packaging interventions have been implemented. We present a library of interventions which can be used by mangers to adopt or benchmark their packaging operations. Likewise, in our review we also identified any drawbacks or challenges managers may face while adopting a particular intervention. Our review of packaging intervention is equally significant for e-commerce. The recent growth of e-commerce, accelerated by the COVID-19 pandemic, made an even stronger case for packaging improvements. Smaller mixed orders, and shorter lead time requirement calls for quick and efficient packaging solutions. Choosing a suitable packaging with high product fill rate requires less void filling material, saves resources (labour time and material usage) and overall achieve cost and environmental competitiveness (Vieira et al., 2021).

Like any other study, our review has some limitations. Firstly, our inclusion criteria are limited to work published in the English language and peer-reviewed academic journals and edited book chapters only. Conference proceedings, technical notes, books, packaging-related magazines, patents, etc. were excluded from our review. Secondly, although we used a combination of keywords for literature search, this review can be enhanced by including new terms such as “box fill rate”, “tote fill rate”, and “container-box fill rate” from the packaging area and “distribution”, “transport”, and “handling” from the logistics area. Finally, our search of the literature was limited to online scholarly databases, namely Scopus and EBSCOhost. Other scholarly databases like Web of Science could be included to expand the literature search.

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