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ABSTRACT

This paper summarizes the common elements of mass customization (MC). It argues that MC should be viewed as a manufacturing management system that synergizes and integrates all the elements. Then, three factors, customer, technology, and organizational factors are identified. The moderating effects between implemented MC and improved performance are discussed.

Keywords: Mass Customization, operations management, Operations Strategy, Manufacturing Strategy, Cellular Technology Manufacturing.

INTRODUCTION

The purpose of this paper is to summarize the common elements of MC and to define MC based on these common elements. Most importantly, it attempts to identify the key factors that influence the performance after firms implemented MC. The key factors such as customer factors, technology factors and organizational internal factors are expected to moderate the relationship between implemented MC and improved performance. The rest of the paper is organized as follows: In next section, I provide a brief literature review to explore and refine the concept of mass customization. I then synthesize the elements as the common foundations of MC and discuss them one by one. Finally, a framework is developed indicating three factors—customer factors, technology products, and organizational internal factors moderate the relationship between implemented MC and improved performance.

LITERATURE REVIEW

Definitions of MC vary. Although MC was introduced by Davis [11] for more than a decade, literature has not come up with a commonly accepted definition of this term up to the present. MC is often confused with other concepts like direct deliveries, maximum product variety, e-commerce, one-to-one marketing, and personalization of communication flows. Some researchers define it as the strategy of delivering as many product variants as possible [20] or delivering the desired product after receiving the expression of needs from the consumer on a mass scale [25]. Kotha [29] defines MC as a strategy exploring the nature of learning and organizational structure. Pine [32] defines MC as a process by which firms apply technology and management methods to provide product variety and customization through flexibility and quick responsiveness. Pine's broad definition of MC is widely accepted by many researchers [1][13][39]. Hart [21] even argues that the visionary definition of MC refers to the "ability to

provide your customers with anything they want profitably, any time they want it, anywhere they want it, any way they want it."

COMMON ELEMENTS OF MC

This literature review reveals how the broadest definition of MC is treated as a link that brings together necessary modules instantly and costlessly to achieve competitive advantages. The narrower definition, on the other hand, views MC as a method that uses flexible processes and organizational structures to produce individually customized products and services at the low cost of a standardized, mass production system.

Nine articles are reviewed and used to summarize the common elements of MC. These articles are selected because they are often cited in the literature, and they all discuss MC from a comprehensive and conceptual perspective. Below are the 21 elements identified and synthesized from different views:

(1) Product Variety	(2) Customer Driven	(3) Low Cost
(4) High Volume	(5) High Quality	(6) Customized Goods
(7) Fast Delivery	(8) Reduced Setup and change over time	
(9) Reduced cycle time	(10) Redesign Manufacturing Processes	
(11) Modularizing	(12) Technology	(13) Flexibility
(14) Responsiveness	(15) Continuous Improvement	
(16) Employee Involvement	(17) Customer Involvement	(18) JIT-based pull system
(19) TQM	(20) Cross-functional Team	(21) Learning Organization

Each element is mentioned by at least two authors more or less as the elements to reinforce the central idea of MC. Finally, a total of fifteen elements are condensed from the previous twenty-one elements and are discussed as below:

Product variety & customization. The large demand for standard mass-market products has fragmented into demand for different flavor of similar products. The goal of MC is to produce enough variety in products or services so that nearly everyone finds exactly what he or she wants. ([1] [14] [21] [27] [29] [32] [36] [37] [39])

Customer-driven. In MC Companies are customer-driven when producing customized high quality products with general purpose equipment and highly skilled workers. Also, companies should produce with greater variety and respond with more quickness to the new market which is smaller and more uncertain. ([26] [27] [29] [32] [39])

Low cost & high quality. Quality and low cost are two forces related to the traditional tradeoff prevalent in manufacturing [40]. MC shows that companies can overcome the traditional trade off MC lowers the cost through economies of scope, that is, lower the cost by increasing the variety of the products or services. ([1] [13] [20] [21] [27] [29] [32] [36] [37] [39])

High volume. Mass customized products may still be produced in relatively large quantities. MC is the capability to offer individually tailored products or services on a large scale for a mass

market. It offers unique products in a mass-produced, low-cost, high volume production environment. ([13] [27] [36] [39])

Fast delivery. To satisfy the customers, manufacturer not only need\s to provide the products and services with what the customers need but also needs to deliver the products or services when they want. In MC, the delivery time can be minimized by increasing the commonality between products, implementing fewer processes on the shop floor with fewer setup times, and implementing group technology. ([6] [20] [21] [32])

Redesign manufacturing processes. The new system should be redesigned to reduce setup and changeover times, which allows for smaller the run sizes and reduces the cost of variety. It involves major changes to core processes that required breaking through previously inviolate functional boundaries. ([1] [13] [14] [21] [29] [32] [42])

Modularity. Modularity is an important aspect of MC. This method minimizes cost and at the same time maximizes individual customization by creating modular components that can be configured into a wide variety of end products and services. ([14] [17] [24] [32] [35])

Technology Technology is a tool that firms can use to share a variety of technical and business information, to support globally dispersed development teams, to test and display product designs and engineering drawings, to manipulate data and create new knowledge, and to manage advanced product development such as CAD/CAM/CAE. ([14] [26] [29] [32] [36] [39])

Flexibility. MC requires flexibility at all levels such as individual machine, manufacturing system and manufacturing function. In general, a flexible manufacturer has the ability to adapt to both the fluctuations in demand and many other changes in its environment. ([1] [21] [29] [32] [39] [42] [43])

Employee involvement. Each individual employee is encouraged to be involved in the MC manufacturing. Employees are not only empowered, but also have access to relevant information to change the way work is performed. ([32] [42] [43])

Customer involvement. The level of customer involvement in the manufacturing plays an important role in determining the degree of uniqueness of the product and the type of customization. Customers' involvement provides a practical indicator of the relative degree of product customization. ([13] [32])

Just-in-time (JIT)-based Pull System. JIT-based pull system interacts with other practices and quality management can eliminate the waste and uncertainties, improve the quality, and reduce the inventory cost. (([32] [42] [43])

Total Quality Management (TQM). TQM is a management strategy aimed at embedding awareness of quality in all organizational processes. TQM is an effective means to ensure MC finally achieves low cost and high quality at the same time. ([13] [21] [37])

Cross functional team. Cross functional team means individual worker knows how his/her functions affect others. The workers are capable of performing a diverse range of jobs. The success of MC requires corporate structure moving to flatten organizational structures with a focus on a high degree of cross-functional integration. ([1] [32] [37])

Learning organization. In a learning organization, all aspects within the organization from people, processes organizational structures, and technology are geared to provide customers specifically with what they need and want. ([1] [13] [26] [27] [29] [32] [37] [42] [43])

In sum, MC should be viewed as a manufacturing management system, that within such a system, a set of interrelated techniques and programs are required to integrate working through different groups inside or outside the organization. The elements discussed above synergize and interrelate to achieve MC manufacturing.

FACTORS RELATED TO SUCCESS MASS CUSTOMIZATION

Successfully implemented MC can improve performance. According to the survey by Ahlstrom and Westhrook [1], performance is improved after the companies implemented MC. These improved performances include increased customer satisfaction, increased market share, increased customer knowledge, reduced order response time, reduced manufacturing cost, and increased profit.

Customer Factors

Customer involvement is a method of involving customers from providing information and seeking views, to customer being responsible for making decisions on the product/service ([13] [32]). It represents a willing to invest a reasonable amount of time to specify their preferences when ordering a mass-customized product. The level of customer involvement plays a critical role in determining the degree of uniqueness of the product and the type of customization. If customers are involved in the early design states of the production cycle, a product could be highly customized. When the level of customer involvement is low, customers are not likely to invest time and money in a configurable product. Instead, they will prefer to go for an off-the-shelf product.

The second customer factor is customer sacrifice, which include (1) willing to pay the extra money; and (2) willing to wait a reasonable time to receive the customized product [21]. Customers' willing to pay extra represents the foundation for the recovery of the additional expenses [4]. Companies should provide MC according to different customer's value criteria (e.g. price, quality, technical attributes) to satisfy their willingness.

To sum up, customers' demands can be diverse, and when customers become more involved and willing to sacrifice time and money, the implementation of MC will probably be more successful and the performance will be improved.
Proposition 1: *In the implemented MC, the higher level of customer involvement leads to better improved performance.*

Proposition 2: *In the implemented MC, the higher level of customer sacrifice leads to better improved performance.*

Technology

Information technology plays a key role in mass customization. It creates a linkage between the customer's preferences and the ability of a manufacturer to produce the products based on those preferences ([14] [39]). Information technology eliminates delays when processing orders and managing product information. Further, it provides efficient means for exchanging product requirements between customers and manufacturer and between manufacturer and suppliers. Information technology designed and implemented for business-to-business, and business-to-customer models. It reduces the cost through standardized networking technologies and creation of entirely new relationships by interconnection of companies with their customers.

Another aspect of technology is advanced manufacturing technology. This includes flexible manufacturing systems and network technologies such as computer-aided design and computer-integrated manufacturing. The flexible production technologies provide opportunities to deal with the customization with great complexity, while keeping the cost relatively low. In addition, the advanced techniques such as JIT delivery, lean production and TQM increases flexibility and responsiveness, therefore increases the variety and customization without parallel increases in costs.

Overall, advanced manufacturing technology and information technology help companies to achieve an integrated manufacturing system that is fast, responsive, flexible, and very low cost at high volumes.
Proposition 3: *In the implemented MC, the higher level of advanced manufacturing and information technology leads to better improved performance.*

Organizational Internal Factors

The organization capabilities represent internal factors that determine the need to make the transition to MC. The first requirement of these internal factors is organizational readiness in attitudes, culture and resources. MC requires executives who are open to new ideas rather than laid-back or cautious corporate leaders. Organizational readiness also relates to the consistency between the changes and the culture. Finally, organizational readiness in resources include: (1) financial issues [21]; (2) technology resources, and (3) human resources.

Logistics and supply chain management are the second important aspect of organization internal factors. Logistic and supply chain management reflects the organization's capability of minimizing the product cost, increasing product variety, and shortening time-to-market. Logistics is the glue that holds the entire system together. Logistics and supply chain management are responsible for receiving customer orders and transforming these into production orders.

Organizational learning capabilities refers to the ability to develop skills to successfully manage any given task by following deliberate, firm-level processes [18], the ability to value, assimilate,

and commercialize new, external knowledge, and the ability to develop cumulatively, be path dependent, and build on prior investments in its individual absorptive capacity [10]. An organization with better learning capabilities can adapt quickly to new customer demands and market changes and can respond quickly. Further, Pine et al. [33] emphasizes the learning from failure in MC. That is, a manufacturer should consider defects as capability failures and create new process capabilities to overcome these defects. Also, a manufacturer should learn from the customer feedback to co-design products and even co-produce them to satisfy their needs.

The following propositions indicate the relationship between the organization internal factors and the improved performance:
Proposition 4*: In companies implemented MC, the higher level of organizational readiness positively leads to better improved performance.*
Proposition 5: *In companies implemented MC, the higher level of organizational logistic and supply chain management positively leads to better improved performance.*
Proposition 6: *In companies implemented MC, the higher of learning capabilities lead to better improved performance*.

CONCLUSIONS

This paper attempts to fill this gap by synthesizing the common elements of the definition of mass customization based on extensive literature review. Fifteen elements are extracted from the previous researchers indicating that MC should be viewed as a total manufacturing management system, or as a set of interrelated techniques and programs that requires integrated working through different groups inside or outside of the organization.

This paper provides a comprehensive understanding about MC and increases the understanding of MC implementation. In addition, based on the literature review, a framework indicates three factors: customer factors, technology factors, and organizational internal factors moderate the level of improved performance after companies implemented MC. This consistent framework can be used to examine the success of MC also. The identified three factors could be used for managers to identify whether there is support for the move to MC. Six propositions are developed to address how the three factors influence the improved performance in MC. They also can be used as a tool to help managers in decision-making process.

(References available upon request from Wai Kwan Lau at 940-565-3166)