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HOW TO MAKE FURNITURE INDUSTRY MORE CIRCULAR?
THE ROLE OF COMPONENT STANDARDISATION IN READY-TO-ASSEMBLE FURNITURE

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Abstract. The transition towards a circular economy has become one of the biggest challenges faced by enterprises in the second decade of the 21st century. It is also perceived as one of the key levers for achieving sustainable development goals. However, the peculiar features of individual industries require individual approaches and careful analyses. The paper focuses on the furniture industry, which in Europe faces a variety of economic, environmental and regulatory challenges. To meet those challenges and truly close the loop a more strategic approach from the industry is needed. There is also a huge demand for practical options that would be immediately accessible for business organisations that need not necessarily be based on breakthrough technological solutions as these may still be economically not viable. The article aims to fill this gap and to meet these challenges. Different models implying varied engagement of consumers, furniture manufacturers/retailers, and external contractors in closing the loop and making the industry more sustainable are proposed and recommendations for the most promising ones are made. The most preferable model requires not only that business organisations take a strategic approach involving a high level of component standardisation but also active consumer engagement in used/unwanted furniture sourcing and disassembly. The primary research allowed us to assess the level of standardisation defined as the level of repeatability of assembly parts used in ready-to-assemble furniture. The analysis was made for the selected product group (sofas) of a global leading furniture producer and retailer (IKEA). It was found that within the specific product series, standardisation is evident, whereas it varies significantly across series of different products leaving some room for improvement.

Keywords: circular economy; sustainability; circular product design; consumer; furniture; closed-loop supply chain

1. Introduction

Over the past few years, sustainable development has increasingly become a strategic goal for businesses and governments. Sustainable consumption and production patterns are strongly recommended in initiatives such as

the United Nations Sustainable Development Goals or the European Union Sustainable Development Strategy, which are priority challenges (Muñoz-Torres et al., 2018). At the same time, it is becoming increasingly obvious that the present linear (take-make-dispose) model of economy has slim chances of effectively adopting sustainable development principles. It is becoming more and more evident that this "linear" formula is coming to an end as natural resources are being exhausted, prices are fluctuating, economy is becoming dependent on suppliers from other countries, and threats to ecological and social balance are rising. Consequently, the circular economy (CE) model, perceived as a tangible set of solutions and a great opportunity to reach sustainable patterns of production and consumption, is gaining progressively more attention (Foltynowicz, 2016; Lewandowski, 2016; Vasiljevic-Shikaleska, Gjozinska, & Stojanovikj, 2017; Vegera et al., 2018) while the need to abandon the linear model in favor of the circular one is becoming increasingly urgent (Koszewska, 2019).

Therefore, the transition towards a circular economy has become one of the biggest challenges posed to enterprises in the second decade of the 21st century. European business needs to comply with new European legislation which sets very clear targets for the Member States and their industries to meet in the near future. Thus, the question for businesses today is not whether to implement the principles of a circular economy but rather when they will become the applicable standard.

Challenges of the transformation leading to a circular economy are related to every area of contemporary economies but each branch of industry will have its specific problems and methods of solving them. Peculiar features of individual industries will, therefore, require individual approaches and careful analyses. The paper will focus on the furniture industry, which in Europe faces a variety of economic, environmental and regulatory challenges.

Nowadays, 10 million tonnes of furniture are discarded by businesses and consumers in the EU each year, a majority of which is destined for either landfill or incineration. Although recycling rates in the EU have improved through the introduction of policy mechanisms such as the Landfill Directive and its diversion objectives, there is minimal activity in higher-value circular resource flows, with remanufacturing accounting for less than 2% of the EU manufacturing turnover (Forrest, Hilton, Ballinger, & Whittaker, 2017).

Increased activity can also be observed as regards looking for circular economy opportunities in the furniture sector both in academia (Forrest et al., 2017; Gullstrand Edbring, Lehner, & Mont, 2016) and in business (Forrest et al., 2017) but, at the same time, there is a need for a more strategic approach to introducing the circular model which would truly facilitate closing the loop in the industry. Business needs practical options that are not only easy to understand and introduce but also economically and technologically viable. Therefore, solutions dedicated to very specific product groups are especially valuable from that point of view. The article aims to fill this gap and meet these challenges.

On the basis of the conclusions from the available analyses and notable industry activities, the authors assume that the key determinants of the effective implementation of the circular economy model are legal regulations, availability of technology, sustainable supply chain management, product circularity potential (resulting from its design), and consumer attitudes towards circular economy resulting in actual behaviors. The paper will focus mainly on the last two board categories under which only selected specific aspects will be analysed in detail (marked in green in Fig.1 and Fig. 2).
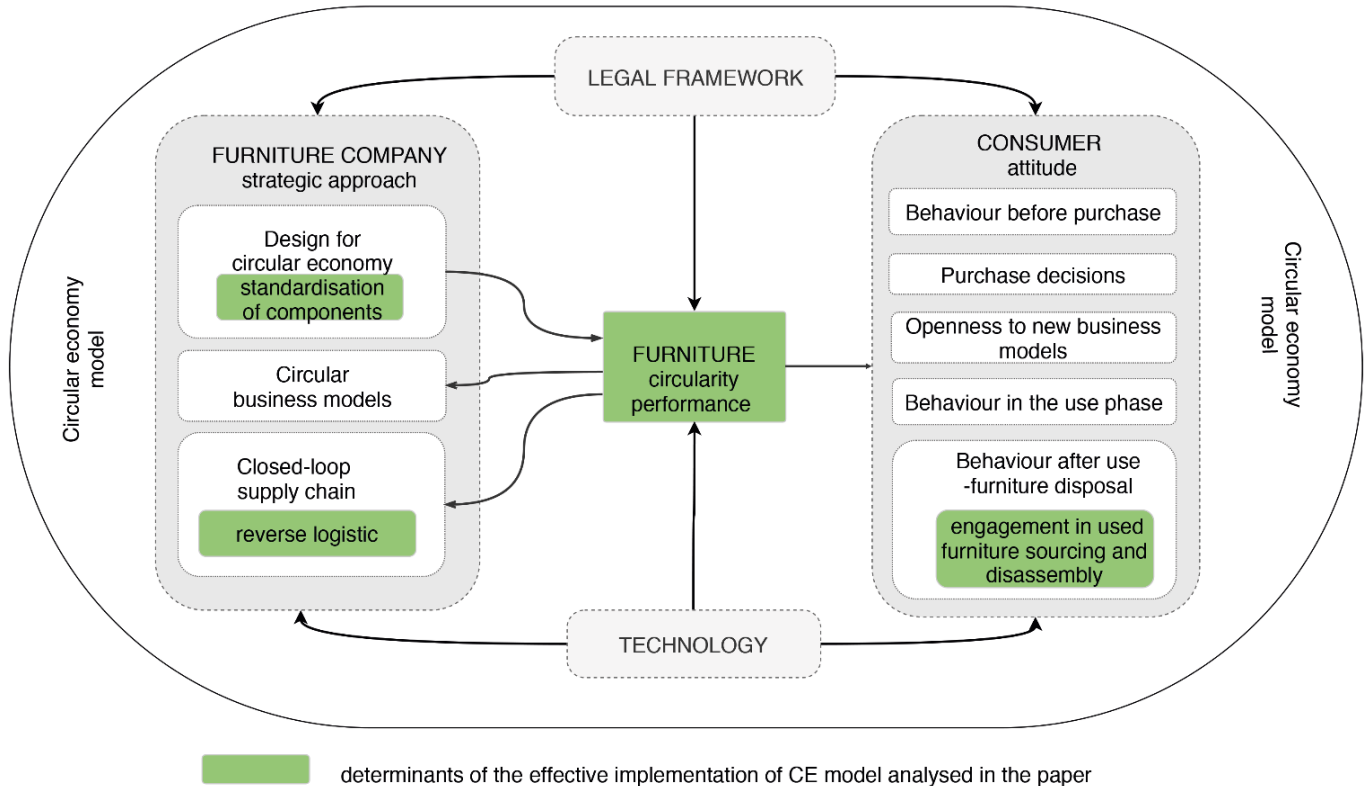
Fig.1. Determinants of effective implementation of the circular economy model in the furniture industry

The choice of the specific research areas was determined by the limited availability of study reports in the literature as well as its utilitarian value– implementation potential for business organisations.

As regards product design, we will concentrate on the aspect of standardisation of metal and plastic assembly components that enables their flow back in the supply chain – effective reuse in newly manufactured furniture. Standardisation will be analysed only concerning the repeatability of assembly parts used in the products.

Based on those premises, we have set our **research aims** as follows:
1. To present the closed-loop supply chain model for the furniture industry;
2. To propose different models (scenarios) implying varied engagement of consumers, furniture manufacturers/retailers, and external contractors in closing the loop, and to make recommendations for the most promising ones in the context of circular economy;
3. To assess the current level of standardisation of assembly components used in ready-to-assemble furniture for the selected product group (sofas) of the global leading furniture manufacturer and retailer and accordingly, determine the scope of potential improvement in this area.

We postulate that a high level of standardisation of assembly components coupled with a long-term organisational strategy and consumer engagement would lead to great progress in closing the loop in the furniture industry. At the same time, we put forward the hypothesis that the current standardisation level of assembly components in the case of global leading furniture manufacturers and retailers is relatively low and leaves a lot of space for improvement.

The **structure of the article** has been aligned with its objectives and is organised in the following way: First, based on the literature review, a closed-loop supply chain model for the furniture industry is proposed and research gaps are pointed out. They become the point of departure for narrowing the range of analysed articles down to the flow back of assembly components to the exclusion of the flow related to the reuse of an entire product - an item of furniture. Next, models (scenarios) implying varied engagement of consumers, furniture manufacturers/retailers, and external contractors in closing the loop are presented and at once, the most promising ones in the context of circular economy are singled out.

Because the effectiveness of the recommended model relies on high standardisation of assembly components, the final part of the article concentrates on the current situation with this regard. To facilitate the description, a method of analysis is advanced and indicators designed to assess the level of standardisation of assembly components used in ready-to-assemble furniture for the selected product group (sofas) of a global leading furniture manufacturer and retailer (IKEA), and thus, to determine whether any improvements are possible in this area.

2. Literature review

2.1. Closing the loop in the furniture supply chain – research gaps

In the current literature, there is a very limited number of studies concerning the circular performance of furniture. At the same time, most of the available ones concentrate mainly on the product flow in the circular economy model and analyse aspects such as systems of collection, repair, remanufacturing, reuse and reselling of second-hand/used furniture (Curran & Williams, 2010; Krystofik, Luccitti, Parnell, & Thurston, 2018), access-based (e.g. renting and leasing) or collaborative furniture consumption (e.g. sharing platforms) (Gullstrand Edbring et al., 2016), and recycling (Nyemba, Hondo, Mbohwa, & Madiye, 2018; Top, 2015).

Also, considering furniture makers' operations in the context of circular economy, it can be observed that they mainly refer to eco-efficient technologies, adoption of cleaner production practices, monitoring environmental impact, handing byproducts over to other companies (Oliveira, França, & Rangel, 2018), modular product design to extend the function of individual products (IKEA modular furniture range to enable customers to upgrade or convert furniture items into alternative uses – including conversion of sofas to beds, replacement of armrests, addition of side tables), leasing, rental and share schemes, and take-back business models - Gispen for office furniture, IKEA (Forrest et al., 2017), incentives for consumers to return furniture for reuse and recycling (tax breaks for repair - Swedish Government, voucher scheme for unwanted furniture, IKEA France) (Forrest et al., 2017).

There is a visible scarcity of analysis as well as business activity in the area of the flowback of assembly components (parts) that could be used in newly manufactured furniture. The place of this area in the furniture industry supply chain model as a whole is presented in Figure 2 - marked in green.
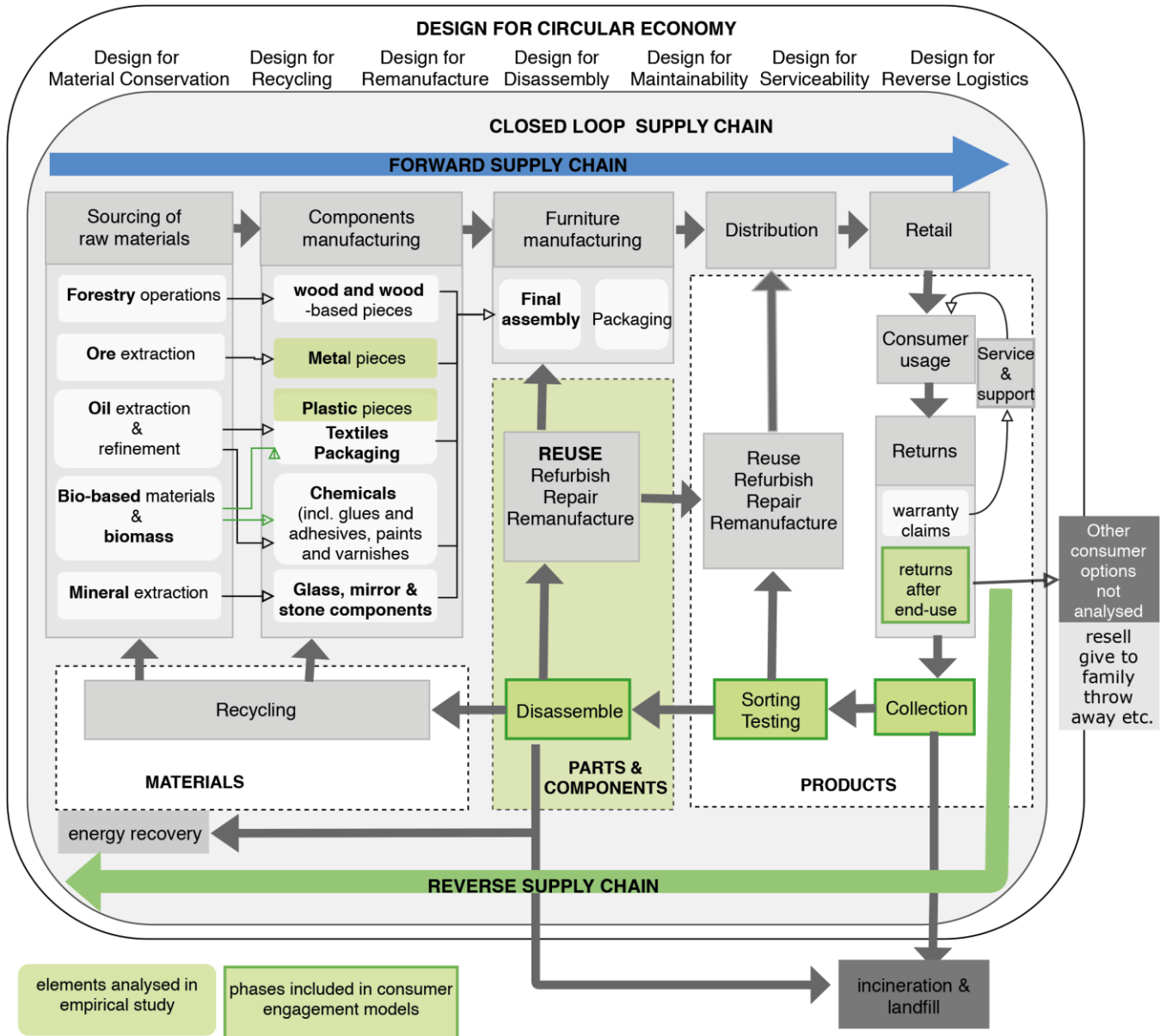
Fig.2. Design for circular economy as a determinant of closing the loop in the furniture supply chain

Source: compiled by the authors based on (Cordella and Hidalgo, 2016, (Bloemhof, Van der Laan, Van Wassenhove, & Zuidwijk, 2010; Fleischmann et al., 1997)

It is also worth emphasizing that **assembly components (parts)** in the case of furniture are mainly made of metal and plastic. Therefore, their environmental impact appears to be generally higher than for wood/wood-based materials or packaging (Cordella & Hidalgo, 2016). Their reuse in new products could bring great opportunities to reduce the need for virgin raw materials thus optimizing the use of resources and decreasing the environmental impact of furniture production. One of the crucial determinants of taking up these opportunities by the furniture industry is a high level of standardisation of components used as it makes it possible to, among others:

- increase the volume and scale of recovered components,
- increase the volume and scale of recycled materials,

- increase the effectiveness of the process of material and part recovery from used products by increasing specialization,
- streamline logistics processes for recovered materials and components and their supply to manufacturers of materials and finished products.

2.2. Measuring standardisation in the framework of general product circularity performance

On a very general level, product circularity performance could be defined as a set of characteristics that determine how effective a product can be in circular economy. It is determined mainly in the design phase and strongly influences the success of introducing closed-loop supply chain and circular business models (see Fig. 1).

At the moment, an animated discussion can be observed concerning the definition and assessment of product circularity performance. Current tools (such as the Material Circularity Indicator (Ellen MacArthur Foundation, 2015), the Circular Economy Toolkit (Evans & Bocken, 2019), and the Circular Economy Performance Indicator (Griffiths & Cayzer, 2016)) provide a rudimentary and rapid overview of a product circularity but they do not provide operational guidance for engineers, designers, and managers on improving their products in the context of circular economy. The need for providing methods and tools to evaluate product performance in the light of circular economy on the operational level is strongly emphasized (Saidani, Yannou, Leroy, & Cluzel, 2017). A recent paper by Mesa et al. (Mesa, Esparragoza, & Maury, 2018) presents a broad overview of conventional indicators employed to assess the sustainability of products as well as indicators for measuring the Circular Economy performance in products. Their analyses showed that the current indicators are designed to analyse single products instead of product families capable of sharing components among their product variants. Therefore, they proposed a set of indicators addressed to measure sustainability performance in product families considering the circularity of components among the product variants as well as functional requirements. Those indicators can provide a useful framework for furniture designers in the field of design for sustainability but they are not intended for measuring the actual standardisation level of furniture assembly components. Indicators of the standardisation level have been proposed in the literature, e.g. the generational variety index (GVI) and the coupling index (CI) put forward by Mark Martin and Kosuke Ishii (Martin & Ishii, 2002). However, they require a thorough understanding of product design specifications. This type of data are not always easily obtainable from organisations, which is why one of the aims of the study is to develop methods that will make it possible to assess the actual level of standardisation of assembly components based on easily available data (e.g. available from product assembly instructions). Therefore, the following tools are proposed: a graphic matrix illustrating the degree in which the same assembly components are used in different products and a quantitative indicator of standardisation saturation.

Standardisation is however only one of the elements required for the system to work in practice. Manufacturers' long-term strategy for planning product circularity performance as well as active consumer engagement are also essential. Therefore, those three aspects will be further analysed in the foregoing paper.

3. Manufacturer attitude models - a strategy for planning product circularity performance

Table 1 presents four models of furniture manufacturer approach to the strategy for planning product circularity performance that assume different engagement levels in circular product design.

Table 1. Models of manufacturer engagement in product design and development in the context of circularity performance

Model	Manufacturer attitude			
	Active engaged	Engaged	Convenient	Passive
Vision/strategy for planning product circularity performance*	long-term strategic level	medium-term	short-term	none
REDUCE – less raw materials in newly manufactured products	✓	✓	✓	✗
REUSE of parts and components in new products	✓	✓**	✗	✗
REUSE of products retrieved from the market	✓	✓**	✗	✗
RECYCLE - use of recycled materials in new products	✓	✓	✓	✗
Performance of 3R processes	manufacturer	manufacturer & external contractor	manufacturer	-
Control over 3R processes	very high	average	average	-
Potential for circular economy	very high	high	average	low

* starting from product design using Design for X methods ** external contractor

The authors hold that the active-engaged model is the most advantageous for the implementation of a circular economy. It implies a system of product circularity planning based on the quantitative reduction of newly manufactured raw materials, materials, and intermediate products in finished products. The enterprise plans 3R processes already in the phase of product design (applying Design for X methods) and develops a strategic system of reuse of recovered raw materials, materials, and components in new furniture. The model requires the organisation to have a sustainable strategy for reusing furniture, or its components, sourced from customers as well as for genuine engagement of designers in the design processes to promote a reduction in the use of materials.

The speed and scale of the transition to the circular economy model will depend on the knowledge, awareness, and engagement of all market participants and will involve the entire product lifecycle, from design to utilization. However, a special role in this transformation will be played by consumers. The rate and success of the changes will depend on their choices, on the quantity and type of the products they buy, on their openness to new business models, and on the manner of dealing with used products (Koszewska, 2019). In the article, we concentrate on the last issue, namely, consumer behavior after product use. Even the most effective system introduced by the manufacturer will not succeed without consumer engagement.

It is also worth stressing that our understanding of consumer attitudes and behaviors in the context of circular economy is still very limited, particularly in the case of furniture. So far, studies have concentrated on disposal and acquisition methods for selected second-hand products, including furniture (Fortuna & Diyamandoglu, 2017), and on consumer attitudes relating to the three consumption models: models for extending the life of the product (e.g. by reselling second-hand goods), access-based consumption (e.g. renting and leasing), and collaborative consumption (e.g. sharing platforms) (Gullstrand Edbring et al., 2016). None have referred to consumer engagement in the system of used furniture sourcing and disassembly offered by the manufacturer. The models presented in Figure 3 aim to fill this gap.
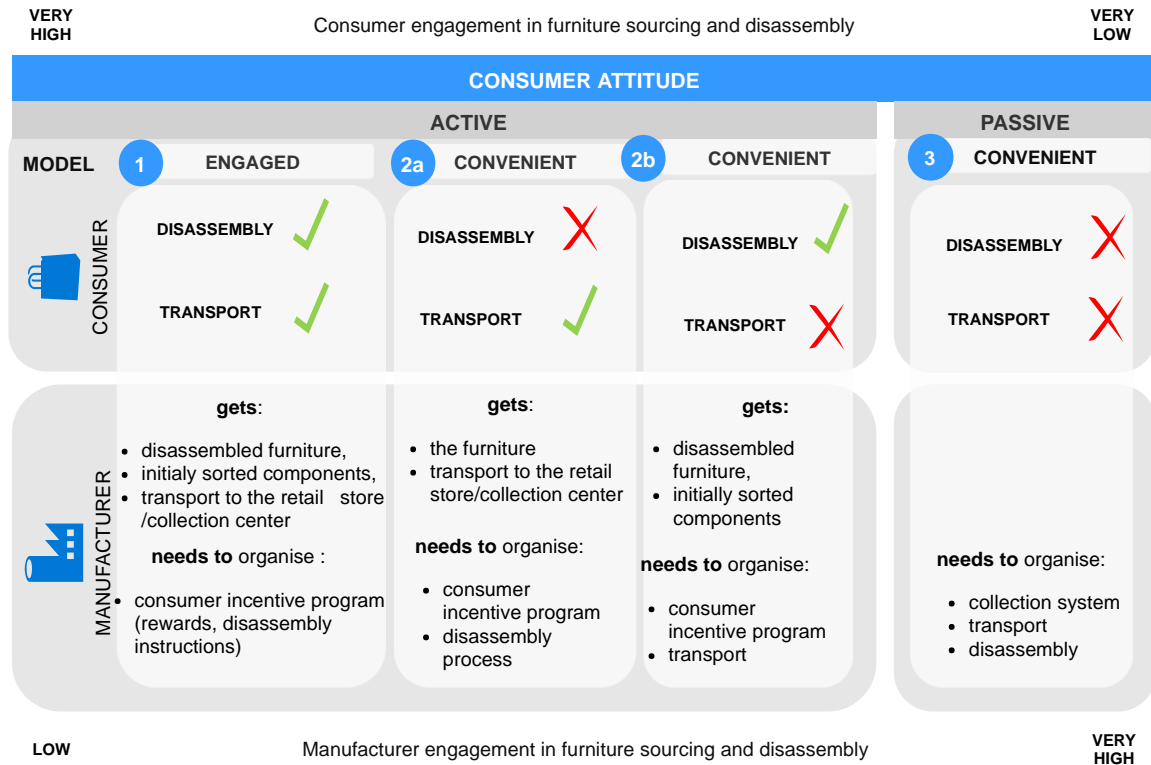
Fig. 3. Models of consumer and manufacturer engagement in furniture sourcing and disassembly

Source: authors' analysis based on (Cordella and Hidalgo, 2016, (Bloemhof et al., 2010; Fleischmann et al., 1997)

The proposed models assume different levels of consumer and manufacturer engagement in used/unwanted furniture sourcing and disassembly.

Table 2. Assessment of the proposed models' potential

	Cost for the manufacturer	Potential for retrieving furniture from the market	Potential for circular economy model
Model 1. Active -engaged	relatively low*	very high	very high****
Model 2. Active- convenient	average	average	average
Model 3. Passive-convenient	very high**	very low***	low

* costs related to consumer incentives programs – communication, reward/discount system, disassembly manuals etc.
**costs related to effective collection systems, cost of organizing transport to individual consumers, cost of furniture disassembly processes
***costs of and difficulty in reaching individual consumers; competition from other furniture disposal options available to consumers such as furniture banks, individual junk removal companies, etc.
**** conditioned by high standardisation of components and introduction by the manufacturer of a strategic system from the very beginning of the furniture design process

As shown in Table 2, the most preferable model both in the context of cost and convenience for the manufacturer/retailer and the potential for retrieving furniture from the market is model 1 which relies on an

active and engaged attitude on the part of the consumer. In this model, the consumer is willing to make the effort and disassemble the furniture as well as transport the disassembled furniture to the manufacturer.

4. Research method

The study aimed to assess the level of assembly components standardisation in global organisations which mass-produce ready-to-assemble furniture. The research was planned as follows:
In the first step, the following criteria were set for the selection of products for analysis
- availability to customers - recognizable and global brand,
- open access to details about products and their assembly components, a range of ready-to-assemble furniture, proved activity in the area of implementing the circular economy model.
Next, by the criteria, products of the leading global furniture manufacturer and retailer IKEA were chosen for analysis.

The initial stage of the analysis involved a preliminary assessment of the rate of part repeatability for product families with the aid of matrices which graphically presented frequency distributions for specific assembly components of individual models. This form of analysis has been termed by the authors a graphic presentation of the level of standardisation saturation. This stage of the study proceeded in the following manner:
- a range of furniture was selected (for the reported research results, it was a range of sofas with fabric covers, without bed function). Four collections (series) were analysed during that stage (Kivik, Vallentuna, Ektorp, Vimle). The selection was based on the time that the given products had been available. Two products that had been marketed by Ikea for a considerable period (the minimum threshold was 5 years) (Ektorp, Kvik) and two relatively new models, i.e. Vimle and the modular system Vallentuna offered since 2017 were selected. Different product variants available on the www.ikea.com/pl website in the first quarter of 2018 were included in the analysis of the product series. They are shown in Table 3.

Table 3. Product variants in the product series selected for analysis

Collection (series)	Product number	Product variant
KIVIK 10 product variants	491.937.33	2-seat sofa
	491.937.28	3-seat sofa with chaise longue
	191.937.44	4-seat sofa with chaise longue
	391.936.82	4-seat, corner sofa
	291.936.87	5-seat, corner sofa
	291.936.92	6-seat, corner sofa
	091.937.54	3-seat, corner sofa
	691.937.08	5-seat, corner sofa with chaise longue
	591.937.18	8 seat, U-shaped sofa
	791.937.03	Corner section
VALLENTUNA modular 6 product variants	291.837.54	2-seat sofa
	891.625.84	3-seat sofa
	491.615.10	5-seat sofa
	391.497.50	6-seat sofa
	791.497.34	3-seat, corner sofa
	791.572.05	6-seat, corner sofa
EKTORP - 4 product variants	191.291.78	2-seat sofa
	791.292.03	3-seat sofa
	491.291.53	3-seat, corner sofa
	091.648.98	4-seat, corner sofa
VIMLE- 6 product variants	292.052.99	2-seat sofa

	592.069.14	3-seat sofa
	192.070.10	3-seat sofa with chaise longue
	192.070.72	4-seat sofa with chaise longue
	292.114.60	5-seat, corner sofa,
	292.115.92	6 seat, U-shaped sofa

Source: authors' analysis based on the information available on www.ikea.com/pl in the first quarter of 2018

▪ assembly instructions with information on all assembly components along with their 6-digit part numbers were identified on the website;
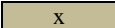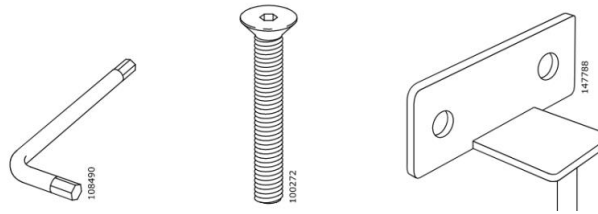

Fig. 4. Example of assembly parts with their 6-digit part numbers
Source: authors' analysis based on furniture assembly instructions from the manufacturer's website: www.ikea.com

▪ information about each model of furniture was entered into rows and information about relevant components (6-digit part number) was entered into columns in a matrix spreadsheet in MS Excel. The matrix showed whether a particular assembly component in a specific sofa model was used - it did not show how many times it was used in a particular product, but merely the fact that it was. Additionally, parts featured in specific product series were marked in different colors. This allowed us to see the differences in standarisation of products within the particular product series and the standarisaton across different product series.

Table 4. A sample matrix illustrating the level of standardisation saturation

Product type		Part type 6-digit assembly part number								
		1	2	…	…	…	…	…	…	m
		108490	100273	…	…	…	…	…	…	…
1	2-seat sofa		x							
2	3-seat sofa	x	x							
…	…									
n	…									

x	assembly part present in the product (darkened matrix cell)

To compare the level of standardisation within individual product series as well as across them, a quantitative indicator termed standardisation saturation indicator has been put forward.

The standardisation saturation indicator is a measure of the extent to which the same assembly part is used across various variants of a product. By reference to the graphic form of the matrix, it is the ratio of the darkened cells to the total number of cells in the matrix. It can be formalised with the following formula:

$$Ins = \frac{\sum x}{Pn * Am} \ \%$$

where: x – assembly part present in a product
 Pn – number of analysed products
 Am –number of part types (number of different, nonrecurring, assembly parts)

It is explained in the following way: the higher the value the indicator takes – the closer to 100%, the higher the repeatability of the assembly part within the examined group of products, which indicates a higher level of standardisation. The value of 100% means that (the same) all assembly parts are used in all analysed products.
The ratio presented above provides information about the potential for standardisation resulting from the fact of using the same assembly parts in different products.

In view of assessing the actual level of standardisation it is also meaningful to know how many other products feature a specific assembly part. Therefore, further analysis was performed to establish to what extent an assembly part was used in different items of furniture by showing what percentage of assembly parts was used in one product only, and what percentage reoccurred twice, three times or n-times. A high value of one-off occurrences would indicate a low level of standardisation.

The indicators discussed above were applied in the analysis of two areas:
▪ assessment of the level of standardisation within one product series. Here, all product variants in a specific product series were analysed (the following four series were analysed: Kivik, Vallentuna, Ektorp, Vimle).
▪ assessment of the level of standardisation across different product series. Here, a specific product type featured in many different product series was examined. Based on purposive sampling, 12 fabric-upholstered two-seat sofas, each from a different product series, were selected.
In the next section, the rates of part repeatability and percentage frequency distributions for specific parts for individual product variants are graphically presented in charts and matrices, and a summary is provided.

5. Results and discussion

The matrix of standardisation saturation, which is a graphic illustration of assembly part distribution by product series for the 4 series (Kivik, Vallentuna, Ektorp Vimle), is presented in Figure 5.

The matrix shows how each one particular assembly part in specific sofas is used - it does not show how many times the part is used but merely the fact that it is. Additionally, parts featured in specific product series are marked in different colours.

Fig. 5. The matrix of standardisation saturation - a graphic illustration of assembly part distribution by product series
Source: authors' analysis based on furniture assembly instructions from the manufacturer's website: www.ikea.com/pl in the first quarter of 2018.

Based on the analysis of the data from the matrix it can be concluded that on the level of specific product series, standardisation, defined as the level of repeatability of assembly parts used in the products, is evident, although it varies significantly across different product series. The situation is perfect in the case of the Vallentuna series - the same assembly parts are used in all analysed sofas regardless of their variant. For the other series, there is still room for improvement as far as assembly part standardisation goes to enable a reduction in the number of their different types used in specific products. To compare the results for the particular series, standardisation saturation indicator was calculated for all products within each series. The results are summarised below.

Fig. 6. The matrix of standardisation saturation for the KIVIK series
Source: authors' analysis based on furniture assembly instructions from the manufacturer's website: www.ikea.com/pl in the first quarter of 2018.

The indicator value for the Kivik series:

$$Ins = \frac{\sum x}{Pn * Am} \% = \frac{138}{10 * 24} \% = 58\%$$

Fig. 7. The matrix of standardisation saturation for the Vallentuna series
Source: authors' analysis based on furniture assembly instructions from the manufacturer's website: www.ikea.com/pl in the first quarter of 2018

The indicator value for the VALLENTUNA series:

$$Ins = \frac{\sum x}{Pn * Am}\% = \frac{48}{6*8}\% = 100\%$$

Fig. 8. The matrix of standardisation saturation for the EKTORP series
Source: authors' analysis based on furniture assembly instructions from the manufacturer's website: www.ikea.com/pl in the first quarter of 2018

The indicator value for the EKTORP series:

$$Ins = \frac{\sum x}{Pn * Am}\% = \frac{28}{4*10}\% = 70\%$$

Fig. 9. The matrix of standardisation saturation for the VIMLE series
Source: authors' analysis based on furniture assembly instructions from the manufacturer's website: www.ikea.com/pl in the first quarter of 2018

The indicator value for the VIMLE series:

$$Ins = \frac{\sum x}{Pn * Am}\% = \frac{71}{6 * 16}\% = 74\%$$

Clearly, the values of the standardisation saturation indicator vary for the different furniture series and range from 58% for the KIVIK series to 100% for VALLENTUNA.

As Figure 5 clearly shows, the picture is decidedly bleaker if standardisation of assembly parts across different product series is considered. None of the assembly parts was found to be universal enough to be used in the assembly of all sofas within the 4 studied product series. To refine the analysis of the level of standardisation of assembly parts used in products representing different product series, one type of product was selected based on the following criteria:

- A two-seat sofa; in the absence of a two-seat sofa, a three-seat sofa,
- fabric upholstery or fabric cover,

Products that met the above criteria, where each represented one of 12 different product series, were analysed. The matrix of standardisation saturation for the analysed group of products is presented in Figure 10.

	Product series	Product type symbol	6-digit assembly part numbers																																								number of unique parts used in the products (max42)
		100837	110439	100712	114509	121303	110019	117175	100854	121236	311526	100178	101350	117142	117145	122550	105209	131289	108014	130911	119577	130913	106629	130914	159169	192241	159176	130646	147786	109142	120208	100109	100259	105103	191109	121779	110737	122577	104864	100032	120075	155852	139454	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	
EKTORP	1 191.291.83	+	+	+	+	+																																						5
KIVIK	2 490.114.17			+			+	+	+	+																																		5
KLIPPAN	3 892.517.83			+	+				+		+																																	4
KARLSTAD	4 798.404.95			+			+	+	+			+	+	+	+																													8
TIDAFORS	5 602.052.49			+			+	+	+						+	+	+																											7
STRANDMON	6 003.254.43																	+	+																									2
KNOPPARP	7 003.242.74																			+	+	+	+	+																				5
DELAKTIG	8 592.596.91																								+	+	+																	3
VIMLE	9 492.069.19			+						+																		+	+	+														5
YPPERLIG	10 303.465.90																														+	+	+	+										4
GRONLID	11 292.562.98		+	+					+																			+		+					+	+	+	+	+	+	+	+		13
LANDSKRONA	12 392.703.26																																										+	1
number of products in which the part was used (max 12)		1	2	7	2	1	3	3	6	1	1	1	1	2	1	1	1	1	1	1	1	1	1	1	2	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	62

Fig. 10. The matrix of standardisation saturation – two-seat sofas in different product series
Source: authors' analysis based on furniture assembly instructions from the manufacturer's website: www.ikea.com/pl in the first quarter of 2018

The indicator value for sofas in the 12 different series:

$$Ins = \frac{\sum x}{Pn * Am}\% = \frac{62}{12 * 42}\% = 12\%$$

The level of repeatability in this case was significantly lower than for products within the same product series. Further analysis to estimate the percentage of assembly parts used in one product only, in two, three, and n-number of products was performed. The results for two-seat sofas as well as for all products in the four selected series are illustrated in Figure 11.
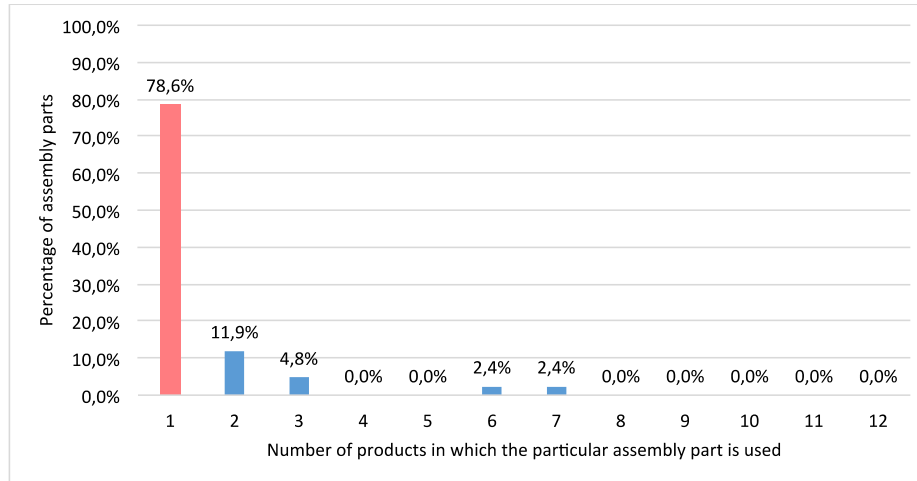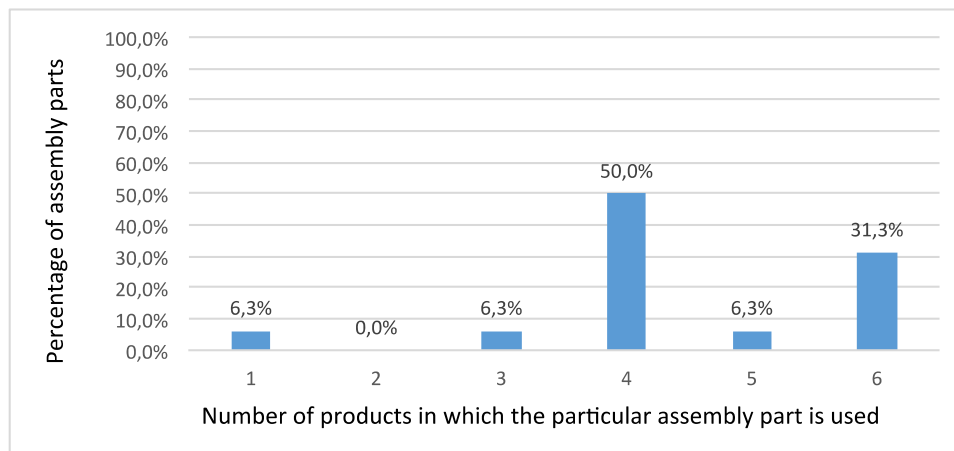
Fig. 11. Percentage of assembly parts used in n- products for 2-seat sofas from the 12 series
Source: authors' analysis based on furniture assembly instructions from the manufacturer's website: www.ikea.com/pl in the first quarter of 2018

It is obvious that assembly part standarisation is at a very low level when one product type in many different series is analysed. Nearly 80% of assembly parts are used in one product only, which means they are product-specific.
The situation is considerably different when different variants of products within the same series are analysed. The results of such analysis are presented in Figures 12-15.
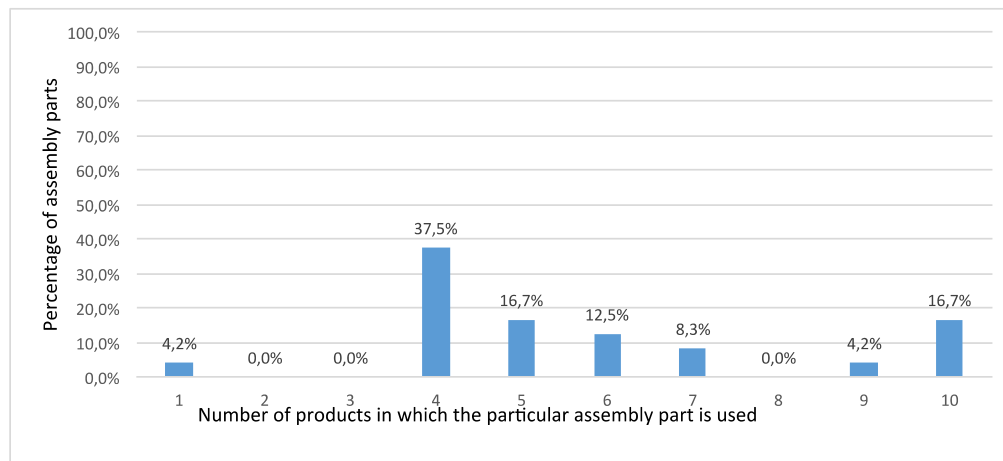

Fig. 12. Percentage of assembly parts used in n- products for the VIMLE series
Source: authors' analysis based on furniture assembly instructions from the manufacturer's website: www.ikea.com/pl in the first quarter of 2018
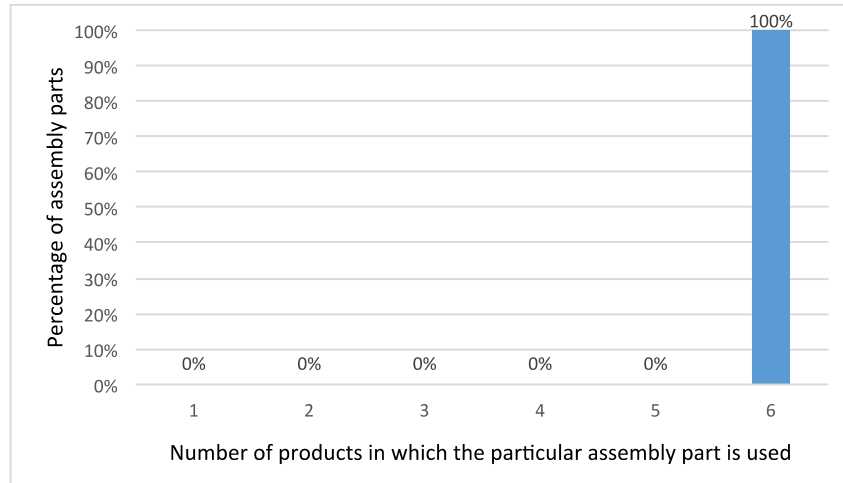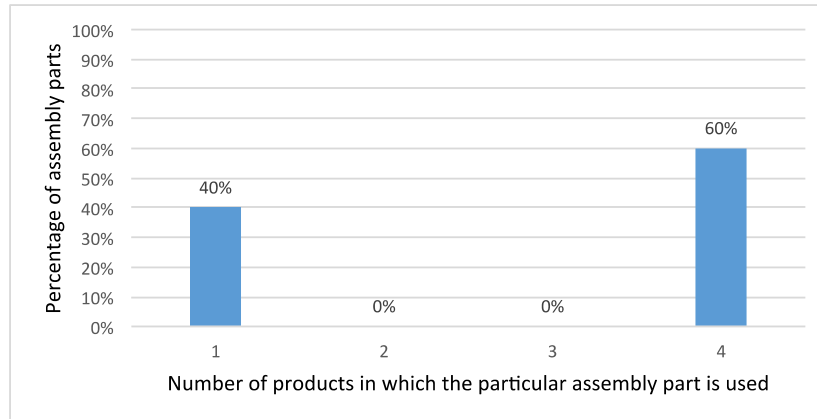
Fig. 13. Percentage of assembly parts used in n- products for the VALLENTUNA series
Source: authors' analysis based on furniture assembly instructions from the manufacturer's website: www.ikea.com/pl in the first quarter of 2018

Fig. 14. Percentage of assembly parts used in n- products for the KIVIK series
Source: authors' analysis based on furniture assembly instructions from the manufacturer's website: www.ikea.com/pl in the first quarter of 2018

Fig. 15. Percentage of assembly parts used in n- products for EKTROP series
Source: authors' analysis based on furniture assembly instructions from the manufacturer's website: www.ikea.com/pl in the first quarter of 2018

The analysis of each product series reveals a rather diversified picture: from an ideal case of the VALLENTUNA series where each assembly part is used in each of the six products to the EKTORP series where 40% of the assembly parts are only present in one product whereas, at the same time, the remaining 60% feature in all the analysed product variants. For the KIVIK and VIMLE series, on the other hand, significant variability in the use of assembly parts across various product types is observed.

The analysis confirmed a prior conclusion that repeatability of assembly parts, although fairly varied across the different series, is still evident at the level of individual product series.

Therefore, the results allow us to assert that standardisation is important for the studied enterprise (IKEA has been making efforts toward the standardisation of assembly parts within product series), however, there is still considerable potential for optimization.

Although the analysis presented above is preliminary, it clearly reveals an enormous, exploitable potential for standardisation of assembly parts used in particular product groups. Also distinctly apparent is a significant dependence of product modularity and the level of assembly part standardisation. The VALLENTUNA series, for which the level of component standardisation is 100%, is marketed by IKEA as "Our most flexible sofa. Ever". Products in this series include modules for sitting, sleeping, and storage, and enable the customer to upgrade or convert furniture items to alternative uses – including conversion of sofas to beds, replacement of armrests, etc.

Conclusions

In the paper, we put forward a thesis that real progress in closing the loop in the furniture supply chain can only be realized through a long-term strategic approach to implementing the demands of circular economy on the part of the industry coupled with active consumer engagement. At the same time, we looked for practical solutions that would be relatively straightforward for business organisations to apply immediately. For that reason as well as due to the visible scarcity of analysis and business activity in this area (most of the observed activities and analyses have concentrated on products rather than parts and components), in our primary research, we focused on standardisation as regards components and parts used in ready-to-assemble furniture.

We proposed different models that rely on the varied engagement of consumers, furniture producers/retailers, and external contractors in the process of closing the loop, and we have recommended those that we deem to have the greatest potential in the context of a circular economy.

We have found that the most advantageous for the implementation of a circular economy is the model in which the manufacturer implements a strategic system of planning product circularity performance based on quantitative reduction of virgin raw materials but also intermediate products in finished products. In the model, 3R processes need to be planned from the very beginning of the product design process and a strategic system for reuse of recovered raw materials, materials, and components in new furniture needs to be developed.

The model requires not only a strategic organisational approach that relies on a high level of component standardisation but also on effective sourcing of used/unwanted furniture and its components from the market. The model is highly unlikely to be effective unless consumers are engaged and the level of standardisation of components and parts is high.

Therefore, we have also suggested a consumer engagement model that appears the most preferable because of the cost and convenience for the manufacturer/retailer as well as the potential for retrieving furniture from the market. In this model, the consumer is highly engaged and active, willing to disassemble the furniture as well as to transport it to the manufacturer.

The manufacturer gains a lot but needs to implement effective consumer incentive programs including reward/discount systems, develop user-friendly disassembly manuals, and establish and maintain good communication with consumers. Indispensable for this purpose would be systematic analysis to enable an adequate understanding of consumer attitudes, motivations, and behavior mechanisms. On this account, and in the face of a scarcity of existing analyses that could facilitate a better understanding of furniture consumer behavior in the context of a circular economy, the authors intend to study this area further in their future research.

In the final part of this article, the authors assessed the level of standardisation of assembly components used in ready-to-assemble furniture for the selected product group (sofas) of the global, leading furniture producer and retailer (IKEA), and accordingly, determined the scope of potential improvement in this area. It has been found that at the level of specific product series, standardisation defined as the level of repeatability of assembly parts used in products is noticeable, however, as the analysis has also revealed, it varies significantly across different product series, which leaves room for further improvements. This exploitable potential for standardisation of assembly parts is even more apparent when products from different series are included in the analysis.

Taking into account that the studied furniture manufacturer and retailer – IKEA, has already taken some steps towards product modularity and standardisation and the fact that IKEA customers have long been accustomed to self-assembling the furniture they purchase from IKEA, we have reasons to think that the solutions proposed in the paper are highly likely to be successfully implemented in practice.

Limitations and future research
The limitations of the study are related to the following aspects: first of all, the analysis was based on one manufacturer and it did not include all product groups. Secondly, the assessment of the potential for standardisation relied on one aspect only: the level of repeatability of assembly parts used in ready-to-assemble furniture. In the proposed indicators, we did not consider the quantities of the assembly components or the measure of statistical dispersion in the standardisation saturation matrix. Nor did we explore aspects connected with product and assembly parts construction. The indicators used in the analysis did not take into account the production- and logistics-related costs of standardized elements. Those aspects should be analysed further to minimize the number of part types used in different product variants in different product series and part reuse

potential, providing an appropriate level of safety and usability. Despite these limitations, the proposed research method allowed the authors to accomplish the objectives set for this stage of the research, and to formulate preliminary conclusions.

The article also aimed to present a closed-loop supply chain model for the furniture industry and different models (scenarios) implying varied engagement of consumers, furniture manufacturers/retailers, and external contractors in closing the loop. This was performed based on the literature review and observation of industry practices in this area. In their further research, the authors plan to empirically verify the assumptions made in the models and to confirm the initial recommendations. Therefore, the next step will involve an assessment of consumer engagement in disassembling, sorting, and transporting furniture they no longer need. Appraisal of factors determining consumer behavior in this regard will be the primary goal.

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