Design for Mass Individualisation: Introducing Networked Innovation Approach

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Abstract. This paper outlines a nascent field of product innovation, which we believe will become significantly more relevant in the near future. Product design for Mass Individualisation is a new product design paradigm that comprises an open hardware platform and multiple modules that are integrated with the platform. It gives freedom to end users to integrate different modules into the platform as per their choice. Large manufacturers will produce the platform and some specific modules. Other modules will be invented and produced by smaller companies and by the user. This type of product integration will be engaged with by the all actors involved in the design and aims to help them to be more creative and innovative. Strategic and technological integration of all these actors, which is also the theme of Innovation 4.0, is the main focus of this work to intensify the innovation. Key areas which need to be focused on are identified and presented by an explorative study of existing product design and customisation approaches. Based on the explorative literature analysis, an industrial questionnaire survey has been conducted and results are presented for the industrial implication and insights on this approach. The findings clearly show that the end product from product design for MI will be more creative and innovative.

Keywords: Mass Customisation, Mass Individualisation, Product Design.

1 Introduction

The need to innovate products has become so intense that traditional product design and development processes cannot fulfil the requirements. Innovation in terms of product or process is one of the key concepts to address this issue. A new product design paradigm which could serve the need of adaptability, upgradability and sustainability, and meets the exact requirement of the end user has the potential to fulfil this demand.

Traditionally, most products are designed by professionals working for the underlying firms in design teams because those people "have acquired skills and capabilities that allow them to perform most design tasks more effectively and at a higher level of quality" [1]. However, product design paradigms have changed significantly over time, led by technological advancement. Innovation Technologies (IvT) [2] have facilitated new strategies for product design and development.

This paper aims to investigate the role of innovation in the product design process with the theme of networked innovation. The basis for the approach to networked innovation is the industrial practice of open innovation. Open innovation is defined as the use of purposive inflows and outflows of knowledge to accelerate innovation, and expand the market for external use of innovation, respectively [3]. The advantages and disadvantages of different forms of openness in firms have also been investigated in recent research on open innovation. Dahlander and Gann [4] studied the influence of this openness on a firm's ability to innovate and appropriate benefits of innovation. However, this kind of engagement between internal and external actors for innovation process requires multi-directional management and strategic integration. The latest practice of Innovation 4.0 addresses this complexity in open innovation.

2 Product Customisation

The concept of industrial product design has changed significantly over time, from individually crafted designs to product design for mass production (MP), followed by product design for mass customisation (MC). These changes are always triggered either by market conditions or the consumers' desire for the product offering.

2.1 Customisation concepts

Up until the industrial revolution, products were designed and made by craftsmen with a localised design stretching back generations. The concepts and processes associated with MP revolutionised the way products were designed and manufactured. Technological advancement later made it possible to design and manufacture products in mass quantities more quickly and cheaply. This is usually attributed to the early twentieth-century industrialist Henry Ford. His assembly-line approach to the manufacturing of the Model T motor car reduced the cost of the vehicles to such an extent that they could be afforded by ordinary working people. The impact on the market, and therefore on product design, was revolutionary. As society's desire to have a variety of similar products to choose from started to change, companies introduced the concept of product design for MC by offering them different variants of the same product. Although MC offers variants of the same product, often the constrained availability of options limits the fulfilment of the need of the end user since variants are provided by the manufacturer itself with few actual changes in design.

2.2 User-centered customisation

An emerging literature stream posits that inclusion of users, rather than internal designers in new product creation may benefit organisations because it results in a product which effectively satisfies consumer needs. Current product life cycle considerations from product conception, design, development, delivery, usage, service, and end of life disposal have not been able to consider customers as individuals.

New technologies have democratized the tools for both invention and production [5]. Anyone with an idea can use advanced and accessible technology and turn it into a product. The user has started to contribute to the design process in parallel to the professional design teams. Certain users are able and motivated enough to innovate and are willing to share their ideas with firms is not new and has been documented extensively [6]. By considering customers as both individuals and as an integral part of the design process, implicit characteristics such as personal taste, traits, innate needs and experience become important integral parts of product design [7]. But recent changes in user aspirations and inclination towards more individualised product offering have motivated innovators and product designers to approach a new paradigm. The continuously increased aspiration level of customers and the growing saturation of the markets are the main drivers for the development of customer individualised products [8]. Kumar [9] has documented the strategic transformation from mass customisation to mass personalization.

2.3 Product Design for Mass Individualisation

Fig. 1 shows the transition of manufacturing in the last 100 years. The volume of each product variant is decreasing from MP to MI. At the same time, product variety is increasing, showing the demand for more individualised products. It tends to reach a situation of market to one. Only the open platform type product architecture can address this demand and will be able to realise this paradigm shift. Initial research on this paradigm shift has been carried out by Koren, Hu [10], but to realise this approach and to convert it into industrial practice much more research need to be undertaken.

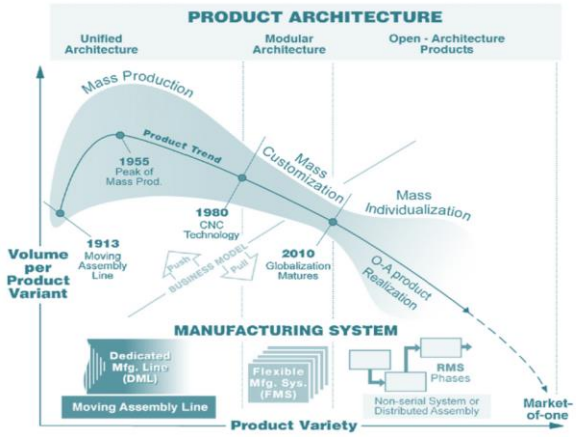

Fig. 1. Emergence of Product Individualisation [11]

In the last few years, a demand for renewed product personalisation to satisfy the exact need of the customers has been observed in the market. Koren, Hu [10] has named this concept "*Mass Individualisation (MI)*", a new paradigm for industrial

product design. MI is based on the open platform product architecture that is mass produced by large manufacturers and multiple independent modules provided by other smaller companies and the end user. In product design for MI, the final product is the end result of the creativity and innovation of various actors, including smaller companies, large original equipment manufacturer (OEM) and end users. The open platform is integrated with different modules as per customer's need and is selected using the interactive design program. Thus the end product, which fits the exact requirements of the customer, is highly individualised. Fig. 2 shows the MI ecosystem with all of its actors actively involved in product design and development.

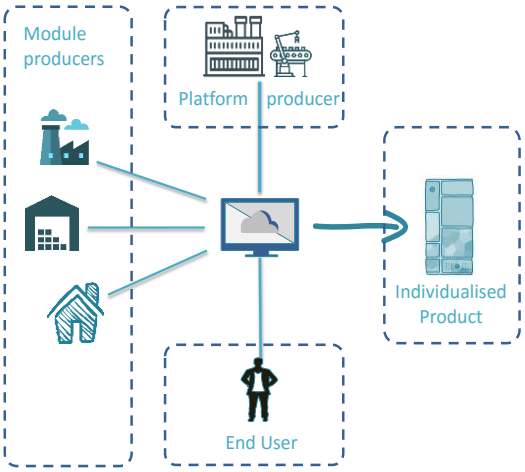

Fig. 2. Emergence of Product Individualisation

The product design for MI provides considerable incentive for the role of innovation. The future practice of *Innovation 4.0*, based on the strategy of "open innovation" first suggested by Henry Chesbrough [12], provides a potential innovation practice for MI. Innovation 4.0 focuses on the strategic and technological integration of various aspects of innovation [13], focusing more on inclusive innovation rather than open innovation. It places the emphasis on the networking of all the areas of innovation, i.e. strategy and methods, technology and products, processes and organization, society, communication and culture [14]. Connectivity becomes the central feature in Innovation 4.0. Everybody and everything needs to be networked. By linking all the steps in the value chain, a world of possibilities opens for companies and other actors. Interactive models that are interconnected with institutions and individuals which develop, test and distribute new practices and artefacts via interactive processes need to be developed. This paper investigates the role and future prospects of networked innovation in product design for MI.

Product design for MI has the potential to create many new jobs in module production companies. End user's purchase intention and willingness to buy products will be enhanced with this product design paradigm. MI has the potential to address

some of the challenges faced by the world today, such as diminishing natural resources, energy efficiency, demographic change, etc. Fig. 3 summarises the roles of different actors in MI ecosystem.

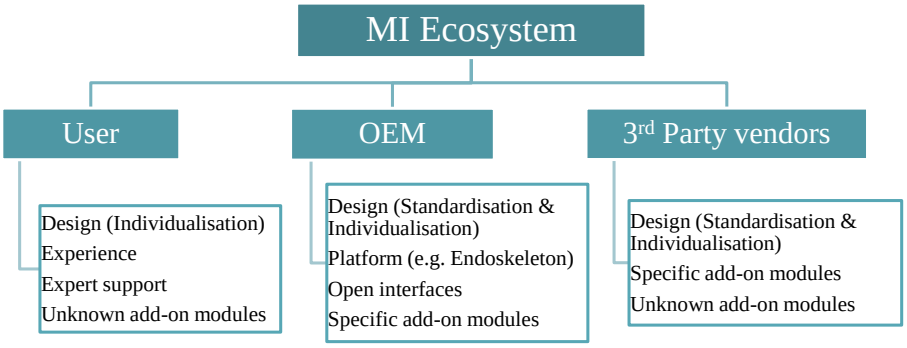

Fig. 3. Roles of different actors in MI Ecosystem

3 Methodology

The cross connection between different actors involved in the design process of MI requires new creative and innovative approaches. It requires changes in the way traditional product design and innovation are approached. This section explains the used research design and applied methods, to understand MI and its industrial implications.

3.1 Overview of the research methodology

As described in the previous sections, Product design for MI is a relatively new and visionary concept. In the absence of existing applications, experimental research or case studies cannot be applied. Thus, to answer the research question in this uncertain context, only an explorative study of existing literature and practical feedback from industry practitioners and experts, allows the derivation of valid conclusions. Therefore, the research methodology combines a qualitative exploration and quantitative analysis.

For a better understanding of this new paradigm, this paper aims to identify the key areas which need to be focused on to convert Product design for MI into an industrial practice. Across many industrial sectors, the end product will be far more efficient, effective, reliable, reusable and more fully utilized, with conservation of scarce natural resources such as energy, water, and raw materials. An explorative study of existing product design and customisation approaches has been conducted, some of them have been included in the last section. Keeping Innovation 4.0 as a central theme, different areas and components of MI that need to be focused on are categorized into three categories:

1. Changes in traditional product design and customisation approaches that need to be focused on
2. Components that need to be focused on
3. Technologies that need to be integrated

Based on the explorative study, an industrial questionnaire survey has been designed. The findings of this survey were then descriptively analysed and interpreted for industrial implication.

3.2 Industrial questionnaire survey

The products from MI offer a rich, new set of value creation and innovation opportunities. A web-based industrial survey constituting multiple choice answers and text answers questionnaire were developed, based on the explorative study of related literature and existing product customisation approaches. Following the qualitative exploration of literature, the questionnaire was structured in the following three sections:

- Product Design for Mass Individualisation (MI)
- Strategical and Technological integration
- Practical suggestions

Most of the multiple choice question responses were measured using a categorical scale, with a provision of providing additional comments. The scale used five categories so that middle one represents a neutral stand point with different levels of agreement and disagreement on both sides. Appendix I shows all the questions, identified for the questionnaire survey.

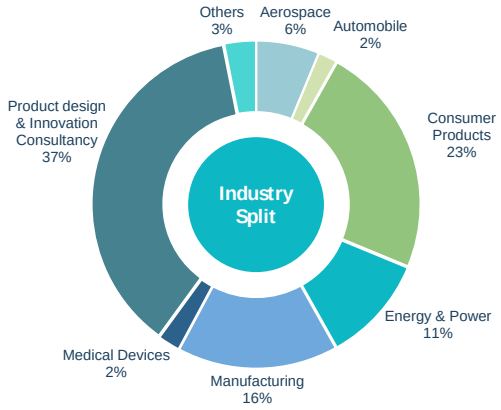

Fig. 4. Industry split of the questionnaire survey respondents

Consumer product design companies (350 companies) across the globe were invited to participate in this survey via invitation email. Fig. 4 shows the industry splits of the survey participants. Before sending invitations to participants a pre-test was conducted on the questionnaire with participants familiar with the topic and feed-

back was used to improve and adapt the questionnaire accordingly. Responses have been recorded and then descriptively analysed to present the industrial insights and implication on key areas of this approach. This will be used to develop the approach further with practical implications.

4 Results and Discussion

The explorative study of existing product design and customisation approaches, identified different key areas and components to be considered for industrial implication. Table 1 summarises the findings of this explorative analysis.

Table 1. Key areas and components identified to be considered for industrial implication

Changes in traditional product design and customisation approaches	Components that need to be focused on	Technologies that need to be integrated
Context Ecosystem Perspective Vendor Discipline Competition Access	Design & Development Manufacturing Assembly After service Sustainability, Adaptability, and Upgradability	Data mining Innovation toolkit Modelling Product realization

50 responses have been recorded and analysed to present the industrial implication and insights on key areas of this approach. Appendix I summarises the responses along with the survey questions. Responses to these questions yielded a sufficient amount of relevant information about the product design of MI. The following sections present the discussion and insights obtained from these results:

4.1 Changes in traditional product design and customisation approaches that need to be focused on

The explorative study of existing product design and customisation approaches, identified changes in Context, Ecosystem, Perspective, Vendor, Discipline, Competition and Access.

Unlike traditional approaches to product design, MI consists of horizontal networking between different actors. The end product is the end result of the creativity of different actors. In MI, there are three main actors: end users, large companies, and smaller companies (includes third party supplier, independent developers etc.). Different actors could be mapped in a multi-level cross connected framework to simplify and manage the relationship between them. The inclusion of the wide variety of vendors in all aspects of the final product helps to intensify the innovation in the process.

Excellence through the interdisciplinary network is the main theme of this paradigm. Highly complex, socio-technical systems need to be developed which will require the collaboration of various academic disciplines. To realise the approach, future engineers needs to look beyond their own specialisation. A healthy competition between different actors need to be encouraged for better design and innovation. The traditional approach of the close access need to be changed as networking of all the actors has to be backed by access to all essential information.

4.2 Components that need to be focused on

The explorative study identified Design & Development, Manufacturing, Assembly, After service, Sustainability, Adaptability, and Upgradability as the design components which need to be focused on.

In MI the end user plays an active role in the design process. With the help of an interactive design platform the end user selects the modules on the platform and designs the final product. This work has identified that it will be an iterative process as an end user will select modules on the platform and will then with the help of an optimisation tool make the end product more feasible and efficient within smaller companies and large manufacturer's constraints. Platform, interfaces and modules are to be manufactured at different places by different actors. Platforms are manufactured by large companies with interfaces which could be mechanical, electrical and software. This type of manufacturing needs advanced reconfigurable manufacturing systems (RMS) which can produce a variety of products with the same equipment and accessories.

A new networked assembly system needs to be developed which can assemble different components on the same type of platforms as per end user requirements. Smaller companies from different regions of the world will provide modules as requested and then the final product will be assembled at platform manufacturer. This paradigm will change the traditional way of after service. A new station or place has to be developed where platform manufacturer can connect users to module providers and provide the appropriate services. One of the key advantages of this new product paradigm is the contribution to the circular economy. As the final product is highly individualised so it reduces overproduction of the products. Users can use the product for a longer time as it is exactly as per the requirements. Users can change the modules whenever they want. They can upgrade the products just by changing the updated module rather than changing the whole product.

4.3 Technologies that need to be integrated

The explorative study of existing product design and customisation approaches, identified the following technologies that need to be focused on: Data mining, Innovation, toolkit, Modelling, Product realization.

Real-time connectivity and fast processing of data are some of the key processors to enable and realise this new paradigm. Internet based innovation intermediaries can help to link different vendors and end user or large manufacturers. Any number of

innovators and designers are able to collaborate to achieve innovative solutions. Access to research data and users' demand pattern are accelerators to the networked innovation process. A new strategic approach has to be developed for optimised use of data mining resources. Innovation toolkits provide a way to transfer design capability to the end user. Users can use this kind of toolkit to enhance their understanding of different product scenarios, i.e. Web learning can be used to educate users in some specialisation needed for the personalised design. In this way, the user can put forward their latent needs which are not possible by conventional user research tools. A new networked innovation toolkit could be developed which can ensure that completed design can be produced on the intended production systems.

Simulation and modelling will be a very important part of this product design process. The objective of this system is to provide a platform for experimenting with products in the design phase. It allows the product to be represented, analysed and redesigned without going to physical prototypes. A new type of modelling tool which provides a platform for all the actors to access the design and receive feedback needs to be developed. Rapid prototyping and 3D printing are some enablers to realise the product before the final production. However, to realise products from MI, development of a new product realisation tool is required where the end user has all the freedom to experience the product and to provide live feedback on that experience to third party module manufacturers or platform manufacturers.

4.4 Industrial questionnaire survey

Based on the explorative study and identification of key areas and components, described in the previous sections, a survey was conducted. The responses of this survey shown in Appendix I have been descriptively analysed for industrial implication and practical insights. First five questions were designed to obtain feedback on the existing knowledge and the importance of the new and innovative product design approach. Responses to Q.1 show that familiarity with the product design for MI is very limited in the industry. It is evident from these responses that MI is a relatively new product design approach and a lot of research needs to be undertaken in this domain. This paper is a small effort in that direction. Responses to Q.2 indicate that a maximum number of the responses came from consumer electronics companies. This agrees with assumptions mentioned in the earlier sections that consumer electronics products could be the starting point for the application of the product design for MI in the market. Responses to Q.3 are encouraging and in the line with the aim of this paper that MI would result in more innovative end products which will be tailored to the users' exact needs. Responses to Q.4 provide mix agreement. It could be interpreted in the way that certain segments of the market will consider MI as more favourable, probably consumer electronics companies as shown in the response of the Q.2. Responses to Q.5 provide an indication of the application of this approach to industry type. 27% of responses considered that the product design for MI is suitable for all industry types, but a surprisingly equal percentage of responses suggested the Fashion industry as one of the main beneficiaries of this approach, and similarly the

Furniture industry. This result was very insightful as the initial idea of this approach was to use MI for the consumer electronics product.

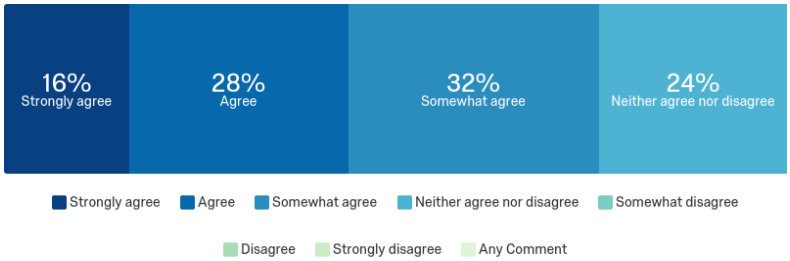

Fig. 5. Responses to Q.6, 'Product design for MI encourages creativity and innovation…… this statement?'

Responses to Q.6, shown in Fig. 5, were very encouraging as 76% of responses are in some degree of agreement with the notion that MI will encourage creativity and innovation towards producing a highly individualised end product. Responses to Q.7 are in line with the response to the last question which shows that the inclusion of so many actors in product design opens the door for innovation opportunities. Responses to Q.8 were mixed in agreement with the question. However, the inclination of responses is towards the positive side which provides encouragement for further research in product design for MI. Responses to Q.9, shown in Fig. 6, confirm that this product design paradigm will provide an innovative means for sustainable product design as the end product is adaptable and upgradable, as more than 50% of responses were in agreement and 27% responses were with neutral stand point.

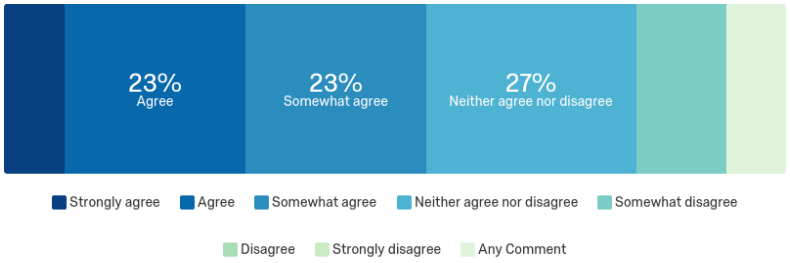

Fig. 6. Responses to Q.9, 'This product design paradigm also…… …this statement?

It can be seen in the Q.10 responses that 32% of the responses agree that the end users/customers will be able to contribute towards product innovation, as they can select and develop product modules. But at the same time, 28% responses are in slightly agree mode, which could be associated with the notion that end users might not have that skill set and knowledge of accessing requirements and converting them into the appropriate modules.

Q.11 to Q.14 present the responses to some strategical changes that will take place because of this new product design paradigm. Q.11 illustrates the mixed response to the question that MI will induct innovation in organisations in the form of organizational structure. This could be influenced by the absence of MI in current organisational structures. Responses to Q.12 indicate that MI encourages positive competition in module manufacturing companies with a few responses in disagreement. A possible explanation is that this approach is not yet implemented in the market. The majority of responses to Q.13 show that access to resources by cross networking between different actors is very important for product innovation. Responses to Q.14, shown in Fig. 7, show that more than 60% agreed that Networking between different actors at the same level and guidance by the platform manufacturers provide the best of the innovative technology available.

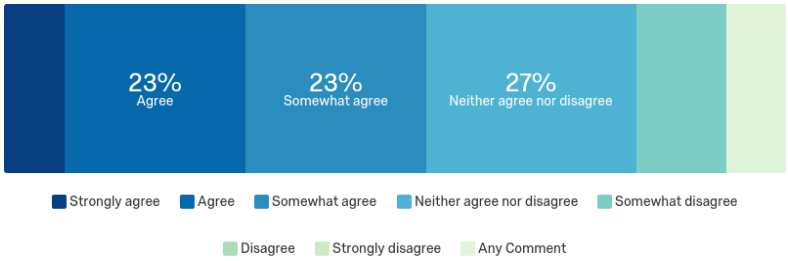

Fig. 7. Responses to Q.14, 'Networking different actors at…… this statement?

Q.15 was a text answer question to explore practical suggestions on concept benefits of the MI over the traditional product design and customisation approaches. Responses to this question indicate that MI will provide more flexibility, distinctness, speed, serving to a new customer segment, organisational capabilities and innovation in terms of the product offering. This response was insightful as it provides many positive improvements from MI in product design. Responses to Q.16 listed some of the barriers to achieving the full innovation potential of this paradigm: complexity, dependence, differentiation, etc. Responses to Q.17 show that more than 65 % of participants agree that MI will create new jobs and more accessible products. Responses to Q.18 address the issue of intellectual property rights (IPR). These present the different point of views to handle IPR, i.e., difficult to forecast, depends on who owns what etc. It shows that this is an important issue which needs careful attention. Q.19 was a general feedback question to know the other practical impediments overlooked by the survey, as participants were industrial practitioners with experience in various product design approaches. It provides many useful insights, as mentioned in the Appendix I. One of the key issues pointed out by participants was the adoption of this paradigm by senior management leadership. This could be influenced by the lack of past study and evidence which proves the significance of this approach in industries. This was a very important feedback as the absence of past application might cause hesitation in acceptance of this approach. So further research needs to be carried out. Responses to the last question give an idea about the potential consumer

segment which should be targeted for initial application of this new and innovative product design paradigm.

In summary, responses to the survey questionnaire provide multi-dimensional insights on the approach. It shows that product design for MI encourages creativity and innovation towards the highly individualised product, for a significant proportion of respondents. However, some of the responses were not in agreement with this new approach. This inspires to investigate this field further.

5 Conclusion and outlook

The objective of this paper is to explore the question how does a change in traditional product design approach help to nurture and accelerate innovation. It explores product design for MI, which is a relatively new product design approach, for the most individualised and technologically advanced products to satisfy the exact needs of customers, in a combined qualitative and quantitative study. Based on the identification of key areas for the realization of MI as an industrial practice, with an explorative study, a survey has been designed to get the industrial insights. Most, more than 65%, of the responses indicate that the end product from product design for MI will be more creative and innovative. This kind of innovation will lead to the most innovative and technologically advanced product.

However, some responses question the feasibility of the innovation management which needs to be addressed in the future work. This kind of product design approach provides ample opportunities in the terms of product innovation and upgradable, adaptable and sustainable products, which need to be studied further.

Acknowledgement

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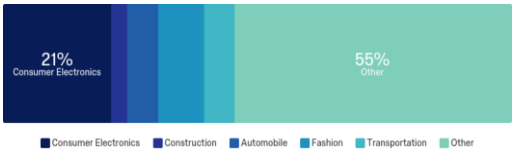
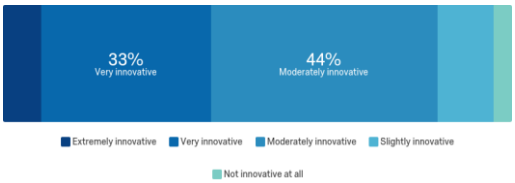
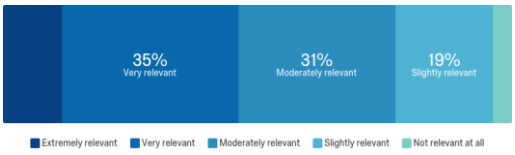
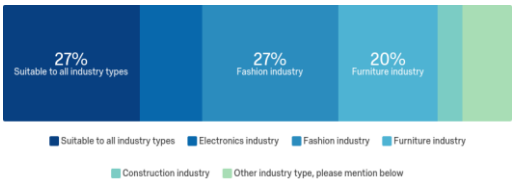
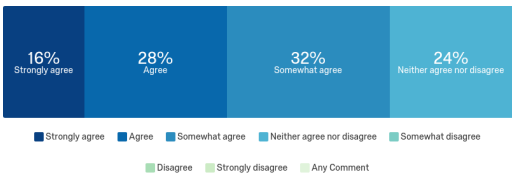
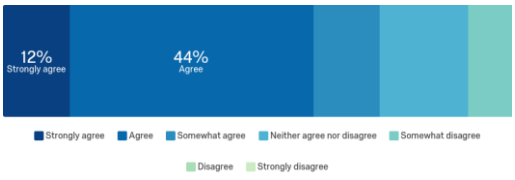
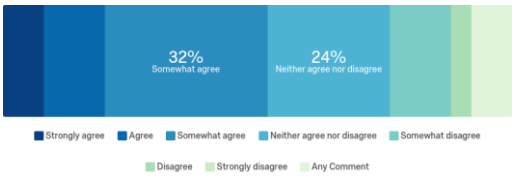
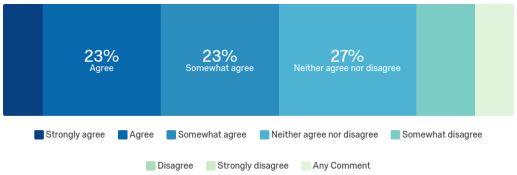
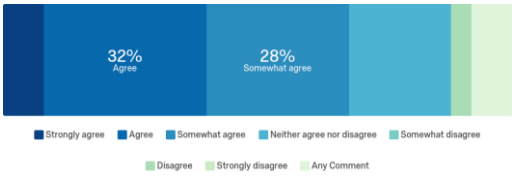
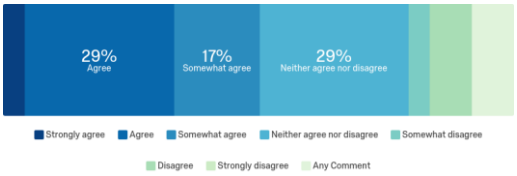
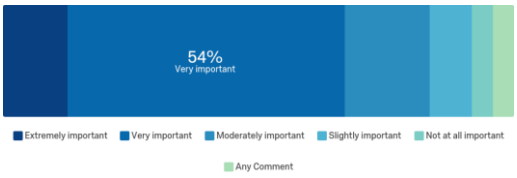
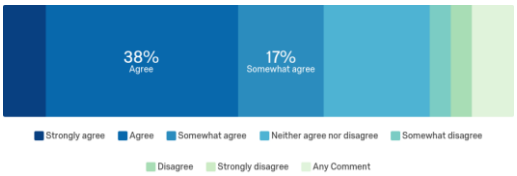
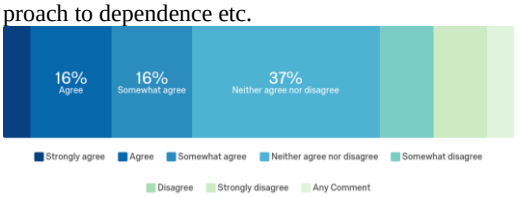
APPENDIX I: QUESTIONNAIRE SURVEY WITH RESPONSES

Q. No.	Survey Questions	Survey Response
	Product Design for Mass Individualisation	
1	Are you familiar with the concept of product design for MI (Mass Individualisation)?	
2	What kind of industry are you affiliated with?	
3	Which statement best describes how innovative could be the new product design paradigm (MI) for product design?	
4	Which statement best describes how relevant the idea of product design for MI is for your industry?	
5	What do you think about the suitability of this product design concept to a particular type of industry?	
6	Product design for MI encourages creativity and innovation. Do you agree with this statement?	
7	The inclusion of so many actors in product design opens the door for the innovation opportunities. How do you agree with this statement?	

8	Different participant companies with different expertise will be able to provide their best in field modules for users which will make the product most advanced and innovative? How would you agree with this statement?	
9	This product design paradigm also provides an innovative means for sustainable product design as the end product is adaptable and upgradable. Do you agree with this statement?	
10	End users can develop a product module for their products and can contribute towards product innovation. How would you agree with this statement?	
	Strategical and Technological Consideration	
11	Product design for MI changes the industrial structure from vertical (different actor in a single organisation) to horizontal (different actors in different organisations). How do you think it affects the innovation in organisations?	
12	This new product design paradigm helps to encourage a positive competition between companies by giving them equal opportunities to invent and produce modules. Do you agree with this statement?	
13	Access to resources by cross networking between different actors is one of the key advantages of this product design paradigm. How important you think this would be for product innovation?	

14	Networking between different actors at the same level and guidance by the platform manufacturers provides the best of the innovative technology available. Do you agree with this statement?	
	Practical Suggestions	
15	What would be the concept improvements over current industrial product design approaches?	Flexibility, Agility to deploy new modules and improvements for products with the possibility to serve new customer segments. Speed could be an improvements, Organisational capabilities and innovation process (lean, stage/gate, agile, open innovation, etc.), Distinctness.
16	What would be the barriers to achieving the full innovation potential of this paradigm?	Complexity, Platform, IP, People, Capabilities, Dependence, Competitors, Differentiation, Approach to dependence etc.
17	This product design paradigm would not only provide innovate the product design process, but also influence the society and economy in a positive way by providing more jobs and more accessible products. Do you agree with this statement?	
18	How do you think firms should manage ownership of intellectual property rights when this many actors (other firms) are involved?	Depends on who owns what, Difficult to forecast, Seems context specific, Hard to generalise, Complex, Capabilities etc.
19	Can you identify any other practical impediments overlooked by this survey for this new approach?	Organisational Culture, Senior management leadership in adopting this paradigm, Difference between firms and startup, Product dependent, Revenue maximisation, Complexity, Who manage the transaction etc.
20	Which consumer segment should be targeted by this new approach?