

Life-Centered Concurrent Packaging Design: Integrating Packaging, Product, Logistics Process and Supply Chain

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Abstract

Using a life-centered packaging design approach in the context of packaging applications for consumer goods, this paper presents a conceptual model for the concurrent development of packaging, product, logistics process, and supply chain (SC). The objective is to enhance the understanding of packaging logistics and logistics management in SCs and to identify current packaging logistics issues in the SC. The four-dimensional concurrent engineering (4DCE) framework, based on the alignment of and interaction between SC, logistics, packaging, and product, is used to increase overall SC efficiency. The model is applied and tested via three case studies within different industries. The results indicate improved understanding and knowledge-sharing between SC actors, with collaborative efforts leading to an increased overall SC performance.

Keywords

Supply chain

Logistics

Packaging

Competitiveness

Coordination

Introduction

In increasingly competitive environments, a business can survive and succeed only if it can fulfil the challenges of the present demands regarding logistics (Azeez & Al-Tayar, 2021). For supply chain managers, this involves interaction and coordination with other businesses, working to minimise costs and create effective logistics and distribution operations which provide customer value. Channel arrangements move toward managerially coordinated initiatives to increase efficiency, continuous improvement, and competitiveness (Freichel et al., 2020; Bowersox & Closs, 1996). While increased competitiveness and efficiency have great potential for the businesses involved, there is high complexity as the number of interactions in coordination and collaboration increases (Bode & Wagner, 2015).

In light of life-centred packaging design which is understood as a collaborative, inclusive and holistic design approach (Feng et al., 2018), this paper explores the potential to integrate packaging with the concept of concurrent development of product, process, and supply chain (SC), as suggested by Fine (2009), Ellram et al. (2007) and Ellram & Stanley (2008), to obtain a more holistic packaging design solution. This research takes on the challenge of integrating packaging and extends the concept into the four dimensions of the product (Dahmas et al., 2019), packaging, process and SC. Supported by empirical data, the paper proposes and explores a conceptual model which aims to contribute to a better understanding of the interaction and potential integration of a packaging system when applying concurrent engineering practices. Specific packaging performance in the SC results from an interwoven network of aspects, often partly unknown in the design stage but with implications for all the actors involved in the SC. However, it is difficult to systematically identify and convert all impacts into helpful information for further packaging development.

The objective of this paper is to enhance the understanding of packaging integration in the SC using a life-centred holistic packaging design approach; and to develop and apply a conceptual concurrent engineering model that integrates packaging, product, logistics process and SC to improve overall SC performance. A conceptual model is developed based on a literature review and three case studies.

Literature Review

The role of packaging is gaining strategic importance as it covers both potential customer value enhancement and cost-efficiency aspects (Lockamy, 1995; García-Arca et al., 2017). In addition, the overall increase in the trade of products has led to an immense demand for efficient packaging which functionally and commercially performs at the right time (Blackwell, 2017) and in the right place. Another concern is the changing role of packaging (Coelho do Vale & Verga Matos, 2015; García-Arca et al., 2017; Prendergast & Pitt, 1996), including sustainability concerns, fierce global competition, future legislation, increased product returns, and customers' environmental consciousness.

Efficient performing packaging increases logistics efficiency. A packaging system often has its unique impact performance profile, indirectly impacting the overall SC performance (Chan & Chan, 2010). Consequently, with significant impact stemming from indirect effects, monitoring the packaging system's overall performance is problematic (Pålsson & Sandberg, 2021). Minor modifications in the packaging system could have a significant impact on the SC. However, such impacts are not always easy to detect, and this may cause inefficiencies and create unnecessary waste, product damage, and costs (Fugate et al., 2006).

Packaging is an essential component in the SC (Lockamy, 1995). It facilitates efficiency for businesses directly involved in SC activities by increasing product safety and protection while providing added value by passively selling the product. Packaging thus involves many considerations and often brings with it conflicting or at least challenging demands and requirements. These must be known and jointly managed, or at least considered, by the actors in the distribution system to achieve a sustainable and efficient flow of products to the consumers (Abbasi & Nilsson, 2016).

A holistic view is required to understand packaging system performance within the SC (Vernuccio et al., 2010; Twede, 1992). Similarly, Min et al. (2019) concludes from a process perspective that, in the development of new products, logistics processes have a strategic role to play. Chapman et al. (2002) conclude that increasing knowledge-sharing with logistics functions and providers in the SC increases efficiency. Achieving greater efficiency, increased customer satisfaction, and better strategic planning can lead to more flexibility and adaptation to market changes, rapid and flexible SC management processes, and other benefits which lead to rapid innovation capabilities. Coles & Beharrel (1990) state that "with high distribution costs, increased profitability from product or packaging innovation can be wiped out immediately if new packaging units do not fit existing distribution systems". Failure to consider distribution and logistics aspects in the development process may be very costly, especially if special handling is needed, warehousing procedures are unsuitable, or a complicated, inappropriate distribution system is chosen. As a result, rethinking distribution and logistics processes can create innovation potential for packaging by focusing on handling, delivery, hand-over and service features to the customer/consumer. In line with this suggested rethinking, Fine (2009) presents the concept of three-dimensional concurrent engineering (3DCE), in which the product, process and supply chain are designed in parallel. Dominic et al. (2000) and Bramklev (2007) both suggest an integrated product and package development procedure model. They state that it is preferable to consider the functional decomposition of a product and its package when specifying the product. Dominic et al. (2015) focuses on product strength versus packaging mechanical protection properties. The integrative aspects will depend heavily upon the product sector, where joint modelling of product and package can lead to technical, organisational, process, and goal-oriented modifications. When the market segment is also known, relevant measures to integrate product, packaging, logistics processes and SC at the operational level could be outlined. Thus, packaging could be integrated and become the fourth dimension in concurrent engineering (4DCE).

Methods

The tool Packaging Scorecard (PSC) (Olsmats & Dominic, 2003) was used in the case studies to evaluate the concurrent packaging performance in a specific SC. The focus was on partially conflicting yet crucial criteria for the actors involved in a specific SC. The performance level for criteria i for actor j is denoted as τ_{ij} , and each performance criteria i ($i=1$ to n) is assigned a weight factor γ_i . The model systematically evaluates performance criteria and indicates the performance of each actor, which can then be summarised to a holistic SC level, schematically illustrated in Figure 1. The model can be represented using the following formulas:

$$A_1 = \sum_{i=1}^n \gamma_i \tau_{1i}, \quad A_2 = \sum_{i=1}^n \gamma_i \tau_{2i}, \quad A_3 = \sum_{i=1}^n \gamma_i \tau_{3i}, \quad \dots \quad A_N = \sum_{i=1}^n \gamma_i \tau_{Ni} \quad (1)$$

where:

A_N = Total packaging performance score at Actor N in the SC

γ = Performance criteria weight

τ = Performance score

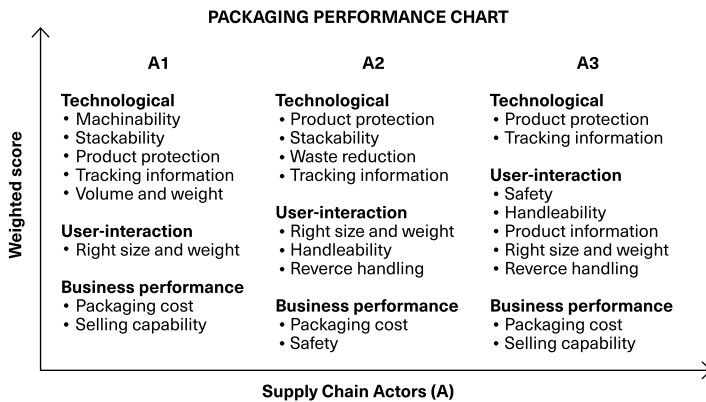


Fig. 1
Bar charts indicating packaging performance and criteria for different SC actors.

The packaging system involves many actors, and Fig. 1 illustrates an example of how the packaging system performs for three actors in a supply chain. The requirements for each actor are classified as Technological, User-interaction, and Business performance related. Finally, the weighted score for the requirements are summed up to indicate overall performance.

Four-Dimensional Concurrent Engineering (4DCE)

To increase the efficiency of the SC, alignment between the logistics processes, product and packaging system is suggested and conceptualised in the developed 4DCE framework. The 4DCE has its basis in the interaction between SC, logistics, packaging and product, where a correct alignment between them can enable effective and efficient operations throughout the SC. The actors within the SC should work together to satisfy customers' requirements and needs through deliberate coordination and self-organisation. At the same time, each actor is typically primarily interested in making their processes efficient and, as a result of this risk to sub-optimize the whole SC with their specific demands on the packaging level, that they primarily interact with within the SC.

Consequently, when it comes to the packaging system, no single actor has a holistic approach regarding the SC. No one actor owns or controls the overall packaging system or the entire logistics processes. Therefore, a concurrent approach can facilitate SC actors to work together with a focus on packaging-related problems. The concept of 4DCE could facilitate such interaction and thus improve overall SC efficiency.

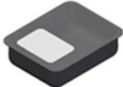
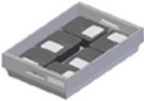







The 4DCE framework starts by evaluating the SC's packaging using PSC. The SC actors can interact with the overall and specific assessment results, aiming to increase efficiency through reflection, discussion and creation of packaging modifications, process improvements and/or SC set-up changes. Dialogue is encouraged and processes are incorporated to facilitate focused meetings. From this interactive process, outcomes emerge concerning modifications and reengineering as well as results which indicate increased understanding and knowledge-sharing between the actors. Hence, the overall performance of the SC can be increased as participants broaden their understanding of and become integrated within the SC.

Case Studies

To explore the potential of 4DCE, empirical verification and testing of this concept have been crucial, as suggested methodologically by Eisenhardt & Graebner (2007). This has been done through three in-depth, action-oriented case studies, as defined by Yin (2018). The case studies were carried out within three different industries present on the Swedish market: brewery, vitamin-producing industry (non-pharmaceutical), and fresh food industry. Each case study has served as a different data source, providing rich data for further quantitative and qualitative analysis or, as Dubois & Gadde (2014, p. 555) states, a relationship between "everyday language and concepts". Snowball sampling was applied to select the informants. The initial informants were packaging and logistics managers who introduced informants involved in solving strategic and operational tasks in the SC, e.g. packaging and development manager, supply chain and sourcing manager, transport and operation manager, technical manager, and sales and marketing manager at different SC actors.

The informants provided multiple data and perspectives for the studies. In-person visits were used to collect data for the PSC assessment through a series of unstructured and semi-structured interviews. Each interview was recorded, transcribed, and documented in written reports. The key informants were asked to verify that case facts were accurate and possible uncertainties were subsequently clarified by telephone. The interviews were printed and analysed based on the thematic areas of the PSC framework, and the packaging system performance was assessed. A report and presentation material were created as input for the subsequent meeting with the SC actors. In all cases, workshops were held, in which participants were given information in advance about the PSC assessment results. The workshops then focused on identifying and prioritising improvement potential in the SC from a packaging and product perspective. One of the participating researchers documented the workshops and analysed them afterwards based on content, process and outcome. One case study is presented below as a representative example.

The case study from the fresh food industry, in which the holistic packaging development concept has been used (see Tab. 1), will be presented in more detail in the following.

Case Studies	Primary packaging	Secondary packaging	Packaging system	Performance indicator value
Fresh food industry				2,63
Vitamin industry				2,83
Brewery industry				2,33

Tab. 1
Case study packaging systems studied for three industries. Performance value based on PSC evaluation.

The primary packaging in the fresh food case was a plastic tray with a lid, sealed with a label which provided information for logistics activities and the product. Secondary packaging was a reusable tray; tertiary packaging was a plastic pallet. The performance value is the current performance of the packaging system measured by applying PSC.

The retail supply chain for the fresh food product was a network consisting of various stages: packaging suppliers, product fillers, distribution centres, warehouses, convenience stores, supermarkets, and hypermarkets. A reusable system for plastic pallets was implemented. The product-filling actor adapted multiple sourcing strategies to avoid disruptions in the product-filling process and guarantee a continuous flow. There were reverse logistics systems to reuse or recover secondary and tertiary packages. Fig. 2 shows a

consolidated flow of how packaging is filled and assembled at the product-filling actors, re-packed by the distributor, and disassembled by the customer.

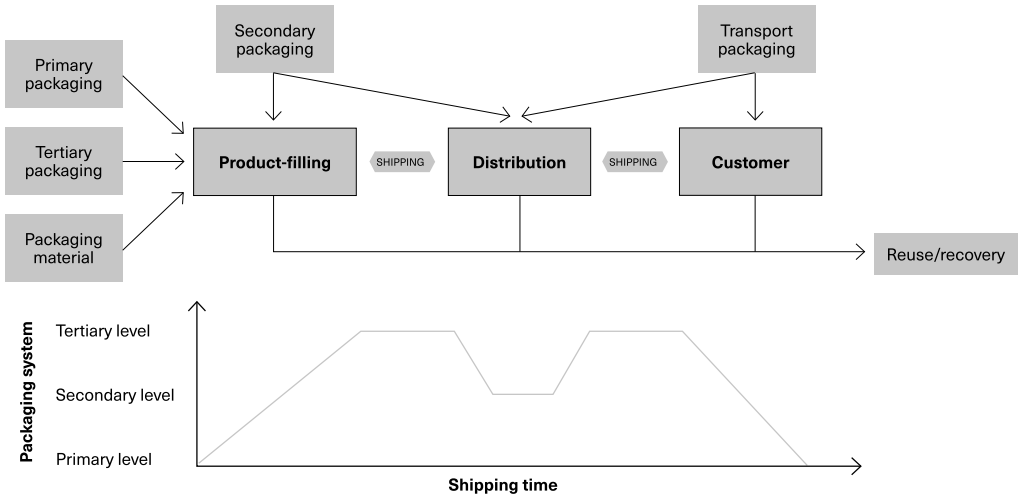
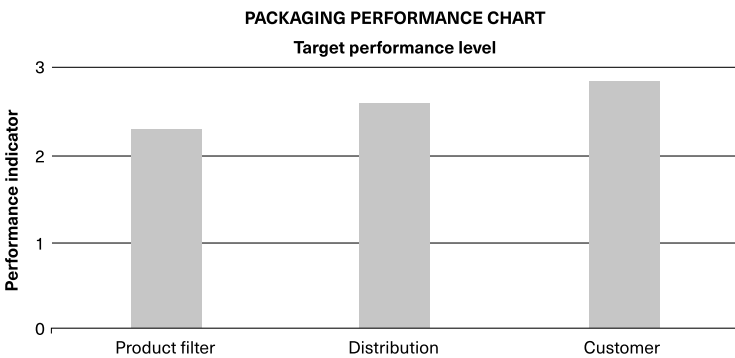


Fig. 2 Illustration of how the packaging system is mounted, and interactions with the SC.

There was a joint perception by SC actors that the packaging system was performing unevenly, underperforming in some functions and overperforming in others. Based on this perception, the target performance level jointly agreed by SC actors was three (out of four) in the bar chart corresponding to neutral performance, neither over- or underperforming, in all functions at all stages in the SC. Fig. 3 presents the results of the packaging system for fresh food by consolidating the performance for each SC actor. The packaging under examination was, at an aggregated level summarising all performance criteria, underperforming at all stages within the SC.

Fig. 3 Aggregate results for the fresh food case study.



The bar charts in Fig. 4 show the normalised criteria sorted in descending order for all the criteria, which the three main SC actors weighted. The packaging performance scores indicate a value for each criterion on the SC level.

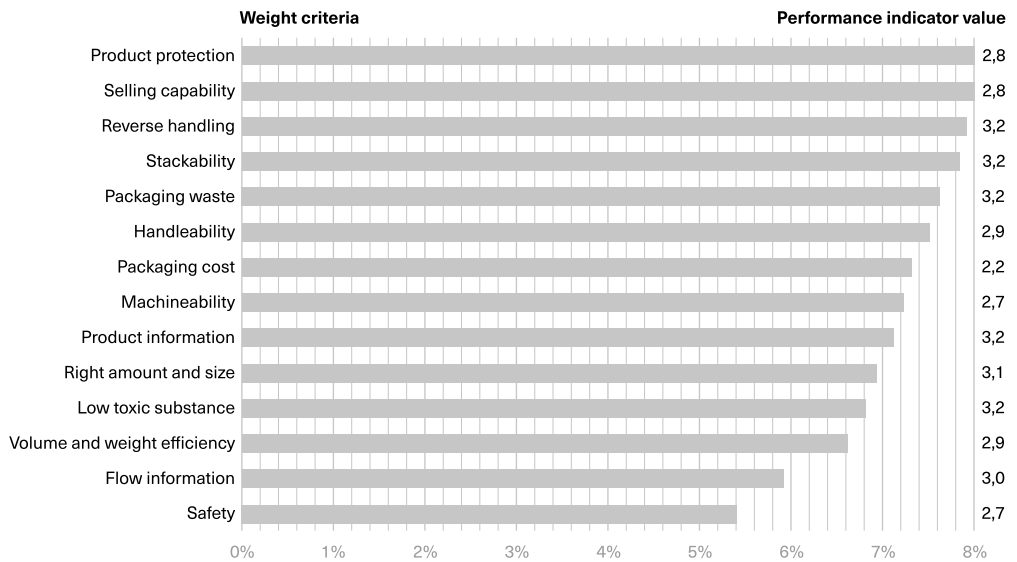


Fig. 4 shows that the most essential criteria were selling capability, product protection, reverse handling, and stackability. However, the performance indicator values for selling capability and product protection were slightly lower than the target value of 3.0. This underperformance was due to the primary packaging not being fully adapted to the number of products sold or secondary packaging. Moreover, pallets caused slight problems when handled manually, while reverse handling, stackability and packaging waste performance was slightly above target with a score of 3.2. On the other hand, the packaging cost performance indicator was significantly below target.

Fig. 4
Aggregate values for a fresh food case study, sorted by most important criteria and on a weighted level.

The PSC data was used as a starting point for the redevelopment, which was supported by a workshop. The purpose of the workshop was to systematically understand the performance of the packaging systems in the SC, with the support of ocular investigation, and to establish stronger links between the actors interacting within the SC. The idea was to rethink packaging and its interaction with processes and structures in the downstream SC. Several issues and problems were elaborated during the workshop, and suggestions for redesigned packaging solutions and logistics processes were made. Each participant expressed a long-term view towards creating efficiency along the SC.

The analysis carried out by the participants indicated a problem at the distribution centre with the packaging system packed with mixed products which required extra time for re-sorting. It was suggested that secondary packages be clearly labelled with different coloured labels to make the distribution actor's task more manageable. Fig. 5 illustrates how packages containing other products were placed on pallets. Colour-coded labels were added and pasted onto the trays, which helped when re-sorting the trays. This minor adjustment reduced re-packing time at the distribution actor by half an hour per load carrier.

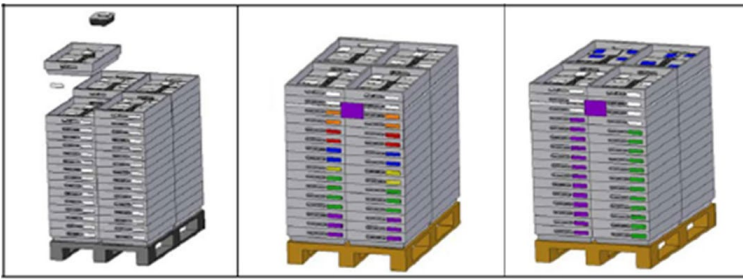


Fig. 5
The white trays (left) show the unsorted fresh food packages arriving at the distribution centre. Coloured labels (middle) made it easier to sort and re-pack the system (right).

By implementing colour-coded labels, the consolidated performance indicator value was raised by 15%. Insights from the other two case studies are to a large extent similar regarding performance impact. The space utilisation and usability for the vitamin packages were significantly improved after a design modification on the primary packaging. For the brewery case study, the product damage occurring during transport was significantly reduced after modifications in the design of the transport packaging. In all cases, improved SC performance and integration between the SC actors has been obtained using the 4DCE approach.

Discussion

Packaging has to fulfil many functions at various stages in the SC, and different actors make demands. Functional demands can be contradictory, e.g., low cost and minimum amount of material versus user functionality and convenience. The impact of a specific packaging design will vary considerably across the SC. It can be both direct and indirect, e.g., a design change to provide better product protection can result in higher direct costs at the product filler and lower direct costs for handling in distribution, as well as lower indirect costs for product damage during distribution. The effects of changes are often hard to assess as SCs habitually lack transparency.

The case studies covered both holistic aspects at the SC level and detailed analyses of the packaging system at various actors. The proposed 4DCE framework was applied by evaluating the packaging system in each process along the SC to obtain and assess each actor's requirements and needs. The PSC was used as a framework for the evaluation. The studies and subsequent dialogue provided sufficient input to rethink the packaging design using a more holistic packaging development approach. Workshops were conducted to elicit input from the SC actors. Based on the PSC assessment, the visualisation of these results was the input for the actors to interact, mainly to create increased efficiency by reflecting, discussing and making packaging modifications, process improvements, or SC set-up changes.

Nguyen et al. (2020) states that meetings, in which representatives from most SC actors focus on discussions of packaging-related topics, are very rare. Instead, mainly two or maybe three significant actors (e.g., customers and product fillers) meet to discuss various business issues, which are then transformed into

requirement specifications communicated to the other actors (e.g., distribution and packaging supply actors). With this partial view and separation of the SC, it is difficult to achieve integrated SCs. The case studies showed that the 4DCE integrative activities were essential in that they were viewed as part of the core of development for improved SC performance based on packaging and its related processes. Modifications and innovations resulted from this interactive process as well as increased understanding and knowledge-sharing between the actors.

Conclusions

In this paper, an approach for 4DCE has been proposed and tested via action-oriented case studies. The performance evaluation part of the concept is based on the PSC framework and is an extension of 3DCE. The 4DCE approach can contribute to packaging logistics theory and aid practitioners by suggesting an approach to balance and trade off conflicting packaging demands and functions to reduce sub-optimization for overall SC performance. Small changes in a packaging system can often lead to significant changes for the entire SC, thereby increasing (or decreasing) SC efficiency. Furthermore, the holistic packaging development concept is supported by transparent knowledge of the packaging system, how it interacts with its actors, and performs to fulfil requirements along the SC. In line with the above, it can be argued that 4DCE can be a valuable approach to support life-centred packaging design, understood as a collaborative, inclusive and holistic design approach with a view to the entire life cycle of the packaging system within the SC.

This research has certain limitations which can be addressed in future studies. For example, even though the case studies indicate that the 4DCE approach provides valuable data for packaging development processes, there is a need for broader studies within different industries to enable a generalisation of findings. Further research could also strive to deepen the analysis of the concept. Moreover, it might be interesting to develop studies which consider applying new technologies, such as rapid prototyping, to present at workshops involving SC actors to further boost the generation of life-centred innovative packaging concepts. This can be potentially useful when it comes to improving overall SC performance.

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