SELECTED ASPECTS OF PRODUCT LOGISTIC EFFICIENCY AS PART OF THE DESIGN FOR LOGISTICS CONCEPT - CASE STUDY

Maciej Bielecki
Lodz University of Technology, Department of Production Management and Logistics, Poland
E-mail: maciej.bielecki@p.lodz.pl

Lukasz Hadas
Poznan University of Technology, Faculty of Engineering Management, Poland
E-mail: lukasz.hadas@put.poznan.pl

Received: June 4, 2018
Received revised: July 4, 2018
Accepted for publishing: July 5, 2018

Abstract

The problems of logistics and supply chain management are increasingly aimed at the characteristics and properties of the product itself and their impact on product flow processes and information about them. This is because the optimization of the logistics processes themselves (transport, storage, packaging, inventory management, order processing), without interfering with the product as such, brings less tangible benefits for the company. Analysis of the product susceptibility from the logistics point of view and its logistic efficiency should become a key element of logistics services. Such aspects as optimizing the level of product integration, a high level of standardization, the use of industry standards (industry) or design supporting the product life cycle (Design for Life Cycle - DfLC), etc. are some of the basic principles of the concept. Design for Logistics (DfL) has a number of solutions that indicate the directions of changes in new or modified products, translating into further logistic vulnerability. The paper presents the preliminary research results, selected aspects of product logistic efficiency as an element of design for logistics, in one of the largest furniture manufacturers in the world

Key words: Design, Product, Logistics, Efficiency; DfL

1. INTRODUCTION

Challenges facing logistics and supply chains in 21st century stimulate the companies to look for various solutions in processes, products, IT, infrastructure and organization. The mentioned possible areas for improvement are interrelated, however, it is the product that in most cases is the determining element of the selected areas of logistics and supply chain. The product (physical good) that flows through subsequent logistic phases (supply, manufacturing, distribution, disposal and returns) and takes into account the basic logistic processes requirements (transport, warehousing, packaging, handling orders, stock management) generates logistic solutions in the company. Undoubtedly, in many cases specific features and properties of the product itself contribute to the efficiency of the material flow realization. Therefore, the product design process more and more becomes a key element of the company's competitiveness and the product logistic efficiency concept discussed in the article is one of its important aspects.

The issue of the impact of the product on logistics and the supply chain also appears to be of great interest in the context of scientific work. Searching for specific design solutions in products that have a positive impact on logistics processes is one of the elements that fit in with the original, the product logistic efficiency concept. The question also arises of what is the place of the product logistic efficiency concept, in the wider issue of Design for Logistics concept. The article presents preliminary results of scientific research works on the presented issues.

2. DESIGN FOR LOGISTICS AS AN ELEMENT OF DESIGN FOR EXCELLENCE

Design for Excellence concept – DfX is inherently connected with the concepts of product design and development. According to Ulrich and Eppinger (Ulrich & Eppinger, 2007) marketing, design and manufacturing functions are the main determinants for product design and development. Marketing functions enable to identify a number of circumstances related to the market product concept, i.e. customer needs analysis, price targets, market segments or the given product promotion elements. Marketing mix concept also highlights the relation between the product, marketing and logistics. Marketing mix concept in 4P formula (product, price, promotion, place) was first presented in 1960 by McCarthy (McCarthy, 1960).

Design functions are the key elements in defining the product physical form which best meets the customers' expectations and take into account the aspects of engineering design (mechanical, electrical, software aspects) and industrial design (aesthetic, ergonomic aspects, etc.). Manufacturing functions are primarily responsible for the production process organization, often including such issues as purchase, finished products supply and their assembly at the end-user (Ulrich & Eppinger, 2007).

The basic assumption of the DfX concept is to consolidate a set of various design methods aimed at different operational targets. After World War II the first concepts of design for various processes, mainly aimed at manufacturing, assembly and disassembly processes, were proposed as supplementary elements to the Concurrent Engineering (CE). In 1960s' Design for Manufacturing became one of the first supporting design methods and was described by General Electric in their first industrial manual called Manufacturing Producibility Handbook (General Electric Co., 1960). The publication put together the existing industrial knowledge and indicated how to design products efficiently. It mainly focused on the individual products design for their „producibility", however, it also mentioned the assembly issues. In many cases it led to creating solutions appropriate from the manufacturing perspective (f. ex. designing a detail divided into a number of parts instead of designing one whole detail. It definitely facilitated manufacturing, however, the overall costs of these solutions, taking into account the assembly and other processes, exceeded significantly the costs of using one whole detail). It was noticed that rather than trying to reduce the manufacturing costs the attention should be shifted to the attempt to the product structure simplification and the overall product costs reduction (Boothroyd & Alting, 1992). In 1970s' there was an intense development of Design for Assembly (DfA) concept. The extent of complications in the guidelines for the Design for Assembly was noticed. In 1983 Boothroyd and Dewhurst published the first edition of their handbook "Product Design for Assembly" and in 1986 Hitachi released the first industrial manual presenting a method of the assembly susceptibility valuation. Since then other product life cycle phases began to get assigned specific design approaches: Design for Maintainability – DfMa, Design for Sustainability – DfS, Design for Obsolescence - DfO, Design for Network – DfN, Design for Recycling - DfR (Becker & Wits, 2013), Design for Quality – DfQ (Booker, 2003), Design for Services - DfSv (Subramani & Dewhurst, 1993), Design for Testability – DfT (Williams & Parker, 1983), Design for Environment - DfE (Fiksel, 1996), Design for Flexibility – DfF, Design for Cost – DfC (Lehto et al., 2011). Among the methods one should also mention Design for Delivery – DfD, Design for Logistics – DfL or Design for Supply Chain – DfSC by many authors regarded as overlapping concepts (Lamothe, 2006). Other research areas such as global sourcing (Galinska & Gradzki, 2013) could also be included in the framework of widely understood design methods, however, from the concept perspective they would constitute a separate set of circumstances to be considered.

Chiu and Okudan performed a thorough review of the DfX concept literature and made an attempt to structure the concept by classifying it into 5 basic categories based on the presented tools characteristics (Chiu & Okudan, 2011). Taking into consideration the level of detail they managed to distinguish: guidelines, checklists, metrics, mathematical methods and general methods. Guidelines provide advice that should be followed and indicate the objective that should be pursued. Checklists include opinions, calculations and a set of yes/no questions concerning the design that need to be answered which identify the circumstances to be considered while the project realization. Metrics often represent a combination of guidelines and checklists and are used to assess quantitatively if the product meets project guidelines. Mathematical models verify the formulae and models used during design process and allow to assess the effectiveness and project works efficiency. Comprehensive method includes a systematic, clear and procedural description of previous actions and it does not assign specific project tasks to the methods and does not define the sequence the tasks should be completed (Becker & Wits, 2013).

First theoretical issues connected with the DfL concept were included in the publication by a group of managers Foo, Clancy, Lindemunder, Kinney (Foo, et. al., 1990) where they presented the idea of Design for Material Logistics – DfML. The authors proposed an ideal product model from the perspective of material logistics and defined key elements which should be considered when designing such products:

- minimizing the number of potential parts and components,

- using standard or small group of dedicated parts or components „preferred parts”),
- reducing the number of final elements configurations (final element is the product sold as supplemented /service parts or any other element included in the client’s order or sales forecast) and
- using modular product structure and material structure (Bill of materials – BOM).

The authors pointed out that three first recommendations of Design for Material Logistics, in case of the example discussed in their article, were used appropriately and did not require any redesign. As for the fourth recommendation, although limiting the product configuration number brings financial benefits, business strategies adopted by the companies force them to adjust the product to the clients’ requirements. Therefore, in the business reality, offering a limited number of product configurations for the discussed product was not feasible. The final element concerning product modularity and material structure BOM became the most critical issue. The authors also notice that limiting the possibility to supplement the final product by the client (limiting personalization) facilitates DfML.

Design for Logistics concept was first defined in 1992 when Mather, based on his previous works, described it as a prompt response to the client’s needs in the moment they appear – “… to delight the customer with product when needed”(Mather, 1992). He rightly argued most logistic issues connected with the product design cannot be compensated by the work of marketing department or manufacturing techniques. In his article he described a series of actions taken to launch a product from the electronic industry and pinpointed a range of mistakes made during the design phase and their subsequent consequences. The key element of Mather’s concept was P/D ratio, where P is the overall cycle time, starting from the raw materials acquisition until they are processed into finished goods and D is the customer service time starting form placing an order by the client until the product is delivered to them. According to Mather for most companies the ratio is less than one, which is compensated by the production make-to-stock strategy, deeply rooted in forecasting processes and results from the decoupling point placement. Decoupling point can be understood as a specific point in material flow where product is connected with specific (one might say, personalized) client’s order (Olhager, 2012). In case of ‘make-to-stock’ production strategy the decoupling point is placed directly in the finished goods warehouse. In case of assembly-to-order strategy the decoupling point is placed in the preassemble warehouse and in case of design-to-order it is placed in raw materials acquisition phase. Each presented solution is closely related to the product design. Based on that observation, Mather claimed that in many cases the only right solution which allowed to optimize logistic processes was the product redesign according to their logistic requirements. The author concluded his DfL concept presentation with the statement that in order to implement it one should attempt to:

- use the maximum number of standard components or modules in the production process;
- delay any kind of product personalization – it should take place in the latest possible order handling moment.

In the summary the author claimed DfL (in the article referred to as design for world-class competition) was becoming a serious challenge for the designers. The significance and impact of the design process, as well as the project itself, should be defined as the ideally matched foundation for any kind of business activity.

A few years later, in 1995, Dowlatshahi also addressed the DfL issues (Dowlatshahi. 1996). The author discussed the concept in the view of Concurrent Engineering (CE) concept. He distinguished two key elements which allow to successfully implement the CE and are an appropriate justification for the DfL introduction:

- all activities connected with the product development should concentrate on all design aspects integration at the early stages and thus bringing tangible effects,
- described impact and limitations resulting from diversified functional requirements should be provided to the designers at the right time in the form of precise and sufficient data or information.

According to Dowlatshahi, effective DfL combines numerous functional areas of the organization and focuses the product design process on the attempt to include all the necessary product characteristics and properties it will have to perform in the market. Therefore, DfL should take into account the issues connected with marketing, manufacturing, supply (purchase), quality control, finance, packaging, distribution, transport, plant location, materials management, orders forecasting and handling, warehousing, environment, sales or scheduling. Obviously, design works should converge and create a product that depends on specific circumstances and conditions. In the author's opinion DfL model should include:

- logistic engineering (understood as the area of logistics focused on the product and system support throughout their whole life cycle and concentrated on the design process where logistic requirements – size, weight, reliability, safety, cost, manufacturability, etc. – should be considered in the product final configuration),
- manufacturing logistics,
- Design for Packaging – DfP,
- Design for Transportability,
- Design for Material Handling and Movement,
- Design for Environment.

The same author performed hierarchical decomposition of Design for Logistics, listing a series of logistic design factors referring to DfL model crucial elements.

It this approach he distinguished the following logistic design factors which he called modules in each area discussed.

In the area of logistic engineering the author distinguished the module of Design for Supportability (taking into consideration at the product design stage some requirements considering logistics system service and equipment), the module of the product range (analysis and assessment of the current product lines), the module of project attributes (determining achievable and feasible qualitative and quantitative boundary conditions).

In the area of manufacturing logistics the author indicated the modules of production processes (considering and referring the production processes specific characteristics – quick changeover, production cycles predictability and stability, etc. to the solutions implemented into the product which take into account logistic aspects); the module of planning and production control (considering the production batch length and their impact on logistics; the impact of production plans and other manufacturing aspects should become a basis for the search for common solution for the production and logistics departments); the module of appropriate materials use (one should tend to minimize the overall material management costs and create compact and light products) and the module of plant location (which influences the transport costs for supply and distribution and the response time to market changes or deliveries reliability).

In case of Design for Packaging the author presented the module of functional packaging requirements (related to various business activities of the company such as marketing, manufacturing or logistics the packaging becomes a great opportunity to combine a variety of the company functional requirements) the module of materials used analysis (in the context of their internal structure and the number of packaging solutions used), the module of the packaging testing (against the shock or vibration resistance or their fragility), and the module of packaging design (reducing the external factors impact and the overall packaging costs as well as considering both internal and external conditions and circumstances

For Design for Transportability, Dowlatshahi presented the modules of transport susceptibility (identified project characteristics supporting transport processes such as physical features and properties, dynamic, environment and other limitations related to different risk types); delivery, warehousing and manipulating requirements (close link between logistics and design with reference to logistic infrastructure availability and selection); conditions for transport processes (business aspects of transport solutions selection) and the module of the Design for Transportability criteria (considering and minimizing the average delivery time and the delivery time volatility).

The Design for Logistics elements and structure proposed by Dowlatshahi seem, in the authors' opinions, slightly chaotic. The degree of convergence between various DfX concepts and the lack of one common logic denominator are the most significant shortcomings of the presented model.

Koike, Blanco and Penz (Koike, et al., 2005), took a different approach do DfL issues. They proposed a concept of proper interface between designers and logisticians in Concurrent Engineering (CE). In their opinion, the guidelines for the DfL designers could be brought down to costs reduction, reference parts number reduction, packaging adjustment and logistic processes facilitation. The authors also put forward the model guidelines for the logistic profile supporting the interface between designers and logisticians and based it on three key elements: variables, profile handling programme and the profile chart.

The literature review presented above shows a truly diversified approach to DfL concept. Setting the DfL concept in the sphere of DfX concept as a supplementary element appears rather obvious, however, DfL as such needs to be organized and more details need to be provided. The multidimensional and interdisciplinary character of the whole concept imposes the necessity to search for common denominator enabling to identify related areas. The following chapter presents the model approach to the discussed issue which, according to the authors, seems to be a compromise proposal.

3. PRODUCT LOGISTIC EFFICIENCY IN DESGIN FOR LOGISTICS

Undoubtedly, the DfL concept should aim to design logistically efficient products. The concept of logistically-effective product related to the idea of logistically-effective design was first conceptually indicated by Mather (Mather, 1992). The author noticed the need to place logistics in the design processes, however, he did not define the concept precisely. When performing the literature review one can clearly distinguish the DfL aspects directly related to Concurrent Engineering (CE), i. e. the interface between designers ang logisticians at the design phase, the issues of implemented solutions impact on other business functions and the relationships between logistic phases and processes which should be reflected in the final product form. Based on that approach a **logistically efficient product** is created and it is defined as a material object of the market exchange which possesses a set of features and properties allowing for:

- from the internal organization's perspective, effective and efficient flow through the supply, production and distribution phases,
- from the external organization's perspective, the logistic management to effectively and efficiently integrate the orders handling, stock management, warehousing, packaging and transport with other third parties within the supply chain concept (Bielecki, 2013).

In the literature review we can notice that concrete industrial solutions frequently recur in the publications. Therefore, they might be regarded as the guidelines for the designers who consider logistic aspects when designing their products. The authors of the article defined the guidelines as follows:

- standardization of the elements contained in goods/products, assortments and whole product ranges;
- multifunctionality of the elements contained in goods/products, assortments and whole product ranges;
- logistic standardization (taking into account the standards resulting from supply chain integration in the areas of logistic phases and processes, f. ex. packaging);
- logistic personalization (connected with the decoupling point analysis and location);

Parts and assortment standardization is connected with the use of widely available and commonly standardised solutions. It can take different forms and options depending on the division criteria. Taking into account the standardized parts traceability, the division into direct, indirect and non-traceable standardization could be adopted. Direct standardization uses solutions available in the market on one-to-one basis. It means standardized elements/parts have no modifications, are unequivocally traceable and available in the market. Indirect standardization occurs when the specific final product is sold under a different name, however, due to its features and properties as well as information elements, it can be directly identified.

Non-traceable standardization uses standard parts, however they are impossible to identify or can be identified solely with the use of specialist knowledge or equipment. The modularity concept is also a standardization form. Modularity is understood as the use of purposefully designed elementary product units which allow to configure, separate and re-configure the product to the elementary product units called modules. Modules constitute a bit more complex standard parts that enhance the economies of scale in the whole system.

Parts multifunctionality reflects the principle to use one given solution for different functions. An example of one screw once used as the stabilising element and then used simply to connect parts is a good illustration. It increases the benefits of implementing standardization.

Logistic standardization focuses on taking into account logistic processes in the supply chain (transport, warehousing, packaging, orders handling and stock management) during the design processes. Paying attention to packing the products into outer packaging, and later into freight units which enable tracing the flow in the whole supply chain is another challenge for the logistically efficient product. In many cases the difficulties in developing efficient solutions supporting all the logistic processes indicate the need to optimize selected product parameters most significant from the company's logistic operations perspective. The issue of packaging susceptibility and the packaging compression rate, calculated as the ratio of the packaging cubature to the assembled product cubature.

The last discussed element is logistic personalization which allows to shift the decoupling point as close to the client as possible. The combination of the mass production benefits and the possibility to offer personalized product is the key element of the product logistic efficiency concept. Mass customization (Bielecki & Hanczak, 2016) combines two contradictory ideas and that is why a compromise between the clients' and producers' expectations needs to be reached. The client in involved in the product creation process, however, their impact can reach various production process phases. In literature four customization levels are distinguished, each with a lesser product personalization degree:

- pure customization,
- tailored customization,
- standardized customization,
- pure standardization.

In case of pure customization the client participates in the product design and it is possible to create a product fully satisfying their preferences. Tailored customization assumes the client's engagement in the production phase. This enables any modifications of the standard element shapes or sizes in accordance to client's requirements. The client's involvement in the assembly phase is characteristic of standardized customization and can lead to product changes within the standard available options. Pure standardization disregards individual client's expectations. The client's involvement in the product manufacturing process defined in this way, in many cases, is not in line with the company's needs for effective and efficient flows, What is more, it is easy to give examples when the client's needs might be in the opposition to the company's logistic objectives. Thus, more and more often, the organizations try to develop a business model in which product logistic efficiency becomes a key competitiveness element.

The concepts of DfL and logistically efficient product are also very much in line with Total Logistics Management concept (Bielecki & Galinska, 2017) which focuses on the product and its design as the key aspect of logistics management. It is worth mentioning the concept of product logistic efficiency is also consistent with the Industry 4.0 concept, and sometimes cited in literature concerning Logistics 4.0 idea (Wrobel-Lachowska et al., 2018).

The assumptions presented above allowed to construct the research idea aiming at identifying practical examples of the product logistic efficiency concept application in business reality.

4. PRACTICAL USE OF THE PRODUCT LOGISTIC EFFICIENCY DESIGN ASPECTS

The authors decide to verify empirically the practical use of the product logistic efficiency design aspects (parts standardization, multifunctionality, logistic standardization and logistic customization). Although the literature provides some examples of research on similar test group – furniture (Rajkiewicz et al. 2017) the adopted approach seems simpler and more effective. The authors took the steps to identify companies which clearly adopted DfL concept in their business practice. This was the basic criterion, however, it was not the only one. The authors decided, based on their pilot studies, the best companies for the sample selection should:

- offer logistically efficient products in the market;
- organize their logistic processes using the principles of the product logistic efficiency concept.

Additional criterion for the company selection was the data accessibility about the products and their parts.

The entity which met all the research criteria was an international furniture producer which also has its own retail network. Mass production, declared parts standardization, packaging optimization and use and assembly manuals availability for the products on offer allowed to commence the study of the discussed issue. The producer's marketing materials also provide confirmation the company applies the concept of logistically efficient products. The company declares their competitive prices result not only from mass production, but also from the logistics and high packaging compression rate (which enables to reduce transport and warehousing costs).

The company choice was a purposive sampling and the article presents only partial results of the study on standardization and packaging. Due to the pilot character of the study two general issues were addressed:

- what is the share of repetitive, standardized parts in the selected assortment groups and the whole analysed assortment,
- what is the level of packaging compression compared to the actual size of finished products.

To carry out the study, the products from various assortment groups (sofas, dressers, beds) were selected purposefully. Then, their manuals for assembly and use were downloaded from the producer's website (all available online). In the first part of the study, data about the parts for different products were entered into the Ms Excel spreadsheet in order to analyse the frequency of common parts occurrence in the whole assortment and in specific assortment groups. To address the second research question other furniture assortment was purposefully selected and analysed, based on the data available online about the assembled products sizes and their packaging sizes in order to calculate the packaging compression ratio.

The study on the furniture standardization included 52 purposefully selected products in which 252 kinds of parts occurred. The total amount of the parts was 715, however, the given part could occur in a number of models. Only one part occurred in more than half of the products and the occurrence frequency of the remaining parts was divided into intervals and presented in Table 1. As shown in the Table only 0.4% of the parts – 1 part occurred in more than half of studied furniture and this result does not allow to regard standardization as dominant for all assortment groups. The ratio between 10% to 20% of standard parts concerns more than half of the furniture. This might result from the specific features and properties of the given furniture.

Table 1. Common parts occurrence frequency in all studied furniture (all assortment groups)

Occurrence in products	Per cent of all parts – number of all parts
Up 50%	0,4% - 1 part
40,00% to 49,99%	0,8% - 2 parts
30,00% to 39,99%	1,2% - 3 parts
20,00% to 29,99%	1,2% - 3 parts
10,00% to 19,99%	50% - 126 parts
Below 10%	46,4% – 117 parts

Source: Own study

To investigate the issue in more depth, the groups of studied objects were divided into relatively coherent assortment groups of goods. When analysing the dressers (11 different objects) it turned out only 47 out of 272 parts occur in the assortment group, and 3 parts occur in all examined dressers – Table 2.

Table 2. Common parts occurrence frequency in the assortment group "dressers"

Occurrence in products	Per cent of all parts – number of all parts
11	6,4% - 3 parts

10	4,3% - 2 parts
9	2,1% - 1 parts
8	0%- 0 parts
7	0% - 0 parts
6	12,8% - 6 parts
5	44,7% - 21 parts
4	2,1% - 1 parts
3	0% - 0 parts
2	6,4% - 3 parts
1	21,2% - 10 parts

Source: Own study

There was also a significant increase in the standardization ratio in case of the assortment group of beds, however the rise is smaller than in case of the dressers. 7 different beds were selected and 47 parts out of the total number of 272 parts occurred in this assortment group -Table 3. It can be stated, based on the achieved results, the parts standardization in this assortment group is at a very low level.

The standardization ratio was also determined for the tables – Table 4.

In 9 different types of analysed tables 58 parts were identified. The obtained results were interesting as it was expected that due to the construction simplicity and a relatively small number of components, the standardization process should be high. The results do not confirm this assumption and the standardization level in the assortment group was the lowest. The variety of components might result from the aesthetic/ style aspects of the design process. Since over 70% of parts occur solely in the studied products the potential for improvement in this area seems high. However, this assumption requires further extended analysis.

Table 3. Common parts occurrence frequency in the assortment group "beds"

Occurrence in products	Per cent of all parts – number of all parts
7	0% - 0 parts
6	0% - 0 parts
5	6,4% - 3 parts
4	8,5% - 4 parts
3	0% - 0 parts
2	27,7% - 13 parts
1	57,4% - 27 parts

Source: Own study

Table 4. Common parts occurrence frequency in the assortment group “tables”

Occurrence in products	Per cent of all parts – number of all parts
9	1,7% - 1 parts
8	0% - 0 parts
7	8,5% - 5 parts
6	0% - 0 parts
5	0% - 0 parts
4	3,4% - 2 parts
3	3,4% - 2 parts
2	15,3% - 9 parts
1	67,7% - 39 parts

Source: Own study

The study of the parts standardization level in the products was accompanied by the analysis of their multifunctionality**. No multifunctional parts were identified** in the studied objects. It means this DfL aspect might not be applied in the company.

The second part of the study concentrated on the packaging compression ratio. The ratio was calculated based on a simple formulae:

Packaging compression ratio = Packaging cubature / Furniture cubature *100%
and the lowest possible ratio value is desired.

Based on the information about the product (dimensions after the assembly) the furniture cubature was calculated and it was then referred to the packaging cubature (packaging sizes were available at the producer’s website).

First, 2 and 3-seat non-convertible sofas were examined – Table 5. As shown in the Table, the packaging compression ratio is relatively similar and there is no significant difference between 2 and 3-seat sofas. All results oscillate around 64% packaging compression ratio.

Table 5. Packaging compression ratio for the category “sofas”

Sofa model / option (seat number)	Furniture cubature- m3	Packaging cubature-m3	Packaging compression ratio
Model A / 3-seat	1,79	1,15	64,24%
Model B / 2-seat	1,49	0,94	63,33%
Model C / 3-seat	1,78	1,22	68,53%
Model D /2-seat	1,49	1,01	67,78%
Model E /3-seat	1,88	1,17	62,23%
Model F /2-seat	1,34	0,86	64,17%
Model G /3-seat	1,59	0,95	59,74%
Model H /2-seat	1,14	0,74	64,91%
Average	X	X	**64,36%**

Source: Own study

The packaging compression ratio study for the assortment group “dressers” provided far more interesting results - Table 6.

The packaging compression ratio for this assortment group was 27% on average which is a much better result than in case of “sofas” where the ratio reached approximately 64% on average. What is more, the discrepancy between the weakest result (35.12%) and the best result (17.31%) allows to assume that the two cases thorough analysis might be the source of valuable information. The assortment item with the 17.31% packaging compression ratio could be used as a benchmark for other items. The identification of factors which led to the model ratio value in the specific assortment group should provide the information on the best practices and be later applied when the production and packaging processes are designed.

Table 6. Packaging compression ratio for the category “dressers”

Model	Furniture cubature-m^3	Packaging cubature-m^3	Packaging compression
A1	0,11	0,04	34,27%
A2	0,30	0,07	24,12%
A3	0,38	0,09	24,14%
A4	0,24	0,08	32,01%
B1	0,09	0,02	25,58%
B2	0,27	0,05	17,31%
C1	0,08	0,03	35,12%
D1	0,12	0,03	27,24%
E1	0,13	0,03	26,43%
F1	0,16	0,04	26,45%
G1	0,30	0,07	22,03%
G2	0,20	0,06	30,30%
Average	X	X	**27,08%**

Source: Own study

Table 7. Packaging compression ratio for the category “tables”

Model	Furniture cubature-m^3	Packaging cobature-m^3	Packaging compression
A	0,41	0,09	22%
B	0,41	0,05	13%

C	0,50	0,06	12%
D	0,63	0,06	10%
E	0,77	0,10	13%
F	0,19	0,02	9%
G	0,04	0,02	50%
H	0,05	0,02	52%
I	0,66	0,08	11%
J	0,67	0,11	17%
K	0,83	0,13	16%
L	0,42	0,01	3%
Average	X	X	**20,00%**

Source: Own study

Generally, results achieved for the assortment group "tables" (Table 7) could be interpreted in a similar way. Probably, due to the product specific construction (vertical legs and a table top) the high average packaging compression ratio of 20% was obtained. However, there are significant differences between specific assortment items with the extreme values from 3% to 50%. The analysis of the discrepancy should also provide useful information which could be later used in developing production and packaging standard in order to achieve the product logistic efficiency.

5. CONCLUSION

In conclusion, it should be noted the obtained pilot study results provided information of general character. However, it can be stated that the standardized, repetitive parts share was much below the expectations. The share was lowest for all the assortment groups in total and increased when the assortment groups were analysed separately. It might result from the product structure similarities within the same assortment group and therefore higher construction standardization.

As for the packaging compression ratio, two facts were identified:

- there is a significant difference in the packaging compression ratio between the assortment groups,
- within the same assortment group, the ratio values can be similar or varied.

As it was mentioned in the results analysis, the cases of big ratio discrepancies within one assortment group require extended analysis in order to identify best practices and apply them when the production and packaging processes are designed. It might lead to obtaining logistically efficient products. The extended analyses, preferably performed by the practitioners in a given company, should provide more detailed information why the specific results on standardization and packaging compression ratio were achieved. Their analyses outcomes should be the basis for the changes introduced in the selected processes realization by the company. The table below presents recommended actions in this respect (see Table 8).

Table 8. Suggested extended analyses and recommended actions for the company

Subject of analysis	Recommended actions
Parts standardization	
– The analysis of the common parts occurrence frequency within homogenous assortment groups – The analysis of the parts wear value (80/20 rule – Pareto principle) – The analysis of the common parts occurrence frequency within purchase categories (category management)	– Establishing a cross-function team from Logistics, Sourcing and R&D Departments – Addressing RFS - Request for solution and RFP - Request for proposal to the preferred suppliers as for the possibility to reduce the variety of used parts. – Engaging key suppliers in selected aspects of product design – interface between R&D Department and the suppliers – Implementing developed solutions and the analysis of the logistic costs impact in the area of stock management.
Product compression after packing	
– The packaging compression ratio highest value identification in each assortment group separately – The best practices analysis for the items with the highest packaging compression ratio – The key factors identification that impact the packaging compression ratio in the area of product production and packaging design	– Establishing the cross-function team from Logistics and R&D Departments, – Adopting benchmark point (normative value) for specific assortment groups and its application in the company's own production plants and the finished products suppliers (that supplement the offered assortment), – Developing best practices and standards catalogue to meet the set requirements in the area of product compression after packing – Implementing developed solutions and the analysis of the

	logistic costs impact in the area of transport and warehousing.

Source: Own study

Having implemented the solutions concerning parts standardization and product compression, one should not ignore their impact on the logistic costs. The actual costs reduction depends on numerous factors related to the company's logistic processes internal characteristics and the supply chain. However, determining the tangible benefits expressed in monetary units allows to prioritise subsequent improvements (most desired improvement categories identification) and assess if they are justified from the perspective of financial investment necessary to accomplish them.

6. REFERENCES

Becker, J. & Wits, W. (2013). *A template for Design for eXcellence (DfX) Methods*, [in] Abramovici, M. & Stark R. (2013) [ed.] *Smart Product Engineering*, Springer-Verlag, Berlin-Heidelberg, pp. 34-35

Bielecki, M. & Galinska, B. (2017). *Total logistics management concept and principles in manufacturing enterprise*, Proceedings of the 17th International Scientific Conference Business Logistics in Modern Management, Faculty of Economics in Osijek, Osijek, Croatia, pp. 93-109

Bielecki, M. & Hanczak, M. (2016). *Mass customization as one of the key elements of logistic efficiency of a product*, Acta technica corviniensis - Bulletin of Engineering, Fascicule 3/2016, pp. 27-30

Bielecki, M. (2013). *The influence of a logistically efficient product on the logistics of a manufacturing enterprise*, Annals of Faculty Engineering Hunedoara – International Journal of Engineering, vol. 6, pp. 175-180

Booker, J. (2003). *Industrial Practice in Designing for Quality*, International Journal of Quality & Reliability Management, Vol. 20, No. 3, pp. 288-203

Boothroyd, G. & Alting, L., (1992). *Design for Assembly and Disassembly*, Keynote Paper, CIRP Annals – Manufacturing Technology 41 (2), p. 625

Boothroyd, G. & Dewhurst, P., (1983). *Product Design and Assembly*, Designer Handbook, University of Massachusetts, Dept. of Mechanical Engineering,

Chiu, M. & Okudan, G., (2011). *Investigation of the Applicability of Design for X Tools during Design Concept Evolution: A literature review,* International Journal of Product Development, Vol. 13, No. 2, pp.152-153

Dowlatshahi, S. (1996). *The role of logistics in concurrent engineering*, International Journal of production economics, Vol. 44, pp. 189-199

Fiksel, J. (1996), *Design for Environment: Creating Eco-Efficient Product and processes*, McGraw-Hill, New York 1996

Foo, G., Clancy, J.P., Lindemunder Ch. R. & Kinney L. E., (1990). *Design for material logistics*, AT&T Technical Journal, pp. 61-76

Galinska, B. & Grądzki, R., (2014). *Factors which determine the achievement of benefits deriving from the concept of Global Sourcing*, Carpathian Logistics Congress 2013, Congress Proceedings, (CD - reviewed version), Tanger,

General Electric Co., (1960). *Manufacturing Producibility Handbook*, Manufacturing Services, Schenetady, New York, 1960

Koike, T., Blanco, E. & Penz B. (2005). *Logistic profile: a new concept for interfacing designers and logisticians in concurrent engineering environment*, Proceedings International Conference on Engineering Design, 2005 – [available at https://www.designsociety.org/publication/22907/LOGISTIC+PROFILE%3A+A+NEW+CONCEPT+FOR+INTERFACING+DESIGNERS+AND+LOGISTICIANS+IN+CONCURRENT+ENGINEERING+ENVIRONMENT access may 8, 2018]

Lamothe, J., Hadj-Hamou, & Aldanondo M., (2006), *An Optimization Model for Selecting a Product Familiy and Designing Its Supply Chain*, International Journal of Operational Research, Vol. 169, No. 3, pp. 1030-1047

Lehto, J., Harkonen, J., Haapsasalo, H., Belt, P., Mottonen, M. & Kuvaja, P., (2011). *Benefits of DfX in Requirements Engineering*, Technology and Investment, pp. 27-37

Mather, H. (1986). *Design, Bills of Materials, and Forecasting-the Inseparable Threesome*, Production and Inventory Management Journal, Vo1. 2 (1), pp. 90-107

Mather, H. (1992). *Design for Logistics (DfL) – the next challenge for designers*, Production and Inventory Management Journal, Vol. 33 (1), pp. 7-9

McCarthy, E.J. (1960). *Basic Marketing, a Managerial Approach*, R.D. Irwin, Homewood-Illinois

Miyakawa, S. & Ohashi, T., (1986). *The Hitachi Assemblability Evaluation Method (AEM)*, Proceedings of International Conference of Product Design for Assembly, Newport

Olhager J. (2012). *The Role of Decoupling Points in Value Chain Management*, [in] Jodlbauer H. et al. (eds.) (2012). *Modelling Value, Contributions to Management Science*, Springer-Verlag Berlin-Heidelberg, pp. 37

Rajkiewicz M., Walaszczyk A. & Wiśniewski Z. (2016). *Quality management in toy and children's furniture manufacturing*, [in:] Goossens, R. *Advances in Social & Occupational Ergonomics,* Springer, Florida, pp. 107-116

Subramani, S. & Dewhurst, P., (1993). *Efficient design for Service Consideration*, Manufacturing Review, Vol. 6, No. 1, pp. 40-47

Ulrich, K.T. & Eppinger, S.D. (2007). *Product design and development*, 4th Edition, McGraw-Hill, p. 4

Williams, T. & Parker K., (1983). *Design for Testability: a Survey*, Proceedings of the IEEE, Vol. 71, No. 1, pp. 98-112

Wrobel-Lachowska, M., Wisniewski, Z., & Polak-Sopinska, A. (2018). *The role of the lifelong learning in logistics 4.0*, Advances in Intelligent Systems and Computing (Vol. 596), pp. 402-409