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Impact Factors of Mass Customization on Sustainability

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Abstract: *Mass customization (MC) has been broadly discussed as a potential business model for heterogeneous markets in the management literature. In market settings that are characterized by high levels of customer need heterogeneity, MC has to be considered as an economically viable strategy. However, it might not be sufficient to assess the business model solely on the basis of economic indicators. Environmental problems and the exacerbating climate change have sparked a global debate about ecological thinking and sustainability. In this context, existing literature describes the need for strategies that are sustainable in terms of economic, social and environmental aspects. In accordance with this aspect, more and more authors claim that MC – besides being an economically attractive business approach – also carries the potential to be an environmentally and socially beneficial business model. This paper aims to identify potential impact factors of MC on sustainability in order to establish a research agenda concerning the role of MC for sustainability. One aspect is that new tools and new methodologies from other theoretical areas than the traditional MC theory and practice can be brought into the research agenda.*

Key Words: ***Mass Customization, Environmental Sustainability, Research Agenda***

1. INTRODUCTION

Mass customization (MC) is a strategic approach that is developed to cope with high levels of heterogeneity among the needs of customers in a given market. The basic idea is well explained by Davis [1, p.169]: MC aims at serving customers individually through a high-variety product offering, whilst broadly retaining the same overall sales volume as a comparable mass production strategy [1]. Thus, from a strategic management perspective, MC is a hybrid competition strategy that attempts to master the simultaneous realization of product differentiation and cost efficiency [2].

The concept is based on the idea that every customer envisions an “ideal product”, which will be used as a benchmark for all products that are available on the market, comparable to the well-established expectancy disconfirmation model [3, 4]. Following the concept of Chamberlin’s [5] theory of monopolistic competition, customers gain the increment of utility of a customized good that better fits their needs than the most suitable standardized product that is available in the market. Subsequently, the better a product fits the customer’s needs, the higher will be the customer’s willingness to pay [6, 7], and the higher the level of customer need heterogeneity, the larger will be this gain in utility [8]. Following this rational, a MC strategy holds the potential to increase revenues by turning heterogeneities in the customer domain into an opportunity to create value [9]. That way, the implementation of MC has to be considered as an economically viable strategy: on the one hand, firms can charge higher prices for customized goods because of the increased customers’ willingness to pay for individualized goods. On the other hand, the realization of flexible manufacturing processes and suitable customer interaction tools allows providing these customized goods at cost levels that are comparable to those of mass produced goods. Subsequently, profit margins may be higher compared to those of standardized products under such heterogeneous market conditions.

However, in view of the challenges that the global community faces today, it might not be sufficient to assess the MC business model solely on the basis of economic indicators. Environmental problems and the exacerbating climate change have sparked a global debate about ecological thinking and sustainability. We are very well aware of the difficulties with the definitions of the terms “environment” and “sustainability”. From the theory of externality within mainstream economics there is a huge discussion about how to measure, how to incorporate externalities into cost etc.. If we go into the pluralistic paradigm of “ecological economics” we also find confusion and different frameworks according to how to treat the idea of the notions because of their complexities. “Does the life and the activities of a butterfly in The Amazon influences the environment in Scandinavia and consequently incorporated in the measure accounting of cost and benefit in industrial activities?”. However, this discussion is broad and complicated so within this paper we take the definitions as “granted”. Having stressed these two topics we also must stress the general confusion about the term business model. Internationally there does not exist a general academic consensus about the definition. Consequently, in this paper we must neglect the discussion about definition and take it for granted. In the conclusion we briefly return to the question.

Turning the attention to customer demand for more environmentally friendly products on one hand and the strict governmental regulations on the other hand bring out the concept of sustainability as a point of attention for companies. In this context, Elkington [10] claims that companies need to develop so called “Win-Win-Win”-strategies, which are sustainable in terms of economic, social and environmental aspects. In accordance with this aspect, more and more authors claim that MC – besides being an economically attractive business approach – also carries the potential to be an environmentally and socially beneficial business model. For example, literature sees MC as a mean to reduce overproduction and waste of resources [11], claims that customized products have a longer life span [12] and allow better reuse and recycling possibilities [13].

Nevertheless, there are only very few studies that support these hypotheses concerning the role of MC for environmental sustainability; especially beyond conceptual research. Thereby, the existing trade-off of considering MC and sustainability simultaneously can trigger a new research stream for academia. Research initiatives need to support companies in implementing MC in a more sustainable manner. Therefore, in a first step, this paper aims at identifying general impact factors of MC on environmental and social sustainability primarily based on the existing literature and inspired by the results of the special session on MC and sustainability at the MCPC 2014 conference in Aalborg. In a second step, the paper will then provide a research agenda including the above-mentioned aspects of the MC-sustainability-relationship that need to be addressed by future studies.

2. A PRODUCT LIFECYCLE APPROACH

»In essence, sustainability is an enlarged framework through which to view the making and selling of products and services« [14, p.52]. In this light, the realization of sustainable development requires a reduction of wasteful and environmentally and/or societally harmful practices in all stages that are relevant for this act of making and selling goods and services [14]. Subsequently, our considerations on potential impact factors of MC on sustainability need to employ a total product life-cycle approach, which considers all the stages of a product's life. In this context, Jawahit et al. [15] suggest a framework of four separate stages: premanufacturing, manufacturing, use and post-use [15].

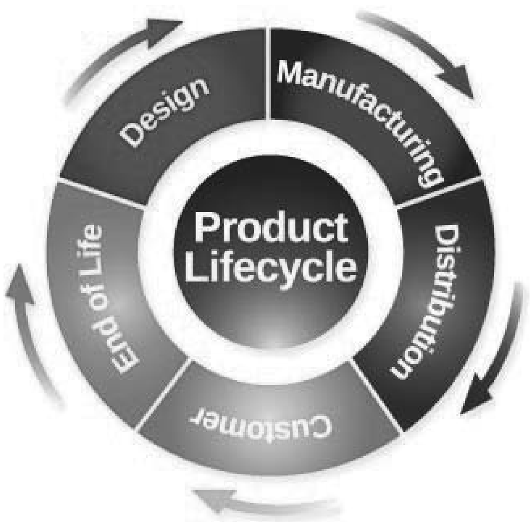

Fig. 1. *Close looped product life-cycle*

Primarily; this approach forces emphasis on design and production that look beyond getting the good or service to the end customer (the conventional end point). Secondly, this total product life-cycle focus calls for innovative approaches to transform from open-loop material flow for a single product life-cycle to closed-loop material flow across multiple product life-cycles in which the components and parts can be reused several times before disposal [14].

In this paper we go beyond the four stages suggested by splitting the manufacturing phase into two different phases namely manufacturing and distribution. Hence the product life-cycle contains five phases. Initiating with design phase and continuing with manufacturing and distribution as the two other phases, the product enters its use phase while it is delivered to the customer. Finally the product enters the final phase of the end of life where proper waste management strategies should be implemented. The pursuit of waste management strategies supports companies to close the life-cycle loop by bridging the end of life to the beginning of life of the product. Figure 1 illustrates the life-cycle loop and all the five phases.

Furthermore, it has to be considered that the impact factors are not necessarily beneficial. It is conceivable that certain aspects of an MC business strategy show negative impacts on certain environmental indicators. In the following analysis, it will be attempted to include all potential impact factors – both positive and negative.

2.1. Impact Factors in the Design Phase

Through a product lifecycle, the design phase is considered as a very critical stage. The decisions which are made during the design phase affect significantly the final performance of the product [16]. Moreover, design is not only the initial stage of a product lifecycle, but also an essential step to close the lifecycle loop through merging the beginning of life with the end of life of the product. In this regard, sustainable design is widely known as an eco-design concept that includes environmental, social and economic concerns during the design phase of a product [17].

MC is always known as a strategy which is fundamentally based on interaction with customer and collaboration during the design phase. The process of co-design allows customers to articulate their requirements of a product and configure their desired product within a finite solution space and consequently be involved in the process of value-creation [18]. Involving the customer in the design phase of the product can enhance not only the social aspect of sustainability, due to higher customer satisfaction, but also the environmental aspect. The co-design process results in designing a product with attributes that are much more aligned with the customer's needs and desires compared with a standard one. In other words, the MC company produces only the products that are needed and requested by the customers. Accordingly the amount of waste will be decreased through producing less useless products [19].

Beside the co-design process itself, applying the configurator during this process can act as an impact factor for sustainability as well. A configurator is an essential resource to implement MC and is widely applied by MC companies to enable their customers to design a product based on their needs and desires. Configuration of an MC product takes place in several steps and considering different aspects of customization defined by the company such as color, fit, and performance [20]. Extending the configuration choices by giving information about the environmental impacts of the selected features increases the customer awareness [19]. Consequently, providing customers with information about potential environmental impacts of each selected feature and likewise of the whole sustainability impact of the final product during the co-design process can get them to choose and design a more eco-friendly product.

In addition to co-design, an MC product is usually characterized by its modular architecture. Modularity is always seen as one of the main operational enablers for MC. A modular architecture gives the manufacturer the possibility to produce a large number of varieties using standard components. Each module represents one or more functions of the product and is available with several options that result in different performances of the product. In fact, modularity could result into advantages in terms of economies of scale and further reduction in lead-time if well-defined [21]. Thanks to its modular architecture, an MC product can be managed in a more sustainable manner at the end of its life. However, it should be noticed that modular products cannot be optimized with the same efficiency as integrative solutions with regard to weight and performance. Hence, more material resources are required for MC products than for mass-produced ones [22, 23].

2.2. Impact Factors in the Manufacturing Phase

During the early years of the emergence of the concept of sustainability, manufacturing companies that intended to pursue sustainability started to focus on waste reduction during the production phase and later on reduction of resource and energy consumption. According to the National Council of Advanced Manufacturing (2009) sustainable manufacturing refers to "*creation of manufactured products that use processes that are non-polluting, con-serve energy and natural resources, and are economically sound and safe for employees, communities, and consumers*" [24].

The MC practices which are deployed during the manufacturing phase, have controversial effects in terms of environmental sustainability. An MC product is only produced after receiving an order from the customer. The *manufacture to order* nature of the MC products prevents production of not demanded products and hence avoids over production. In this case there is no unsold product since every product is produced based on a received order. This results not only in a notable decrease in the level of waste of the final products, but also in a lower level of energy consumption for production. According to an estimation in 2009, 300 million pairs of shoes are overproduced annually. Considering the energy required to produce each pair of shoes, the total energy consumption to manufacture all the unsold shoes equals to 14% of the energy consumption in Switzerland in one year [25]. Such information highlights how MC can be a positive driver for sustainability in terms of manufacturing. Nevertheless, the negative side of MC during the manufacturing phase should not be neglected neither. It can be argued that producing customized goods results in a higher amount of waste of raw materials in comparison with mass-produced products. Coming back to the example of shoes, every customized pair of shoes requires a different type and cut of the leather, while for a standard pair of shoes the same type and cut of leather is used and therefore the optimization of raw material usage leads to a lower consumption of raw materials. The same thing is valid regarding energy consumption. In order to produce customized products, different and more complex manufacturing processes are necessary compared to standard products. Therefore the optimization of these processes in terms of both material and energy consumption is more complicated [26]. Hence, a higher level of production process variety in a MC environment negative environmental impacts.

On the other hand, the type of production system applied by the MC enterprise can be a source of sustainability performance improvement. In order to be successful, an MC firm requires robust production processes as one of the main MC capabilities [27]. A crucial challenge of MC is the efficient production of customized products. Heterogeneity in customers' needs generates additional costs for production systems. These costs derive from the need of recombining or reconfiguring production resources to increase the flexibility of the manufacturing system and respond to diverse orders of customers within a reasonable period of time [27, 28]. The feasibility of such a system depends upon a robust process design. Robustness of production processes refers to the capacity to reuse or re-merge the existing manufacturing resources to satisfy a diverse range of the customers' needs and requirements [29]. Having robust processes, a company can deliver customized products with near mass production efficiency. Accordingly, a successful MC business model should aim at creating stable, but still responsive and flexible, processes to manage the dynamic nature of orders and eventually products [27, 28, 30]. Such types of robust production systems such as Flexible

Manufacturing System (FMS), Reconfigurable Manufacturing System (RMS) and Rapid Manufacturing (e.g. 3D printing) can conserve more energy due to their energy-efficient structure and thus enhance the sustainability performance of the company [31].

2.3. Impact Factors in the Distribution Phase

Talking about environmental sustainability, the distribution phase of the product lifecycle is always considered as a critical stage with respect to the amount of energy consumption and emissions. The emerging environmental impacts in this phase are not only related to the distribution strategies, but also to the type of channel selected by a firm in order to reach the customer. In terms of distribution channel the majority of Mass Customizers offer web sale and at home delivery to their customers. Widely used by most of the MC companies, at home delivery is a popular and efficient channel for MC. In such a scenario, customers place the order online and receive the final product at their place without any need to go to a physical store. However, having such a distribution channel necessitates individual shipments of the products to the customers. Obviously, this requires more materials in terms of packaging and results in more energy consumption [23, 26]. Moreover a single batch delivery (compared to several batch deliveries in the case of standard products) requires a higher number of delivery transports and hence creates a higher level of emissions as a negative impact. Nonetheless, the fact that for all the online retail businesses, customers do not have to travel to the store for picking up the final products suggests a reduction in the amount of consumed energy as well as emissions. Furthermore, it can be argued that in an MC environment the product does not travel through several tires of suppliers and therefore the shorter route from producer to customer does also positively affect the level of energy consumption and emissions [26].

While discussing about the distribution phase, the impact of reverse logistics is a critical point. Generally speaking, MC companies enjoy a less complicated distribution system in terms of reverse logistics. The fact that the customized product is produced to satisfy the individual needs of a specific customer makes it quite impossible to apply a return policy for the products. Having no return policy has its own controversial impacts in terms of environmental sustainability. On the one hand, no returned goods means no reverse logistics for MC companies, which significantly reduces the level of energy consumption and emission thanks to the absence of reverse logistics and re-shipment of the product. On the other hand, a lack of return policy can result in an increase of waste since the customized product (in case of not being compatible with customer's desire) can be rarely used by another person due to its personalized features and thus will be disposed without being used.

Apart from the above discussed impact factors, the future trends in MC can also have a significant role to convert MC to a more eco-friendly strategy. For instance, the increasing popularity of micro-manufacturing and mini-factories highlights them as a potential production paradigm for the future of MC. Mini-factory is a small-size manufacturing system with downsized production processes which consequently result in the overall space reduction and thus reduced resource consumption. In addition to their micro dimension, mini-factories are usually characterized by their extreme precision and efficiency in different machining processes. Such a manufacturing paradigm can be a potential choice of the MC production system since it can benefit the MC firm through space reduction, shorter process chain, higher flexibility and quicker response, modularity of production processes and eventually cost reduction [32]. Beside the increased efficiency and flexibility, mini-factories can also enhance the level of environmental sustainability. In general, these small-size factories are located in the proximity of the market. Therefore the distribution rout from the producer to the customer would be significantly shorter compared to the mass products which are usually produced in countries with low labor cost. The shorter rout, thus, is a positive impact factor to lower energy consumption and emission during the distribution phase [33].

2.4. Impact Factors in the Customer / Usage Phase

The use phase of a product life-cycle refers to the time span in which the product is delivered to the customer and is applied by him/her to satisfy his/her needs. Based on the life span of the product the environmental impacts of the use phase might vary. However, it is commonly believed that the use phase is usually the longest stage of the product life-cycle and thus can have significant impacts on sustainability. In terms of MC products, the life span is usually considered to be longer due to the fact that customer craves more for a customized product, which is co-designed by himself, and therefore use it for a longer period of time compared to a standard product. This eventually enhances the environmental sustainability since less waste is produced.

Furthermore, the modular nature of an MC product facilitates upgrading of the product and consequently extending its life-cycle [26]. Having a modular architecture, a product can be easily re-configured through changing or replacing one or more modules and hence it can be used for a longer time. Moreover, modularity facilitates the maintenance of the product during its use phase since the defective module can be simply replaced by a new one [34], while in products with an integrated architecture the defective parts cannot be disassembled and therefore the product cannot be used any longer. On the other hand, taking into account the necessity of efficient production in an MC environment, most of the MC companies try to develop standard modules which can be used in multiple products. As a consequence, the company can invest more in optimizing these modules to make them more energy-efficient. Considering the high volume of these modules, due to their application in several products, the level of energy consumption in the MC products can be significantly lowered compared to mass-produced products [26].

Apart from modularity, the fact that an MC product is produced in a way that its attributes fit the individual needs of the customer could be a potential impact factor for sustainability too. In the case of standard products, the purchase price for a certain group of products is so low that consumers do not hesitate to dispose a nearly unused product if it does not meet their needs and purchase a replacement, assuming that it will better fit the needs [23, 35]. However, this would be less likely in the case of a customized product not only due to its premium price, but also because of its compatibility with the customer's needs so that the consumer does not see any reason to replace it with another product.

2.5. Impact Factors in the End-of-Life Phase

Decisions that are made at end of life phase – e.g. regarding how to manage the waste and to treat the product – significantly influence the environmental sustainability impact of the product. In this regard, several methodologies have been proposed in order to pursue a closed-loop life-cycle including the 3R concept (reduce, reuse, recycle) [36] and the 6R methodology which is an extension of the 3R concept. The 6R methodology considers six main strategies (reduce, reuse, recover, redesign, remanufacture, recycle) for a sustainable treatment of a product at the end of its life-cycle [14]. While the main focus of "reduce" is on the prior phases of the life-cycle (design, manufacturing, distribution, and use) by emphasizing on reduction of the amount of consumed energy and raw materials as well as the produced waste; the other strategies mainly refer to the actions which should be taken at the end-of-life phase.

In the case of customized products, the "reuse" strategy might seem challenging considering the fact that an MC product is tailored to satisfy the individual needs of a specific customer, which is obviously different from another one's. Hence, it seems very unlikely that the product and its attributes fit an entirely different consumer and thus can be re-used [23]. From this perspective an MC product seems quite non-reusable; however it can be argued that if a product contains an embedded toolkit or the possibility to adapt / reconfigure a product after purchase, the likelihood of re-use increases.

The two strategies of re-design and re-manufacturing emphasize on creating a multiple life-cycle for a product. In other words the life of the product would be extended by re-designing or re-configuring some parts of it and creating multiple use phases for the product. In the case of re-manufacturing the product would be disassembled, cleaned, inspected, repaired, replaced and finally reassembled so that it would be revived as an entirely new product in terms of both performance and durability [37, 38]. Considering the characteristics of products within the MC strategy, re-designing and re-manufacturing seem to be applicable and realistic strategies for waste management. In fact, the modular architecture of the MC products makes them a proper choice for disassembling and re-assembling. In this regard, re-manufacturing of an MC product would be much more cost-efficient compared to a product with an integrated platform. Moreover, the redesign process can enable consumers to assess the impact of each customized alternative with regards to resource consumption and environmental benefits during the co-design process [19]. The same argument could be made for recycling. The initial step of recycling of every product is disassembling and separating the recyclable parts from those that are non-recyclable. MC products again, thanks to their modular architecture, can be disassembled very easily and quickly.

3. CONCLUSION

From its emergence as a trend, MC has been extensively discussed as a proper business model to satisfy the individual needs of customers. However, the increasing importance of sustainability in the last decades has pinpointed it as a crucial point of attention for manufacturing companies including MC firms. This paper tries to have a closer look at the concept of MC from an environmental sustainability point of view. It discovers potential interdependencies in order to explore the impact factors of MC on environmental sustainability. To this end, a product life-cycle approach was considered including five phases of a product life-cycle.

The analysis in each phase of the product lifecycle reveals that in some aspects MC products can enhance the environmental sustainability thanks to the employment of specific practices and capabilities which are required for successful implementation of MC. For instance the modular architecture of an MC product can be a positive impact factor for sustainability. It facilitates disassembling of the product at the end of its life as well as re-designing or re-manufacturing to extend the product life cycle, and decreases waste production. Customer involvement in the co-design process (during the design phase), fit of product attributes with customer needs and robust production processes (during the manufacturing phase) are other examples of MC practices which might result in lower environmental impacts. While the first two practices can cause a reduction in waste the third one might lead to lower energy consumption.

Nevertheless, beside their positive impacts, MC practices can also negatively affect sustainability. Taking into account the necessity for individual shipment delivery of MC products during the distribution phase, the level of energy consumption and emissions could increase significantly. Moreover, the customized features of an MC product make re-use at the end of its life quite impossible. Accordingly, our analysis points out that MC is a strategy which can both benefit and harm the environmental sustainability through various impact factors. The final influence of MC on sustainability, however, is a trade-off which should be managed by MC firms to reach the desired level of sustainability performance. In other words, the main challenge of MC enterprises, in terms of sustainability, would be the implementation of MC in a more eco-friendly manner.

In practice, firms would have to evaluate how the different impact factors are related to their specific MC business model. Certain mapping methodologies such as the Business Models Canvas [39] could lead them to solve this assignment. Also, the Business Model Cube could be a useful mapping tool [40]. The identified impact factors can be linked to seven different dimensions of the business model including the dimensions' sub-dimensions. Doing so, an MC-firm will get a detailed picture of the interrelation with the relevant impact factors. As in each case some impact factors may be regarded as more important than others a kind of ranking could be a useful next step.

Beside the environmental impacts of MC, its effect on social sustainability should be a point of attention too. MC products can be extremely socially sustainable during the use phase due to their customized features and attributes (e.g. in the case of people with special needs or disables people). Moreover MC can be seen as a driver to create local jobs and protect local labor thanks to the use of mini-factories and decentralized production systems. As a conclusion, the future research directions should be focused not only on the environmental dimension of sustainability but on the concept of sustainability as the triple bottom line. In addition, the increasing interest and involvement of MC companies in sustainability might make it feasible for future researchers to extend the qualitative research into a quantitative phase by measuring the impact of MC on sustainability through quantitative key performance indicators. The "MC assessment and measurement framework for industrial applications" [41] could be used as a reference for such a quantitative assessment.

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