Mass Customization and Technology Functions: Enhancing Market Responsiveness

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***Abstract*—**Manufacturing companies are constantly confronting the challenges of competitive markets and lack of know-how of application of technology innovations within their environments. Industries are also getting very dependable to end users' voice and satisfaction, therefore forcing them to seek appropriate organisational strategies with the aim towards creating a consistent customer experience and efficiency enhancement. The aim of this research is to investigate the impact of IT based strategies, innovative manufacturing and marketing practices within the mass customization operations. Therefore, the authors aim to pursuit the current state of mass customization within the manufacturing industries and the existing challenges particularly relevant to customer experience. The findings of this study would be utilised by researchers and practitioners who seek explore integrations between demand aspects of mass customisation practices with a particular focus to technological infrastructure.

Keywords—Supply chain; demand-driven chain; customer responsiveness; technology innovation; digital customisation; mass customisation; IT based strategies

I. INTRODUCTION

In recent years, rapid technology advancements and emerging high number of competitive industries have raised the customer expectations on the way to be more selective and demanding to their access to real-time information, required for better quality, delivery and services. This has caused companies and organisations to appraise and review their operations, supply chain structure and importantly marketing practices to be in line with the changing markets and customer fluctuating needs. In this regard, the demand paradigm can be a proper response to the existing company challenges wishing to prosper and survive. This means that the accountability and survivability of the firms is now more relying on downstream view of end users rather than exerting power towards upstream view of suppliers and manufacturers. Commonly, demand chain has always been observed through a lens of being included within the supply chain concept and mostly from a general point of view. However, business executives need to strategize, plan and adopt new approaches within supply chain processes towards transforming it into demand focused and market responsive distribution networks. As a key enabler of demand-driven chain, a robust infrastructure such as technology advancements assist companies to get adapted to the market fluctuations and customer needs. These technology infrastructures vary depending on the company size and nature of work such as digital customization, postponement, mass customization and additive manufacturing (AM). The common purpose of all these practices is to shorten the distance between the manufacturer and the customers in order to reduce the lead times, operating costs, warehousing costs and transportation costs towards getting more practical, sustainable, reliable and environmental responsible. This study would provide with an early understanding within the main aforementioned concepts which would further develop framework linking MC practices of new product development (NPD) projects with demand chain dimensions.

II. LITERATURE REVIEW

A. Principles of Mass Customization

Mass customization is being considered as an emerging practice for the companies to create value-added customized products as well as profitability enhancement in today's industrial world. This topic is also gaining more consideration within the academic studies. The term mass customization is first mentioned by Alvin Toffler in a book called "Future Shock" in 1971 regarding the features of post-industrial society [1]. It was afterwards introduced by Stan Davis in "Future Perfect" book in 1987 and after that completely developed in 1993 by Joseph Pine who elaborated its capabilities and implications towards future manufacturing approaches as a guidance roadmap for industrialists who tend to adopt it [2]. As a classic description, Mass Customization (MC) is defined as "developing, producing, marketing and delivering affordable goods and services with enough variety and customization that nearly everyone finds exactly what

they want" [3]. In the manufacturing environment, it is referred as automated manufacturing of bespoke products which can be perceived as a combination of direct digital manufacturing (DDM) and smart factory [4]. Therefore, MC implementation requires unique manufacturing systems and operational practices [5]. For instance, innovative products and process designs are mentioned as a key enablers for flexibility and responsiveness of companies [6] and standardized modules are mentioned as enablers for economies of scale and scope, while both are necessary for MC capability development [7, 8]. Within indusial environments MC is also referred as personalization, product modularization, customer driven manufacturing and made/built to order [9]. Four main principles are classically suggested for MC [3]:

1. Collaborative: companies working in close association with customers for development of specific products for their individuals desires.
2. Adaptive: companies producing standardized products able to get customized by end users.
3. Transparent: companies offering unique products to customers without visibly claiming that they are customize products.
4. Cosmetic: companies producing standardized products adopting different marketing approaches.

The comparison of the economic implications of both MC and mass production is shown in Figure 1 [2]. As it is obvious, in mass production, for high volumes of products, the cost of investments on equipment, tools and engineering aspects can easily be compensated. However, in low to medium volumes, the production quantity cannot justify investments, though customers are ready to pay premium price for personalized desired products and therefore, on the left hand side of the curve, MC has got dominance over mass production. Hence, the end products are MC operations with lower volume of production are fairly higher than the mass production with higher volumes of production.

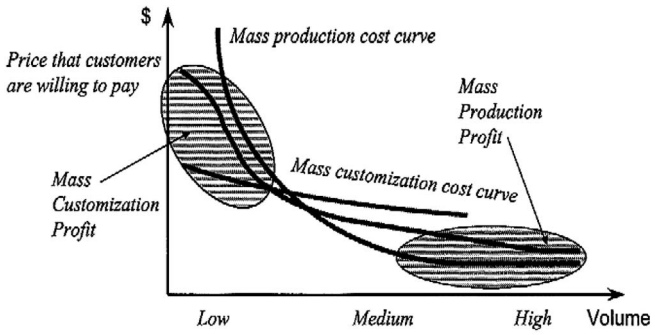

Fig 1. Economic Implications of MC [2]

Considering all the aforementioned, MC seems to be satisfying the customer demand for personalisation and customization effectively [6, 10]. MC is applicable to many industries such as apparel (clothes fit to body measurements), food (personalized foods or vitamins based on body nutritional needs), consumer electronics (personalized variants, graphics), automotive (individualised body, artwork or colour preferences), healthcare (personalised DNA-based medicines) [11] and even housing construction industry [12]. MC is basically driven by marketing and sales functions which discovered the particular customer needs. However, true benefits such as reduction of costs, lead times and increase of profitability will only be gained by integration of all the internal components of company as well as the distribution networks connected to it. As a vital component in MC operations, technology platforms need to be highly considered by business managers and senior leaders so that all the business functions could closely collaborate with the IT and functional mangers to create a business model and adopt the best customization practice. On one hand, research and development (R&D) needs to get involved in NPD projects in order to leverage big data and IT developers to develop and adopt the best choice of mass customization practices as highlighted earlier. On other hand, manufacturing department needs to implement a flexible approach to offer wide variety of options while having minimum complexity to the customers. Likewise, IT department needs to make investments in data warehousing and data analytics and also upgrade enterprise-resource-planning (ERP) and legacy systems to manage additional complexity of products and services [11]. A core functionality of MC is to benefit the companies and even global brands to raise revenue and cash flow as well as achieving competitive advantage and reduce waste and inventory solely through on-demand production [11]. Moreover, as a positive result of MC, valuable data would be generated regarding customer preferences and manufacturing needs which could further help companies towards NPD projects, online marketing and public associations [11]. Despite all the benefits of MC, it is also facing some significant challenges such as high product varieties and complexity of processes [5, 13].

MC enables the manufacturers to produce customized products rapidly at a cost equivalent to unit cost accomplished with mass production [8]. It is expressed that the potential capabilities of MC has got four different dimensions (Figure 2) [14]. High volume customization refers to the customizing large batch of products based on individual customer needs [8]. Customization cost efficiency states producing mass customized products without substantially increasing their costs comparing to mass production [8], since controlling the operations costs is a major challenge for MC executives [15]. Customization responsiveness is the ability to satisfy the customized needs with a proper total lead time [16].

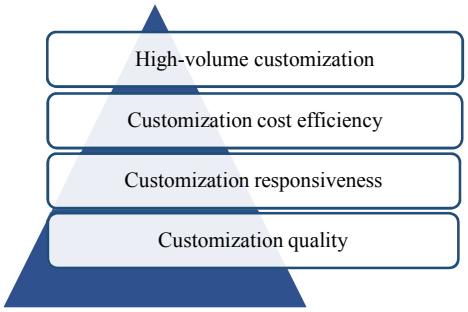

Fig. 2. MC Capabilities [14]

This is due to the fact that usually, customize products takes longer production process time to get ready for customers. Customization quality signifies the quality assurance of the products when the variety of products suddenly increases. Therefore, mass customizers needs to exploit the innovative technologies and operations in order to deliver the efficient products to customers nearly at mass production efficiency [5].

B. Mass Customization and its Impact on Supply Chain

Due to the growing trend in product varieties across many industries, companies aim at promoting higher customer value and more robust strategies towards economic benefits through facilitation of smooth information and material flow both forwards and backwards between suppliers, manufacturers and customers [17]. This opportunity would become possible with the aid of a strong integration between all the supply chain entities, glocalisation (think globally, act locally) [18], electronic commerce [17] or benefiting from the virtual enterprise concept [19]. As a more comprehensive approach, demand-driven chains are now replacing the supply chains, where the main focus is on marketing [20], and creating pull for new products rather than pushing them into the market from the traditional supply chain perspective [21]. In this regard, customer engagement plays a vital role in supply chain operations and has got strong potentials to benefit all supply chain stakeholders. The key benefit is shortening the distance between company and end-users leading by the growth of customer sell-through and satisfaction.

Obviously, the important enabler of close collaboration with customers are technology and information technology based strategies. For instance, Google is now developing fleet of drones in order to deliver consumer goods and medical supplies purchased online especially to remote areas [22]. Furthermore, sharing real-time data within supply chain leads to generation of high volume of information which is hard to process and manage. Therefore, it is claimed that an important success factor for demand chain is to select the right technology infrastructure and to provide with a fast and reliable data-exchange platform to keep the network updated which allows all the relevant participants to easily access and analyse the information [23]. Another key pillar of demand-driven chain is the optimisation of overall supply chain performance not only for reduction of costs but also towards fulfilment of customer expectations. There are some optimisation practices existing in this field which contribute to the efficient use of resources while providing with the best service to customers such as postponement, mass customization (MC) and digital customization. Due to novelty of MC concept and the existing challenges in this field, the authors would be investigating this concept within this paper in order to recommend proper solutions towards its development and linkage with demand chain.

Mass customization is initially conceptualised as an opposite to mass production [24]. Mass production is traditionally based on complex product designs and long-time development for standardized products, while mass customization is based on short-time NPD projects and manufacturing phases with the main aim of satisfying the market segments and customer individualised needs. Hence, customers are located at the end of the value chain within mass production concept. This can be interpreted as pushing supply into markets as supply chain concept offers. On the contrary, customers are located at the beginning of the value chain in mass customization concept, meaning that the supply will be pulled by them based on their particular requirements as demand chain concept offers [25]. This creates a heterogeneous market which engages and integrates customers into product development process from the very early stages.

C. Mass Customization Linkage to Technology Practices

Emerging technologies are now driving MC towards implementation and practices [25]. In terms of technologies for process design, few technological foundations are existing as enablers of MC, such as customized design, modular design, postponement, process automation and flexible manufacturing [26]. Process automation refers to the concept that machines would be able to run within form of self-action, meaning that the information and energy be provided by machines themselves rather than by human force. Process flexibility is defined as the degree to which the sequence, mechanisms, raw materials, knowledge and skills can be utilised of more than one kind of product [27].

There are some existing technology infrastructure which allow retailer and manufacturers to communicate with customers to them contribute towards customization of their product with MC process [25]. Many applications of MC have become possible using specific software for product configurations allowing end users to add or modify specific features of a product [28]. In terms of these kinds of technology facilitators, eight technology setups are identified as crucial factors that will also further move MC towards more advancements in future. These technologies have been divided into two main groups: first the ones that correspond and make add value to customer customization requirements and second the ones that assist the manufactures to control the costs and deal with the manufacturing complexities [11].

a) Creating Customization Value
    1. Social technologies
    2. Online interactive product configurations
    3. 3D scanning and modelling
    4. Recommendation engines
    5. Smart algorithms for dynamic pricing

b) Controlling manufacturing costs
    6. Enterprise and production software
    7. Flexible production systems
    8. 3D printing

Within the Apparel industry, 3D scanning (full body scanning) captures body measurements and enables manufacturers to predict accurate body sizing to produce the specifications based on them. In this case, customers are provided with the opportunity to try their desired clothes with features and sizes near their own using a web based 3D stimulation system giving them more trust and confidence for online buying as well. Digital printing is another technology

revolutionizing the apparel industry which provides quick customer response for unique and customized fabrications for their products [25].

Additive manufacturing and in particular 3D printing is a major more recent achievement which brings a wide variety of benefits to the industrial world. In addition to the primary prototyping of products, 3D printers have now enabled home customers to customize their own products such as jewellery, clothes and even home decorations and get them delivered to their place. For instance, Shapeways Company allow customers to enter their required poems or texts to be printed to the desired products such as games, technology devices or accessories or even 3D print the desired personalized shapes. 3D printers are a good start to digital manufacturing and technologies are yet to emerge such as digital sensors and smart tags which will provide with the automation of tasks and more flexibility, visibility and control of product flows [11]. In general, the adoption of additive manufacturing in the case of mass customized products in low volumes leads to a remarkable redesign of the supply chain and logistics structure in terms of total decentralization [29]. This would further be interpreted that in the near future the distance between manufacturing entity and end-users would be minimised to the point that eventually customers will be able to fabricate their desired products with the personal 3D printers at home. Likewise, in a larger scale, Industry 4.0 referred to as the "fourth industrial revolution" covers digital manufacturing mass customization and knowledge extensive manufacturing lines. Without any doubt, all the modern technology developments are going to make a revolution and an outstanding influence on supply chain management approaches [30].

D. Marketing Practices within Mass Customization

Marketing practices are one of the most significant aspects of any product innovation and creation as they come into the last stage of product launching and nowadays even before the final product developments. Traditionally, manufacturers are looking for the market segments and potential customers, though more recently industrialists and practitioners are insisting on making desired and preferred products for customers instead of finding potential market/customers for new products. The reason is related to the transformation of supply chain approaches moving towards getting demand driven and customer centric, by means of creating pull for new products from early stages of NPD such as design and engineering, so that end users can be aware of the product specification an even involved within the NPD process. Hence, the triangle of Marketing, SCM and DCM is suggested to indicate the close interrelation between these three concepts, meaning that DCM is basically filling the gap and makes the bridge between SCM and DCM effectively [31]. In a more specific scenario of the demand chain approaches such as mass customization, the innovative marketing techniques will vary from the conventional ones. The traditional market research practices such as focused group and test marketing has proven to have several limitations, and inaccuracy for both for manufacturers and customers in addition to the high expenses associated to test marketing [33]. Novel solutions such as "postponement" and "mass customization" are currently substituted by the conventional ones offering both manufacturers and buyers within a safer situation within supply chain. In both of these practices, customers are partially involved within the market search/manufacturing processes [33]. Another more recent practice refers to "collective customer commitment" which is more reliable and flexible engaging potential end-users from the very early stages of design and manufacturing and also makes them committed for purchasing even before final development and manufacturing stages. From NPD viewpoint, the novel marketing approach is in contrary to the traditional NPD projects that tend to keep the final products in a confidential status, therefore, a full disclosure of NPD process is desired by all types of collective customer commitment. This practice could be applicable in two situations, firstly when the market research is ambiguous such as market test for innovative products, Secondly, for small and diverse market products such as food, apparel, household and even musical instruments. These are already adopted by some companies such as Threadless, Muji, Yamaha, Adidas, Procter & Gamble, 3M and BMW. Companies implementing such market research practices and innovative strategies are less likely to face costly product failures. Even heavy industries such as automobile, chemical and real estate agencies are nowadays considering such practices to risk management strategies. Undoubtedly, the significant enabling components of this practice are IT platforms which have now facilitated the complete automation of the entire product development process, therefore, major changes are essential for traditional steps of product development for the successful implementation of this methodology [33].

III. RECOMMENDATIONS AND FUTURE RESEARCH

This paper has examined the most important features of mass customization. Frequently, researchers have sought to investigate it within a more technical and engineering perspective. However, this study focused on supply, demand chain and marketing as well as considering the roles of technological facilitators such as Industry 4.0 or more specifically, 3D printing. Few companies have already started MC practices through 3D printing technique making them accessible for customers to design their own personalised products, and some of them have adopted the innovative marketing practices such as collective customer commitment towards minimising the failures of NPD projects. The future pathways within this field is further the combination of these mentioned developments. This means that the MC can be further expanded to its own main components (development, production and marketing) and getting integrated to supply chain components especially end-users satisfaction which is the key factor towards product development success considering today's rapid changing markets. Exploiting the potential of marketing innovations, technology infrastructures for particular industries, mass customization capabilities and the novel perspective of customer centric chain, all could contribute to discovery of linkage between these concepts as

well as growth of product development projects within global markets. Considering the huge percentage of SMEs in many countries, these practices could be adopted by them in order for achieving the competitive advantage, survivability and accountability.

IV. CONCLUSIONS

The scope of this study comprised of applications of different available technology functions in mass customization practices with a very special focus on the downstream view of customers and end users. Besides, marketing ground-breaking operations are briefly discussed due to their importance both within NPD processes and also its role as a borderline between demand and supply perspectives. The innovative MC practices benefit both companies and customers, importantly by shortening the distance between manufacturers and buyers, reduction of transportation costs and increasing level of customer satisfaction. Increasing profits by even lower product volumes is a key advantage of MC comparing to mass production.

However, it needs to be considered that not all the manufacturing environments have the capabilities for implementation of such MC practices due to high costs associated with R&D practices and engineering complexities. Hence, it is more appropriate for SMEs to develop such approaches. Moreover, companies especially SMEs always face some challenges regarding implementation of IT within their internal organisation due to lack of budget, technical knowhow, traditional organisational structures and managers' attitude. Further researches could be pursued in both academia and practice in order to develop more accurate and specific framework/models considering demand chain, NPD and technological dimensions of MC also considering conservation of costs and gaining profits of doing so.

Acknowledgements This paper is part of an ongoing research project within the research centre and includes a preliminary study towards discovering the demand chain dimensions and its linkage to NPD projects' prosperity. The methodology is based on the literature review studies in order to highlight the current state of the main concepts within the context. As part of the literature studies, MC practices are discussed within this paper. The paper would be further utilised towards the development of the research framework.

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