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ON THE LOGISTICS EFFECTS OF INTEGRATED PRODUCT AND PACKAGE DESIGN

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ABSTRACT

If engineering designers consciously design product and package in an integrated manner, there is a great potential for industrial global enterprises to develop and produce mechanical products, such as exhaust extraction systems, car washer machines and fuel handling systems while simultaneously obtaining error-free deliveries, saving costs and avoiding quality problems. Thus, the authors of this paper see a challenge in developing the theory and methodology for Integrated Product and Package Design. In this paper we take a first step in this direction. Firstly, we have carried out a broad review of literature, which shows that there is a need for research into Integrated Product and Packaging Design. Secondly, we have analysed three cases from industrial practice, which show that a conscious and integrated design of product and package has positive logistics effects, whereas neglecting this issue might result in higher costs and quality problems. On the basis of these cases we have made an initial cross-case analysis, which indicates that it is possible to develop the terminology and methodology for Integrated Product and Package Design.

Keywords: Package, Packaging, Design process, Case

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1 INTRODUCTION

Deregulation and expansion of trade in the world economy in combination with increased competition has created new markets for producers of goods and packaging. Enterprises that previously confined their business activities to national markets are now focusing on broader international markets, thus forming the establishment of *global enterprises*[1]. [1]

One issue of importance to global enterprises is the operational management of their business in a network of functions and/or divisions, e.g. product development and assembly and production, which are separated geographically around the world. One consequence of this is an increased demand for transportation, handling and storage of parts, sub-assemblies and final products between enterprise divisions in a way that ensures error-free deliveries, protection of parts and products, and compliance with respect to environmental standards and regulations for the package. One means to manage this problem in an effective and efficient way could be to develop the package in order to facilitate simplifications in the design of the product by allowing the package to take over supportive product functions during the distribution phase of the product life cycle. In other words, the product and the package are seen as an integrated system of two components, a Product-Package-System (PPS) [2].

In order to meet these product life-cycle demands in the global enterprise, one issue is to facilitate the package design and the product design to be designed as one system. For the same reason, the authors of this paper see a need to clarify package design terminology and to develop methods of Integrated Product and Package Design. The main objective of our research is to contribute to the development of a theory of Integrated Product and Package Design. In this paper we take a first step in this research by

[1] *Global enterprises* are here defined as enterprises doing business on more than one market at the same time in addition to *international enterprises* doing business outside their original national market.

focusing on the effects of a "Design of P&P for Logistics" approach (where P&P stands for *Product* and *Package*) by analysing a number of best and worst case practices.
The first part of the paper is a review of literature related to the concept of Integrated Product and Package Design, followed by a description of the methods used for the compilation and use of the case-study database. Subsequently, product cases are described and analysed by means of a “gallery technique”. Finally, the results are summarised and the conclusions are discussed.

2 RELATED WORK

In this section, the authors would like to illustrate the novelty of the research undertaken in this paper. We embark on this below by identifying and describing the existing theoretical contributions that primarily concern the concept of Integrated Product and Package Design in the following three settings:

- The interfaces between product design and package design.
- The interfaces between product and/or package and the logistics activities of the life-cycle phase system (LPC system).
- The interfaces between product and/or package and the actor(s) in the logistics activities of the life-cycle phase system (LPC system).

The theoretical areas reviewed are: *Engineering Design, Industrial Design, Logistics, Manufacturing Process Design* and *Packaging Technology*.

2.1 Engineering Design

Engineering Design provides the terminology, models, procedures and methods for a rational control of the design process, but also a structure and recommendations for the use of technical knowledge.
The theoretical contribution within this field has traditionally not included the design of the package, or the *interfaces of product and package design*. As the demands for logistics adapted products have increased in the industrial setting, discussions concerning related issues have also intensified within this field. For example, Bjärnemo et al. [3] suggest that Packaging Logistics should be integrated into the product development process, which facilitates a functional decomposition between product and package, and Bramklev et al. [4] suggest a concept for an integrated design of product and package.
Furthermore, knowledge acquired in Engineering Design stresses the importance of designing the product for all phases of its life cycle, which has resulted in research on the subject of “design for X”, e.g. “design for manufacture” and “design for assembly”. However, regarding the *interfaces between product and/or package and the logistics activities of the life-cycle-phase-system*, Mather [5] is one of few researchers to recognise the potential of reducing costs by planning a *logistically* effective design. Later, Dowlatshahi [6; 7] introduces the necessity of facilitating the interface and collaboration between product designers and logisticians. Dowlatshahi provides prescriptive design rules in four areas: *Logistics Engineering, Manufacturing Logistics, Design for Packaging* and *Design for Transportability* for which he also suggests design factors.
It should be noted that no related work was found on *the interfaces between product and/or package and the actor(s) in the logistics activities of the life-cycle phase system.*

2.2 Industrial Design

Industrial Design is concerned with aesthetics, usability, and ergonomics but can also encompass the engineering of objects, usefulness as well as usability, market placement and other issues. Product Design and Industrial Design can overlap into the fields of User Interface Design, Information Design and Interaction Design.
The review of work in Industrial Design provided the general idea that the *interfaces between product design and package design* are considered for the product and package closest to the product, also termed the “primary package”. These two artefacts are usually considered to be two integrated items for marketing reasons; see e.g. Calver [8], Judd et al. [9], Melis [10] and Sonsino [11]. Other authors also stress that the product and the package are two integrated items that would benefit from joint development; see e.g. DeMaria[12], Esse [13], Harckham [14], Kooijman [15], and ten Klooster [16]. They do not, however, offer detailed descriptions of why such procedures are profitable.
The marketing aspect of the package design seems to be deeply rooted in Industrial Design work, which makes it easy for the field to neglect discussing the *interfaces between product and/or package and the logistics activities of the life-cycle-phase-system.* According to Bramklev [17], packaging

suppliers are struggling with Industrial Design consultants who focus on the primary package design and the marketing aspects to the exclusion of issues concerning the whole product-package system, such as manufacturing and logistics. For the same reason, as for related work regarding the *interfaces between product and/or package and the actor(s) in the logistics activities of the life-cycle-phase-system*, no detailed discussions are found on the subject in Industrial Design research. Some brief aspects are mentioned by Giles [18], who discusses issues involved in the decoration of packaging for fast-moving consumer goods as playing a vital role in promoting the product among customers.

2.3 Logistics

Logistics is the art and science of managing and controlling the flow of goods, energy, information and other resources, e.g. products, services, and people, from the source to the marketplace. Logistics support is the key to improving marketing or manufacturing activities. It involves the integration of information, transportation, inventory, warehousing, material handling and packaging.

Since the field is process-oriented rather than product-oriented, the *interfaces between product design and package design* are rarely discussed. Some attempts to highlight the product and its packages as a system have been made by Saghir & Klevås [19] by means of a concept they denote "design for packaging logistics".

On the other hand, discussions of the *interfaces between product and/or package and the logistics activities of the life-cycle phase system* are more frequent. It is commonly recognized that the package has an impact on the efficiency of such logistics activities as transportation, storage and handling, and on the logistics system as a whole. Bowersox [20] was one of the first scholars to discuss such interfaces. It is also, however, generally agreed that the complexity of the logistics system also makes it difficult to isolate the interfaces and functions of each logistics activity [21; 22]. In support of the systematisation of the logistics system, studies by e.g. Lancioni & Chandron [23] state that packaging is a system of seven interfaces in international logistics. Lambert, Ellram & Stock [24] discuss the trade-offs of the package and packaging costs in logistics activities such as transport, inventory, warehousing and communication. McKinnon & Foster [25] discuss how a modification of product and packaging design influences the utilization of carrying capacity. In addition, Jantzén & Alexander [26] provide a list of logistics activities, establishing package design parameters.

There are some reviews of the *interfaces between product and/or package and the actor(s) of the logistics activities of the life-cycle-phase-system*. According to Hellström & Saghir [27], logistics research needs to focus on the interfaces between package design and the logistics activities on the operational level.

2.4 Manufacturing Process Design

Manufacturing Process research provides important insights into the manufacture of products and packages as well as into the packaging process.

No references have been found to the *interfaces between product design and package design*. On the other hand, there is plenty of research in this discipline on the interfaces between Product Design and the manufacturing process. Olesen [28], for example, discusses how a decision regarding a product design affects the type, content, efficiency and progress of activities along the life cycle of that product. He calls these effects "*dispositional effects*". This notion makes it interesting to assume that aspects of the *interfaces between product and/or package and the logistics activities of the life-cycle-phase-system* may follow the same rules.

There are some specific sources that focus on the interaction between Package Design and the manufacturing process. For example, Johansson & Mathisson [29] study how to utilize packaging configuration in order to obtain a high degree of effectiveness in the materials flow system, and Foo et al. [30] discuss the importance of a concept for designing the product for material logistics.

If we now turn to the aspect of interfaces between *product and/or package and the actor(s) in the logistics activities of the life-cycle-phase-system*, Wärnström & Medbo [31] provide examples of how the package design increases productivity in manual car assembly by signalling its contents to the assembler by means of size and colour. Some complementary work is here provided by Lee & Lye [32], who state that packaging specifications influence the completion time of manual packaging operations.

2.5 Packaging Technology

Packaging Technology is the technology of packaging processes and materials.

Studies performed in the field of Packaging Technology generally discuss the *interfaces between product design and package design* based on the idea that the inherent features of the product, and consequently its performance, are supported by its package during essential parts of its life cycle. Paine [33] is one of the first scholars to establish such a dependence between the two objects and to discuss packaging functions directed towards the product.

This perspective on product and package has also founded research defining and describing the inherent features of the package as a product, ranging from simple wrapping to special-purpose containers, as well as the process of manufacture and filling the package. The package, or packaging, is commonly described as a system of hierarchical structure, divided by Paine [34] and Jönson [35] into a three-level hierarchy consisting of "*primary, secondary,* and *tertiary packaging*." Although Johansson & Weström [36] discuss critical properties of packages in the product-package system, they do not discuss the way in which these properties are designed.

As for the *interfaces between product and/or package and the logistics activities of the life-cycle-phase-system*, one difficulty that has been recognized in research on Packaging Technology is the problem for the package designer to satisfy all the demands of all the logistics activities that the package will be exposed to. This is acknowledged by Prendergast & Pitt [37], who claim that there are trade-offs between packaging functions. Furthermore, Twede [38] maintains that packaging engineers frequently overlook costs derived from the package design in logistics activities, something that Bramklev [17] thinks is caused by their common lack of competence in and knowledge of logistics activities and the product life-cycle system as a whole.

For the *interfaces between product and/or package and the actor(s) in the logistics activities in the life-cycle-phase system*, Twede [39] proposes nine universal principles of shipping containers derived from package solutions from the period of the amphora to the package design of shipping containers.

2.6 Point of departure

Related work recognises *interfaces between product design and package design* in Engineering Design, Industrial Design and Packaging Technology, whereas *interfaces between the product and/or package and the logistics activities of the life-cycle phase system* are most heavily emphasised within areas of Manufacturing process design and Logistics, with some notes in the areas of Engineering design and Packaging technology. Nevertheless, the logistics effects of a certain product and/or package design are not discussed in such a way that designers can make their decisions accordingly during the design process. Nor do studies of the *interfaces between product and/or package and the actor(s) in the logistics activities of the life-cycle-phase system,* which are mainly found within research on Logistics and Manufacturing process design, provide recommendations for an Integrated Product and Package Design mindset. In sum, there is no theory for Integrated Product and Package Design. Therefore we adopt the following two hypotheses:

1. We assume that a mindset of Integrated Product and Package Design should be adopted.
2. In order to describe this mindset, we will identify the dispositional effects [28].

We will take the first step in investigating these hypotheses by performing three case studies.

It should also be noted that, according to the literature review above, the term "packaging" is used both for the artefact and the process. To avoid misunderstandings we here adopt the terminology of Griffin [40], who defines the *package* as an object and *packaging* as the process in which the object is manufactured and subsequently filled with the product.

3 RESEARCH METHOD

In consideration of the objective set up for this paper, the methodological approach adopted is *descriptive.* This approach is here applied as a combination of a *literature review* (see above) and the reuse of a *multiple-case-study* database describing the concept of "integrated product and package design" in its natural setting. This approach is frequently applied in studies collecting a wide variety of, mainly, qualitative data [41; 42], which is here used to increase our understanding of, and to identify, the dispositional effects of package design in the product life cycle. Furthermore, it allows us to build theory by treating multiple cases as a series of experiments where each case either confirms or disconfirms the inferences drawn from the previous ones [41; 42].

To maximize the benefits of the sources of evidence and establish construct validity and reliability, adopted from Yin [42], multiple sources have been used and amalgamated into a case study database with subsequent descriptions of the chain of evidence. In following these principles it should be noted that the case study database used here was compiled within the framework of a master's thesis [43] in close interaction with the first author of this paper.

In order to build a theory of Integrated Product and Package Design, Eisenhardt's eight-step process [41] is chosen, as it is a tested and verified method suitable for inductive, descriptive and positivist research:

Step 1 - Getting started. The main objective set out for the master's thesis case study, whose data have been reused for this study, was:

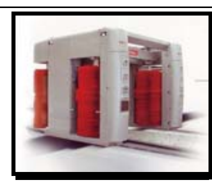
- What are the advantages/disadvantages of integrated product and packaging development?

Relevant for the use of data deriving from such an objective is that the compilation of a database does not mean that the data are less "true", but rather that the objective puts a restriction on the range of what the data can explain. For the same reason it is also here assumed that the objective set for this paper operates within the range of what the case study database used here can explain.

Step 2 - Selecting cases. In building the case study database, *theoretical sampling* is used for the choice of cases and number of cases [41]. To strengthen the reliability of the multiple case results as well as the external validity, literal replication of cases, i.e. what Yin calls "replication logic" [42], is used. Furthermore, since no previous literature or studies could be found on the subject of compiling the case study database, it is not possible to let previous literature help in defining case and unit of analysis [41].

All in all, three cases of privately owned companies developing, producing and distributing mechanical products on the global market were selected (see Table 1 below). Two of these companies are situated in Sweden and one in Spain. Additionally, for the product development process, each company involves different company functions with different disciplinary backgrounds. For each case, the within-case sample is different product cases and their adherent product development process, manufacturing process and distribution process. In this paper, only three product cases are discussed due to a restriction on the number of pages.

Table 1: Product case illustrations

Product case name	*Case 1*	*Case 2*	*Case 3*
Product description	Exhaust extraction systems	Roll-over car washer equipment	Fuel handling systems for petrol stations
Product illustration			

Step 3 - Crafting instruments and protocols. For each case, a protocol is put together in order to increase reliability. This protocol includes a description of the anticipated main components of the study, including an overview of the project, field procedures and instruments, case study questions and general rules that should be observed in using the instruments.

To enhance confidence in the findings and focus a different, and possibly more objective, eye on the evidence, as inspired by Sutton & Callahan [44], two investigators (i.e. the master's thesis students) carry out the operational work of the study, while a third person is exclusively assigned the role of devil's advocate (here one of the authors of this paper). Furthermore, instrument and protocols are based on triangulation [45; 46], here used in a combination of *semi-structured in-depth interviews*, *archival sources* (such as ISO procedures, documents relating to the product development process and intranet information) and *observational technique* (at a minimum, a guided tour of the company facilities). All interaction between interviewer and respondents is also designed to be close, which, according to Clark [47], has also been a valuable mode in industry analyses.

Step 4 - Entering the field. Access to cases is established by means of personal contacts, either because someone high up in the organization was willing to "help out" or because the case description and analysis would be useful for future business. Two to five people were interviewed in each case study, ranging from project leader, development engineer and representatives to manufacturing, purchase etc.

To provide a head start in the analysis, overlapping data collection and analysis are used in field studies. Inspired by Glaser and Strauss [48] to join coding, retrieval and analysis, here *field notes*, in the form of a running commentary and a diary documenting impressions and work procedures, goes through daily *speed analysis*. These results are summarized in the form of a write-up of each case.

Step 5 - Analysing data. Here we reach the point at which the case study database is reused for the objectives set up for this paper. In order for us to become familiar with the data of each case and be able to draw objective conclusions, the analysis for this paper is performed in two steps: (1) within-case analysis and (2) cross-case analysis.

Analyzing Within-Case Data. The first step in the within-case analysis was to become familiar with the data by reading the summaries of the case studies. Secondly, *conceptually ordered displays* were used to find (1) functional descriptions of the package design, (2) descriptions of the Universal Virtues [28] derived from the package design and (3) effects derived from interactions of actor-system-artefact in the product life cycle. The graphical illustration of this procedure is explained in Figure 1.

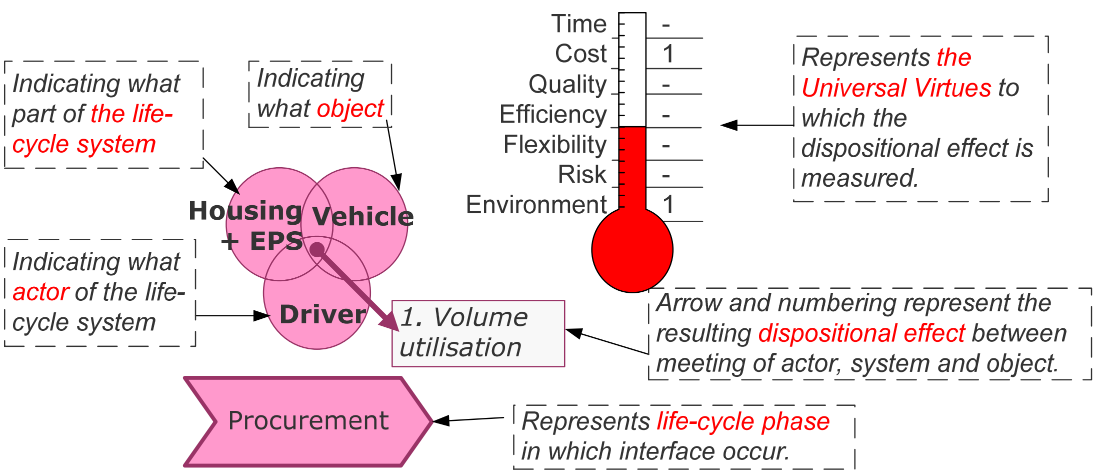


Figure 1: Display of the Gallery technique

In this way the displays help to emphasise well-defined variables and their interaction. In order to uncover the patterns within the data unique to each case and to indicate generalisation through cross-case analysis of the emerging pattern, the following two techniques for case study analysis were used: 1) Matrices of data by data source. and 2) Narrative descriptions of activities involved.

By applying these techniques, the cases could be denoted "worst-case scenarios" and "best-case scenarios" based on the effects resulting from any of the three categories in the conceptually ordered displays. The results of the analyses are presented in Figures 2, 3 and 4.

The third step is to try to find design principles. This will not be treated in this paper due to lack of space, but will be discussed when the paper is presented at the conference. Principles for Integrated Product and Package Design will be treated in detail in a future paper.

Searching for Cross-Case Patterns. To simplify the initial cross-case analysis, the format of displays used in the within-case analysis was selected so that the analyses would be comparable and complement each other [46] and could be compared for differences and similarities, according to Eisenhardt [41].

Step 6 - Shaping hypotheses. In this research, which is a first step in building theory that will be used as recommendations for the operational work of designing product and packaging for logistics, a further step is to formulate hypotheses. Iterating towards this theory, which should fit the data closely, is all about forming patterns, looking at contrasts, clarifying relationships and building coherent understanding.

To establish construct validity, there is an advantage during analysis in using a database consisting of multiple sources of evidence. Thereby measures may be constructed that define the construct and distinguish it from other constructs to be defined. In this way a framework of dispositional effects, derived from the package and product design, will emerge in the product life cycle.

Step 7 - Enfolding literature. Since the results in this study rest on a limited number of cases, one important step before reaching closure is to evaluate the emerging theory of Integrated Product and Package Design. This involves asking what it is similar to, what the emerging theory contradicts and why [41].

Step 8 - Reaching closure. Theoretical saturation is here handled somewhat pragmatically considering the constraints of the case database and time. For example, it is not possible to add more cases due to limited time. However, according to Eisenhardt [41], on the basis of four cases it is possible to create a theory with some complexity and whose empirical grounding is likely to be convincing. Moreover, iteration between data and theory has been avoided when incremental improvements to theory are minimal.

4 CASE DESCRIPTIONS AND ANALYSIS

Below follows a life-cycle system description for each case, from procurement, assembly and testing via packaging, distribution and installation to product use and recycling of materials. An analysis of the interfaces between *product-package-system* (PPS), *an activity of the life-cycle system* and *an actor(s) of that system/activity* is woven into these descriptions. Each interface provides logistics effects in which the design solution is found in the product design and/or package design, which also affects the Universal Virtues [28]. Below, each interface in each case is highlighted with *numbers in italics* in the text and illustrated for each case in Figures 1-3.

4.1 Case 1 - Exhaust extraction systems

This case concerns a hose reel for exhaust extraction systems. The main parts of the product are a *hose reel*, a plastic device used as *housing, a recall spring* and a *ratchet* that locks the reel at a specific point when the hose payout stops.

When it arrives in stock, *the housing* is mounted inside an EPS package. For this solution the EPS package supports materials handling *(1)*, but also serves as a fixture during product assembly *(2)* and supports distribution of the assembled hose reel *(3)*.

For assembly, the housing (with EPS) is mounted on the assembly line. A robot picks and assembles a ratchet (placed in a package consisting of a panel with holes shaped like the piece) to the housing *(4)*. Due to customer complaints regarding EPS recycling *(9)*, the possibility of using corrugated board packages was investigated. However, material changes do not support design of a corrugated box to exact measurements and low tolerances, requirements key to robot picking. A folding machine would also require financial investments. Consequently, the EPS package was retained.

Following, the *recall spring modules* are removed from standard wood pallets with combined wood collars and placed on a plate situated on the floor in the assembly line, from where they are picked up by a robot and assembled to the set housing-ratchet. As the recall springs can uncoil during transport, handling safety imposes the use of standard wood pallets instead of paper boxes. Furthermore, originally a piece of normal paper was placed at the bottom of the wood boxes to collect grease and dust. During distribution, however, dust was generated due to friction between the paper and the recall spring, making the springs useless. To resolve this problem, waxed paper was introduced *(5)*.

The final sequence of assembly is to assemble the hose manually. It arrives wrapped in measures of 6,000-9,000 meters inside an octagonal corrugated paperboard box. Originally, the hose was delivered in 200-metre rolls, with 10 rolls per pallet. Evaluation proved that the amount of hose per roll and pallet increased the metres of (hose) relics wasted for each pallet during assembly *(6)*. Consequently, hose rolls were increased to 6,000-9,000 metres per roll and distributed on one pallet, which contributed to a decrease in transportation volume by 25-30% *(7)* and in costs by reducing hose waste from 30,000 metres/year to 6,000 metres/year (approx. 1-2% waste).

When the hose reel has been assembled, it is tested and the package is closed. For distribution, the packages are automatically loaded on half pallets, each pallet consisting of 45 units *(8)*. However, pallet handling has increased since eliminate the procedure of packing six packaged hose reels into one transportation box, which was then loaded on Euro-pallets, was eliminated. Today's procedure is time-consuming and ergonomically disadvantageous.

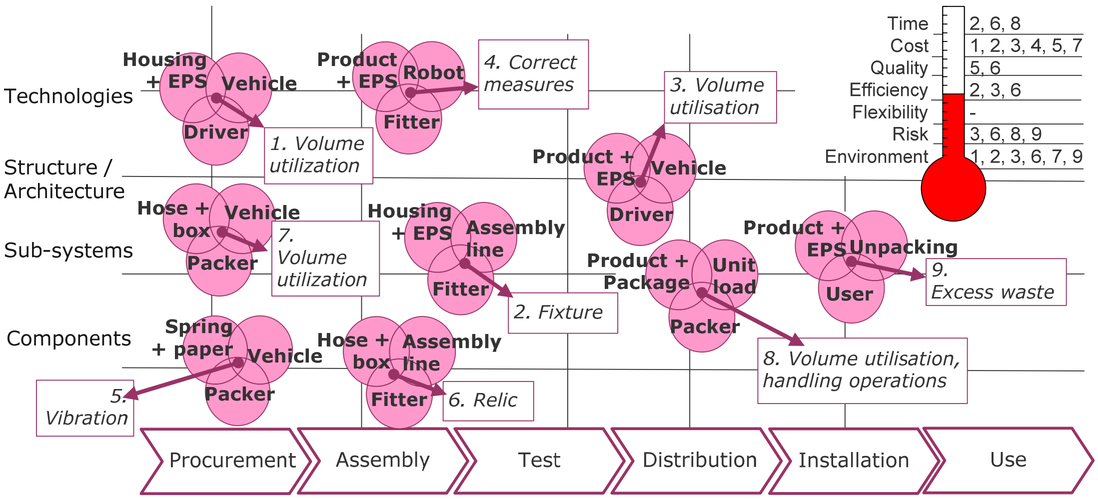


Figure 2. Summary of Case 1 analysis – interfaces and their effects

4.2 Case 2 – Roll-over car washer equipment

This case concerns car washer equipment (roll-over) for indoor or outdoor installations ranging from max. vehicle access of 2.3m(h)x2.35m(w)x5.2m(l) to min. bay size of 3.1m(h)x4.6m(w)x9.5m(l). The main subsystems are the frame (consisting of several galvanized steel parts), five wash brushes placed inside the shop as well as other parts, such as a dryer, the rails and some minor components.

Assembly starts with an order, followed by several working tests and machine approval.

Due to dimensions and weight, the machine must be partly disassembled. For packaging, the (disassembled) subsystems are placed on a platform supporting the entire equipment. Holes that are coincident in the product design and the platform are used *(11)* to fix the subsystems during transport. These holes are used to fix the product both during distribution and for installation *(12)*, thus eliminating additional elements or operations (e.g. drilling) on the components during production.

Subsequently, the wash brushes are covered with meshes to protect against the risk of deformation during handling *(10)*, and loose parts are packed into a corrugated box placed in the empty space between the structures placed on the platform. Regarding the distribution of the packaged product, it should be noted that the structure of the car washer machine itself includes several rings designed for handling the equipment.

In order to reduce installation/assembly time by reducing the number of operations, the product was redesigned to fit six different disassembly/assembly patterns. This increased flexibility in the choice of transportation mode and truck equipment *(13)* and reduced distribution costs by 25% along with a 22% reduction in packaging costs and a 7 % reduction in damage costs.

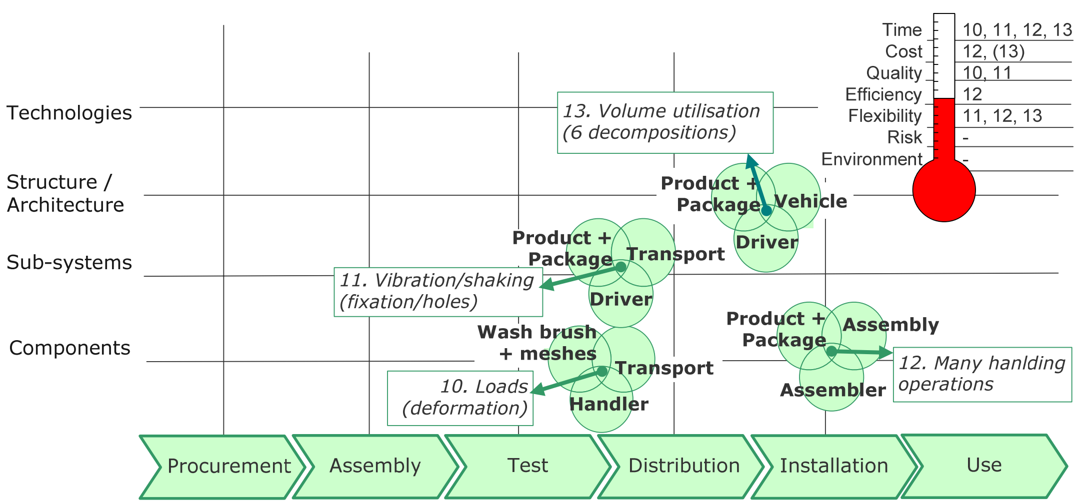


Figure 3: Summary of Case 2 analysis – interfaces and their effects

4.3 Case 3 – Fuel handling system for petrol stations

This case is concerned with petrol pump equipment. The product is a 390 Kg gasoline pump of 1.25m(l)x0.52m(w)x2.2m(h). Its capacity is approx. 40-130 litres/min., depending on model, hardware, connecting dimensions, pipe length and pump-suction height.

The assembly of the gasoline pump starts with the standardised wooden pallet on which the gasoline pump frame is assembled *(14)*, with a number of hydraulic pumps, and distributed *(15)*. Subsequently, the frame, computer box and gas hoses are assembled. Finally, tests of the pump electronics are performed, the pump is approved and the packaging process starts.

For packaging operations, an accessories box is placed under the electronic head. The lower part of the pump is wrapped with bubble film to avoid scratching it. Two sheets of corrugated board are placed along the sides of the pallet and fastened to it. The pump and sheets are covered with a plastic hood. This hood protects the corrugated cardboard from humidity and prevents the pump from becoming soiled during handling, transport and storage. Finally, a stretch film is applied to keep the hood in place. To prevent the stretch film from gripping too tightly around the cardboard, a pre-stretched film is used. Finally, two stickers with information about potential problems in handling the product are placed on the film. This procedure is the result of a package redesign some time ago. An evaluation revealed that the former package-product system exceeded the measurements of the standardised wood platform/pallet *(15)* and that the cost calculations for the package materials were far too high. The redesign reduced the outer measurements by means of an exchange of package materials, which increased protection in conflicting product areas, reduced material costs by approx. 72%, decreased the time spent on the packaging procedure and improved the warning to the handler to be careful by visualising the content *(16)*.

The distribution of the gasoline pump is mainly performed by road and truck. Little is known of what happens after the trucks leave the company, nor are any distribution tests performed. The first crucial problem caused by this situation occurred a few years ago, when the company decided to go international. Customers subsequently began to complain about products arriving in poor condition, which turned out to be the result of the magnitude of loads and other environmental conditions confronting the pumps during handling and transportation. One difficult problem was the vibration effects caused by very bumpy roads *(17)*. An analysis showed that the fastest and cheapest way of solving the problem(s) was to redesign the package, and not the product, and thereby complement the product by facilitating extra protection of the product design.

In this discussion of the mindset of integrated product and package design, it should also be noted that production costs recently increased due to the mistake of designing a new product larger than the measurements of the standardised wooden pallet/platform used in production and as a distribution platform. This increases the costs of the entire distribution system due to less efficient space utilisation in the transportation mode *(15)*. It also leads to decreased handling efficiency in assembly and production due to the use of several platforms *(18)*.

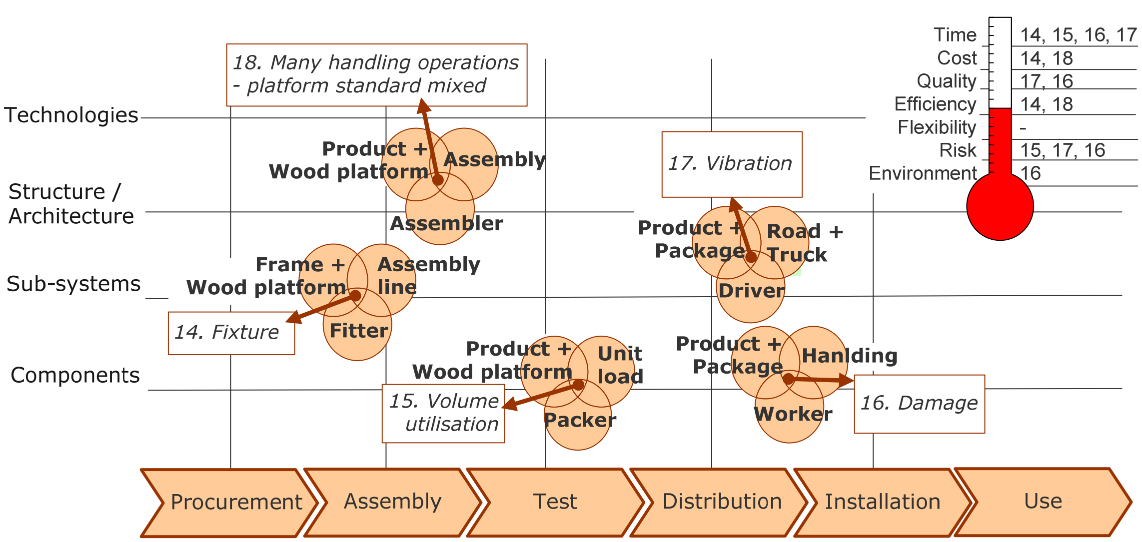


Figure 4: Summary of Case 3 analysis – interfaces and their effects

5 RESULTS

The case studies described above provide interesting results regarding best practise and worst-case scenarios that contribute to the achievement of the objectives set for this paper. According to the analysis, the interfaces between *product-package-system* (PPS), *an activity of the life cycle system* and *an actor(s) of that system/activity* describe several effects over a number of different activities on different levels of describing the product/package design.

Some effects are found on the conceptual level of the product, i.e. man-machine interface, functions, procedures and use of technology. In Case 1, for example, the choice of an automatic assembly and robot picking of the recall spring to the housing resulted in fixation of the product, which is here provided by the EPS package. The same choice of technology also has an impact on the choice of material, since corrugated paperboard boxes cannot be designed with sufficient tolerances and measures due to material changes. In other words, here the choice of technology affects the choice of material, which results in time and costs advantages of logistics activities in both procurement and assembly.

Other effects are found on the structural level of the product, i.e. sub-systems and product and/or package architecture. Case 2 illustrates how a conscious mindset of integrated product and package design provides six different disassembly options, so that the product can be distributed with an optimally low volume utilisation and with the lowest number of operations for installation. The same case also exemplifies how the mindset provides the possibility of planning *1. production efficiency*, *2. distribution safety* and *3. installation cost* by planning the interfaces between product design and package design (platform). In contrast to these positive effects, considerable costs and quality problems arise in Case 3 when the package does not support the product during international distribution/transport and vibrations damage the equipment.

As for the component level of the product, i.e. the choice of dimensions, tolerances, material and scrapping, the cases studied illustrate the logistics problems that are overcome by marking components or dimensioning them to fit to unit loads or by protecting product components by means of complementing package designs. For example, in Case 1, costs are reduced and quality is improved by means of an integrated mindset of product and package by combining the product design and waxed paper during distribution, so that friction can be reduced and dust collected to protect the recall springs. In sum, positive results are seen in transportation costs, handling efficiency and environmental waste.

If the cases are compared, the same logistics effects are achieved in all three. For example, volumes utilisation frequently occurs in combination with storage and handling activities. Additionally, unitisation by unit load standardisation or packaging of disassembled products is, in several cases, applied to minimise logistics effects. This indicates that there is a possibility of developing the terminology and methodology for integrated product and package design.

6 CONCLUSIONS

The cases discussed in this paper demonstrate that there is a pattern and context between product and package characteristics and logistics effects, the so-called “dispositional effects”. Case analysis illustrates that integrated product and package design benefits the logistics activities of those who adopt the mindset and affects costs and quality negatively when this mindset is neglected.

It is the belief of the authors of this paper that better solutions can be designed and created by educating designers with a productive mindset for integrated product and package design. In this way they acquire the competence needed to design interfaces between product and package that will improve logistics activities. According to the case study, results problems also occur during e.g. logistics activities when an inadequate understanding of the mindset of integrated product and package design prevails**.**

We also believe that the use of galleries, adopted from Olesen et al. [49], provides the possibility of analysing interfaces between *product-package-system* (PPS) and *activity of the life cycle system* and *actor(s) of that system/activity*, illustrating what interfaces should be improved, what effects should be reduced and what actor(s) should be considered.

In this paper we have taken one first step towards identifying key terms. Further research is required in order to establish design principles for Integrated Product and Package Design and to justify the mindset by demonstrating the productivity of work where designers equipped with such a mindset are involved.

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