IMPACT OF PRODUCT AND SERVICES CUSTOMIZATION ON THE SUPPLY CHAIN FLEXIBILITY -TOWARDS A DECISION SUPPORT TOOL

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Abstract

The rising demand for customized products induces complex changes in the production system and supply chain of manufacturing and services companies. While variety appears essential to satisfy the customer requirements, it cannot be achieved without flexibility, which is part of performance. Dealing with a mass customization strategy, company managers need tools to help them make decisions. This paper proposes a decision support tool, designed for companies oriented toward mass customization, which links the four key concepts: variety, flexibility, performance and customer satisfaction. Designed in the form of an influence diagram, it highlights the main connections between the key metrics involved in mass customization.

Keywords

Mass customization; Influence diagram; Decision support tool; Variety; Flexibility; Performance.

1. Introduction

The increasing demand for customized goods and services encourage enterprises to extend their offering. More and more companies change their business strategy, to satisfy a larger panel of customers. This strategy, known as *mass customization*, aims to "provide customer satisfaction with increasing variety and customization without a corresponding increase in cost and lead time" [Pine, 1993]. Instead of producing high volumes and being profitable through economies of scale (mass production), some manufacturing and services companies make the choice of low to medium volumes of customized goods, that they produce at the same cost.

In this perspective, flexibility is essential to offer the variety required by the clients. Insofar as mass customization's goal is to satisfy the customers, offering variety, while maintaining moderate costs and thus a good performance, the following question could be asked: How could flexibility enable variety, while ensuring the company's performance and customer's satisfaction?

Variety of products and services aims to meet diversified requirements. Variety is defined as "a collection of different things of a particular class of the same general kind" [ElMaraghy et al., 2013]. According to Blecker et al. [2006], two types of variety could be distinguished: internal and external varieties. "While internal variety refers to the variety of components, modules, products, etc. external variety relates to the product variations that are perceived by customers". In the mass customization context, customers require external variety, while the company must deal with internal variety.

As Garavelli [2003] says, flexibility reflects "the ability of a system to properly and rapidly respond to changes, coming from inside as well as outside the system". Knowing the uncertainty of the market's evolutions, flexibility is quite important in business organization. In a mass customization context, it seems essential to introduce flexibility, as it is "the organization's ability to meet an increasing variety of customer expectations without excessive costs, time, organizational disruptions, or performance losses" [Q. Zhang et al., 2003].

Performance is "the accomplishment of a given task measured against pre-set known standards of accuracy, completeness, cost, and speed" [**1**]. In the literature, this word encompasses various meanings. Whereas a performance indicator calculator could consider only cost and time indicators [Pandremenos et al., 2016], the definition may be larger. Sink [Sink et al., 1984] defined seven dimensions in performance meaning: effectiveness, efficiency, quality, productivity, quality of work life, innovation and profitability. The commonality between those definitions is the need for key indicators, aggregated or not, to compare with standard values. Those indicators, depending on the business strategy, are specific for each company.

Satisfaction refers to a fulfilled need, demand or desire. Customers loyalty and satisfaction are often considered as key factors for success and Customer Relationship Management (CRM) is developed as "a means that could support companies to establish efficient and effective customer relationship while pursuing mass customization" [P. Liu, Wang, & Zhao, 2005]. Responding quickly and effectively to customers' needs is indeed the objective of mass customization. CRM, as a part of customer management, appears to be essential in a MC's strategy.

For companies, the transition from mass production to mass customization requires some adjustments in the organization and processes of the production system and supply chain. Company managers need to be supported through these changes, to know what each decision would modify in the operation of the enterprise. The purpose of this paper is to propose them a decision support tool regarding mass customization.

The remainder of the paper is organized as follows. Section 2 presents an overview of the literature related to the links between variety, flexibility, performance and customer satisfaction, their enablers and their assessment in the context of mass customization. The methodology used to design the model is described in Section 3. The design of the model is detailed in Section 4. Interest for the scientific community, limitations of this model and possible improvements are discussed in Section 5.

2. Literature review

To lead the research on the subject, four data bases have been used with *mass customization*, *variety*, *flexibility*, *performance*, *assessment, customer satisfaction*, *services* and *modularity* as keywords. The target was studies on the key concepts and issues of mass customization, conceptual models linking some of the key concepts and indicators of performance, flexibility and variety. We aimed to select recent papers from journals with non-empirical approaches.

2.1. Variety management

In a mass customization strategy, variety management is essential, as a large range of variants should be proposed. As commonly shared by the literature, flexibility is essential to manage the various changes of product or service considered and the plurality of references during production, storage, transport and delivery. The costs in a MC-oriented firm should be similar to those of mass production (high volumes, small range of variants). Thus, the financial issue is essential. Variety costs could be modelled in different ways. Zhang proposes a representation of product and process variety and a methodology to compute the variety costs and determine the cost drivers [Zhang et al., 2007]. To achieve costs corresponding to mass production and introduce flexibility, Liu [Liu et al., 2009] propose three major drivers:

- Modularity: use the commonalities of variants to cluster them in product families.
- Postponement: delay the products differentiation
- E-commerce platform: link the customers and supply chain actors, to achieve a better customers' satisfaction, while enlarging the offering.

Those enablers of variety are also mentioned in the key metrics system of Blecker [Blecker et al., 2006].

2.2. Drivers of variety and flexibility

2.1.1. Modularity

In the literature, modularity is often considered as the basis for the implementation of mass customization. Indeed, a wide variety of products can be produced by assembling modules. Modularization offers three main advantages [Liu et al., 2009]:

- Reduce the customized parts of the products to a limited number
- Cut down the cost of customization
- Shorten the delivery time

It enables also to face changes in the market changes: when a product is more demanded than another, common modules could be used to manufacture a larger quantity of the most demanded product. In this sense, modularity is part of flexibility of a manufacturing company.

In a mass customization context, the gain of performance through modularity can be assessed by identifying the best profit for a given modularity level and the corresponding variety offered [Medini, 2015]. The sales' increase will then be compared to the manufacturing variety-induced costs: through mass customization, both incomes and costs increase, and the aim is to compensate losses by the variety-induced profit. The modularity level is described by the degree of coupling and the functional encapsulation. The linear programming model described in this paper aims to find the best set of variety to maximize the profit: it links variety to economic performance through modularity, which is a part of flexibility.

2.2.2. Delayed differentiation

Postponement is a key factor of flexibility, and a driver to success for mass customization [Liu et al., 2009]. The aim of postponement is to delay the customization operations to the downstream of supply chain as far as possible. Adopting a delayed differentiation strategy presents two main advantages for a manufacturing company:

- Larger volumes are processed in the first operations (before the differentiation point), which implies an economy of scale.
- The demand uncertainty is reduced and controlled, as the firm can respond quickly to the market demand. Indeed, just a few operations are necessary to deliver a finished customized good from a semi-finished standardized product.

Methods are developed to know where the optimal customization point stands, to minimize the costs. Ngniatedema [Ngniatedema et al., 2015] modelled the interactions between stages to identify the point of the production process where two products can be customized in a cost-effective way. Given the service levels expected, total costs can be computed.

2.2.3. E-commerce platform

To be successful, companies should meet the needs of the customer and, to achieve this, bring customers and suppliers closer. In this sense, a new way of exchange should be created: "E-commerce is the key to widespread mass customization", as it provides an easy and fast way to personalize its product [Liu et al., 2009].

Unfortunately, the issue of e-commerce platform is barely mentioned in the literature of mass customization. E-commerce is underestimated, as it provides not only a means to sell and purchase products, but as well a means to transmit and share information [Wang et al., 2010].

2.3. Assessment of flexibility and performance

2.3.1. Flexibility

The measurement of flexibility appears necessary to evaluate the performance of a MC-company. Welborn illustrates a quantitative index to evaluate the process customization and thus the flexibility for each operation of the production system [Welborn, 2009]. The used formula is:

$$CI = \frac{TC}{V} + \frac{SC}{B}$$

With CI the Customization Index, TC the Tooling Cost, V the Expected Tool Life expressed in terms of Part Volume, SC the Set-up Cost and B the Manufacturing Batch Size. After computing the customization index for each operation, they are sorted by CI and an appropriate process strategy is determined for each: customization strategy for low CIs, or standardization strategy for high CIs. Welborn points out the necessity of a moderate degree of customization.

Other methods for the flexibility measurement consider both the production system and the supply chain. Suppliers and assemblers could be divided in three categories: *no flexibility*, *limited flexibility*, or *total flexibility* [Garavelli, 2003]. As a result, nine configurations of the supply chain network are considered, resulting from the combination of the three degrees of supplier and assembler flexibility. Heuristics are then used to evaluate the work-in-progress and lead time performance of each configuration. In all these situations, the best performance is still provided by the middle configuration (limited flexibility for both suppliers and assemblers), except in the highest demand rate, when other less flexible configurations perform better (mass production configuration). That joins the imperative of moderate flexibility, mentioned by Welborn [Welborn, 2009].

2.3.2. Performance

In the literature, performance assessment in a mass customization context is often considered in the framework of the large research project called DOROTHY (Design of Customer Driven Shoes and Multi-Site Factory), considering mass customization in the European shoe industry. A Performance Indicator Calculator tool has been developed in this context [Pandremenos et al., 2016]. Starting from the needed resources and production configuration, it calculates the cost and time indicators for every existing but also planned product variant. It aims to indicate the cost and lead time corresponding to each variant and help to determine the best set of variants to offer, in terms of performance.

2.4. Mass customization in services companies

In the last years, the concept of mass customization has been developed in many academic researches considering manufacturing companies. However, the research and application for mass customization in the service industry are at their early stages.

Indeed, the service industry has specific characteristics [Liu et al., 2009]. The intangible nature of services makes its interests harder to detect, and the customer satisfaction is only due to perception. Unlike the manufacturing industry, services are produced and consumed at the same time: time and space are indivisible. Moreover, they cannot be stored, and can disappear without consumption, while the quality could vary a lot between two services. Thus, drivers of flexibility and variety are the same for manufacturing and service industries – postponement, modularity and e-commerce platform – but their usage is different. For instance, it is possible to modularize services by designing modular stages and steps for preparation of the services before the moment of consumption.

In the literature about mass customization, many links have been studied, such as the links between flexibility / performance, variety / flexibility or customer satisfaction / variety. But the four main key concepts have not been linked all together until this paper.

3. Materials and Methods

As a basis for the model, we used the key metrics system proposed by Blecker [Blecker et al., 2006] (*Figure 1*). We kept the links which occurred to be related to the topic and significant. Then, we chose the format of influence diagrams to illustrate our model. Rectangles represent controllable decisions; ovals represent uncertainties and hexagons represent the objectives. An arrow from A to B with the sign + (resp. -) indicates that the bigger A is, the bigger (resp. smaller) is B. To this caption, we added one symbol: a red arrow from A to B means that A is a prerequisite for B. The complete caption is available in Appendix (*Figure 3*).

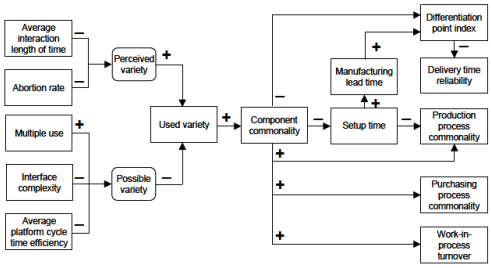

Figure 1: Key metrics system [Blecker et al., 2006]

4. Model proposed

4.1. Design of the influence diagram

The representation of Blecker was the basis of our work. Its first part – the factors influencing perceived and possible variety – did not enter in the subject and thus has been retrieved. The fact that a large range of variety is a prerequisite for component commonality is central and essential in this representation. In fact, a low variety imply that products do not have common parts [Maskell, 1991]. Furthermore, the use of common components for a large range of variety is necessary to make those variants represent an important source of revenue. Some concepts of the Blecker's model have been split and others have been merged – production and purchasing process commonality merged into process commonality.

Since the central issue of the work was the connections between the four main key concepts of mass customization, they were represented as the four objectives of the influence diagram. They have been linked through others indicators, such as setup times or process commonality.

The issue of customer satisfaction is the least mentioned in the literature, comparing with the other main key concepts, and thus it is the least linked objective of the model. However, the point is that variety management is an important issue insofar as a small range will not satisfy everyone, while an oversized range could confuse the customer. Thus, the determination of the right range of variants is essential, not only for the performance but also for customer satisfaction per se.

Concerning variety, the three main drivers mentioned in the literature [Liu et al., 2009] – modularity, delayed differentiation and e-commerce platform – are highlighted in this influence diagram, linked with many key metrics, since they play important roles in mass customization.

The gap about services-oriented studies on mass customization made it difficult to include a services dimension in the influence diagram. As a result, it has been designed for products mass customization only.

4.2. Modelled influence diagram

Using the caption described above, the influence diagram has been represented via an online design tool.

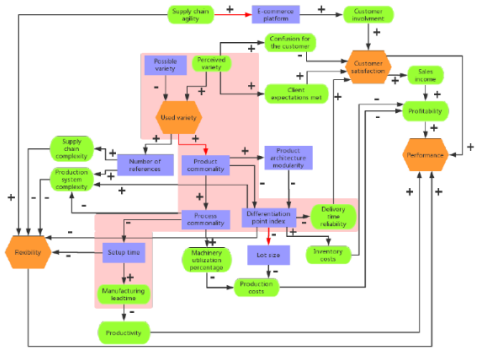

Figure 2: Overview of the modelled influence diagram

A larger version is available in Appendix (*Figure 4*).

5. Discussion

5.1. Analysis of the influence diagram

What appears clearly while looking at the model is the multiplicity of blue rectangles: many indicators are subject to a decision, and the achievement of the objectives is obviously related to decisions which are made. As a mass customizer, many decisions should be taken, thus increasing the complexity and the need for a decision support tool.

Moreover, the balance between variety-induced costs and variety-induced profit is noticeable in the diagram. This is relevant, as the question of costs and profit is central in mass customization. Strategical decisions aim to find a trade-off between variety costs – due to the complexity of the production system and supply chain – and variety profit – due to the increase of sales and selling prices.

We notice also that the objectives are strongly connected, since flexibility and customer satisfaction are part of performance. We could have considered only the performance as a goal, but flexibility and customer satisfaction are essential per se for mass customization as explained in the literature review, and not only because they are features of performance. Thus, the achievement of the four objectives simultaneously is essential, and it cannot be modelled by an aggregated indicator of performance, encompassing the others.

5.2. Interest of the model

The particularity of the tool exposed in this paper is the global vision of the production system and supply chain considering the mass customization strategy. Concepts are linked in a global way, relations between flexibility, performance, variety and customer satisfaction are gathered and highlighted. The literature examines generally connexions between two key concepts in detail and deeply, whereas this model aims to embrace a broader spectrum, leaving details aside. In this sense, it completes the previous works about the drivers of mass customization.

Furthermore, this paper provides a decision support tool in the form of an influence diagram, which is quite new considering the literature about the subject. This tool could be used to make decisions as a company manager, while starting a mass customization strategy, or introducing new products variants: the model points out which key metrics will probably change. It could be useful as well to improve case studies involving mass customization: with the support of this tool, the conceptual map of the software Steer-Cots, designed in the Fayol Institute (École des Mines de Saint-Étienne), will be enhanced.

5.3. Limitations and possibilities of improvement

But this work is still limited, as it is a first draft which requires further improvement. Validation and deepening of the tool are necessary and will be based on empirical approaches and new conceptual models. Company managers using mass customization could be asked to test it and comment on the eventual gaps.

Moreover, the services dimension is absent of this tool, in so far as only a few papers study mass customization in service companies. The next step should be to add a specific part for services in the influence diagram, or to design a diagram intended for services only.

It seems also necessary to define target values for each key metric of the model, since they are relevant only if they can be compared with predefined targets. Those target values could be obtained through a benchmark of other mass customizers, which is only possible with a collaboration of the involved companies, since the concerned data are not public.

Since the literature focuses on production systems, the issue of mass customization implications on the supply chain have been hardly mentioned in the influence diagram. However, a mass customization strategy has significant consequences on the supply chain and this aspect should be reconsidered in the model. The integration of further supply chain issues in the decision support tool is an opportunity of improvement.

Finally, to add value to the decision support tool, the links highlighted could be quantified, since this would complete the information given. Two ways of proceeding are possible:

- give a correlation value for each link: an empirical approach would be needed to determine the values, which will be adapted to a specific situation;
- categorize the links into levels of correlation: those levels could be represented by different widths of arrows; the information would give less details and thus represent a larger spectrum of situations.

6. Conclusion

The model presented in this paper aims to characterize the links between four key concepts of mass customization: variety, flexibility, performance and customer satisfaction. The representation of those links in the form of an influence diagram has been designed as a decision support tool for company managers adopting a mass customization strategy. Short-term, it will probably be used to improve the conceptual map of Steer-Cots, a software designed in the École des Mines de Saint-Étienne.

Since this model is a first draft designed from the mass customization literature, it should be validated, enriched and quantified. More specifically, services and supply chain issues should be better integrated, target values should be added, and correlation values obtained by empirical approaches would help to refine the model.

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Appendix

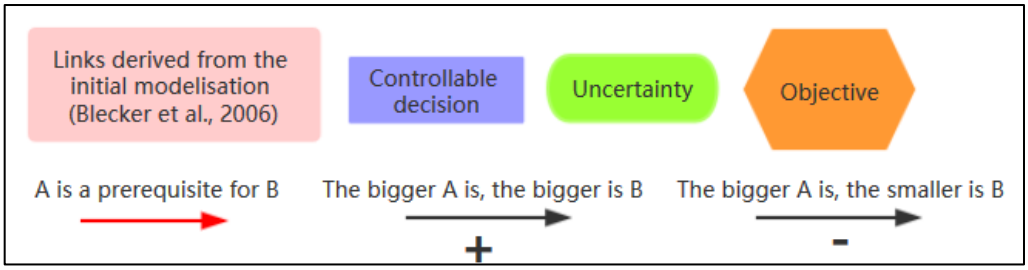

Figure 3: Caption of the influence diagram

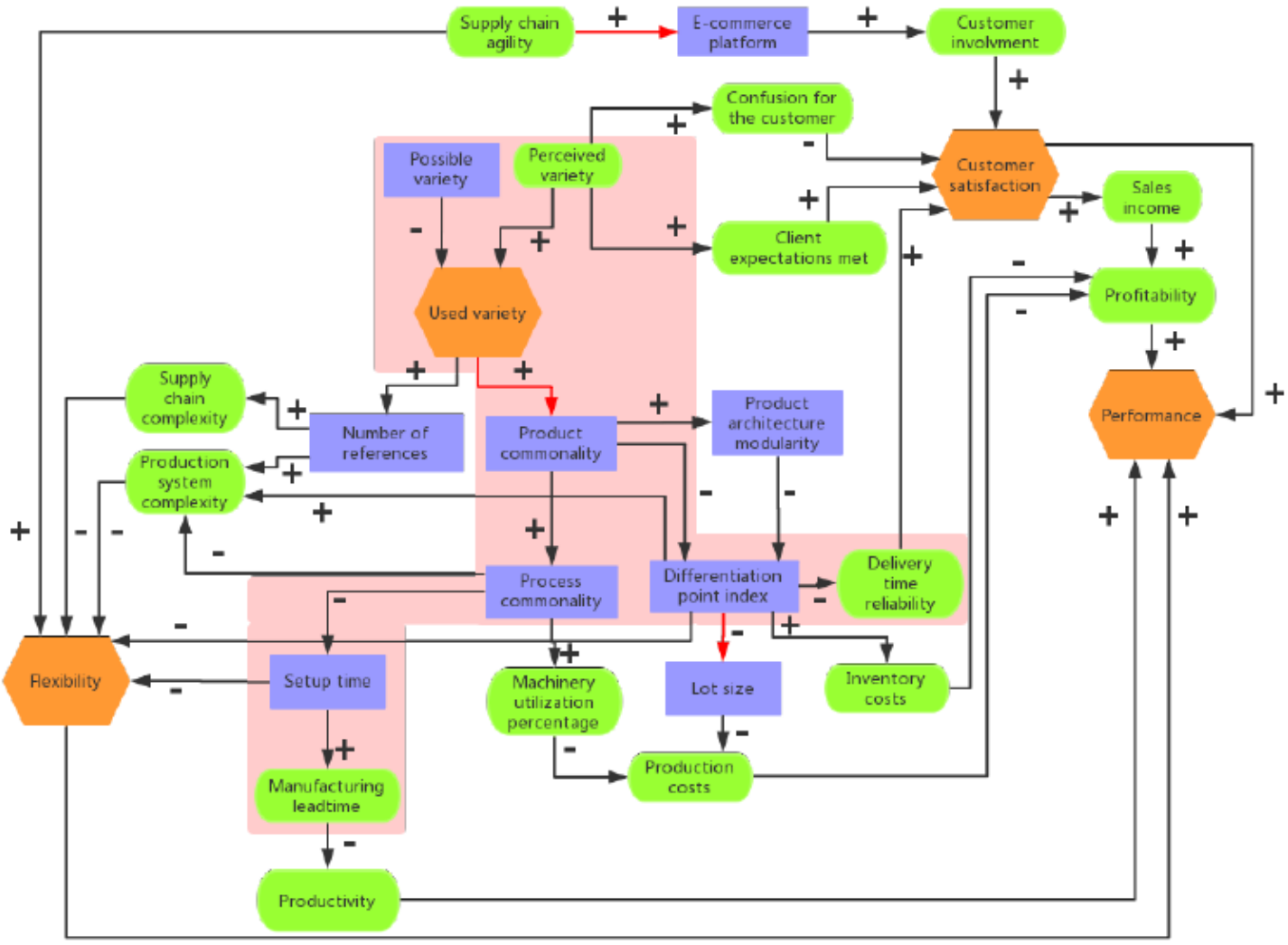

Figure 4: Modelled influence diagram