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Ivica VEZA[1], Natasa JURJEVIC[2]

MASS CUSTOMIZATION OF LARGE, COMPLEX PRODUCTS

ABSTRACT:
This paper gives an overview of past researches in implementation of mass customization. It has been noted that mass communication is principally used for three basic reasons (main purposes): transfer from mass production into mass customization, increased possibility of choosing components and increased productivity and quality as well as shorter delivery times for products manufactured as one-of the kind. Special attention has been paid to mass customization of large, complex products with a reference to shipbuilding.

KEYWORDS:
mass customization, large, komplex products, complexity, shipbuilding

INTRODUCTION

MC has transformed many industries and brought about a possibility of a fast reply to individual customer demands. Such approach, accompanied by adequate production effectiveness has allowed companies to retain their positions on the market and proved vital for business success. From the customer's view, this change in approach to production and sales was accepted really fast. On the other side design and production have to solve many new problems.

This, first of all, refers to accepting the fact that design, production and use process, as well as product write off have to been seen comprehensively and that each product function, characteristics (production, aesthetic or usage), every way of use, maintenance and product disposal has to be foreseen on time during the design period.

Large, complex products represent a special problem as their complexity stems not only from its complexity but from its production process complexity as well.

In the past every product was built as 'one of a kind' – each product was also a project apart. That way did not allow unification of certain production processes, production acceleration and faster and better product price anticipation.

PAST MC APPLICATIONS

Past experiences show that MC can be applied in three possible ways:

1. By changing the approach to production from mass production into mass customization (clothes, footwear ...)
2. MC is implemented only at the end of the production process mainly as a marketing tool. MC is used only to select components (bicycles, cars, ...)
3. It is used to increase their operational efficiency and at the same retain traditional individual approach (motors, Marelli Motori, complex process plant F.L. Smidth).

FROM MASS PRODUCTION TO MASS CUSTOMIZATION

Due to growing globalisation and market competitiveness most of manufacturing companies have cast aside the mass production paradigm and started adapting their products to their customers' needs. Certain number of products can, at present, be bought adapted to individual customer's requirements and needs without any change in price.

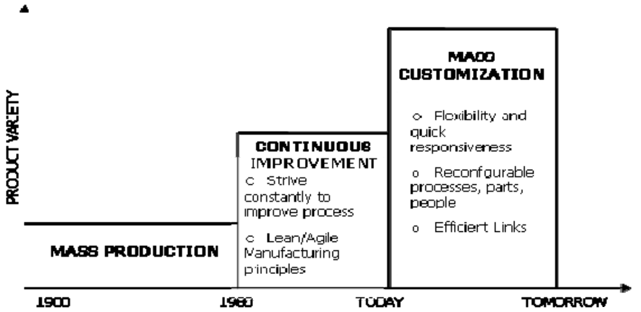

Figure 1. From Mass Production to Mass Customization

There are pages on the Internet that allow their customers to buy clothes and shoes adapted not only to their needs and wishes but to their appearance as well: size they wear, characteristics of their body and even hair colour. My Virtual Modal page helps create fashion outfits by creating virtual models i.e. avatars.

Apart from choosing clothes without affecting production certain clothes and footwear retailers allow not only cosmetic adjustments, but the possibility to influence size and shape as well. In this way Adidas not only offers a choice of numerous colours, but also to customize the shoes with regard to comfort, fit (exact measurements) and functionality (cushioning etc.).

CUSTOMIZATION BY CHOICE OF COMPONENTS

Customization to customer demand can be done by choosing individual product components. In that way customers choose among chosen, previously developed and manufactured components offered by the manufactures and thus compound their unique product from many different feasible combinations.

Car industry is no exception and most car companies today offer customers a possibility to choose the desired look of their car. However, there is a problem of how to define what the customers really want or think they want and what the company can offer. Car industry has thus developed product/sales configurators to make defining orders according to specific customer's needs easier.

In most cases configurators enable exchange of different product components. Without going into product or production process details, configurator enables the producer to see the customer needs that have been formed in accordance to displayed offer. This enables fast and simple product definition, helps both the customer and the sales person and prevents choosing components or component combinations that are unwanted for security, production or other reasons.

This example shows that a configurator was used as a sales tool only with it function to sell a customized product. Such configurator is limited to interaction between manufacturer's offer and individual customer choice without the information exchange with any other design or production department. Product customization is done only at a superficial level and does not affect its functional domain. It is considered normal that a customer will not be able to choose an adequate car configuration as he lacks specialized knowledge that would enable him to change components directly affecting the product's function [1].

Customers of Bayerische Motoren Werke AG can use an online tool kit to design the roof of a Mini Cooper with their very own graphics or picture, which is then reproduced with an advanced digital printing system on a special foil. The tool kit has enabled BMW to tap into the custom after-sales market, which was previously owned by niche companies. In addition, Mini Cooper customers can also choose from among hundreds of options for many of the car's components, as BMW is able to manufacture all cars on demand according to each buyer's individual order.

Bicycle manufacturer Steppenwolf is one of the pioneers of mass customization. It was founded at the time when bicycle sales were plummeting so Steppenwolf looked for a way to rise above the crowd, offer something different and create a brand. Buyers choose individual bicycle components according to their wants, needs and interests from the representative of the manufacturer. The basic principle of assembled-to-order has to be complemented with flexible organisation that will in terms of quality integrate external factors - suppliers and retail traders as well.

Pandora.com enables users to browse radio stations to find the music they like. Users give information about their favourite songs, and Pandora creates customized radio channels playing music in accordance to user's profile characteristics. In December 2008 Pandora.com had 21.5 million listeners who created over 361 million radio stations.

CHANGE FROM ONE OF THE KIND

The biggest challenge to the companies offering large, complex products that demand unique approach to each separate product is how to shorten delivery dates, and at the same time rise productivity and product quality. Hvam [2] describes implementation of MC principle in a company that produces complete processing plants for cement manufacturing. As this is a really complex product that is usually planned as one of a kind, this approach, accompanied by the use of modular product structure and configurational system shows that use of MC is both possible and useful even for such extremely complex structures.

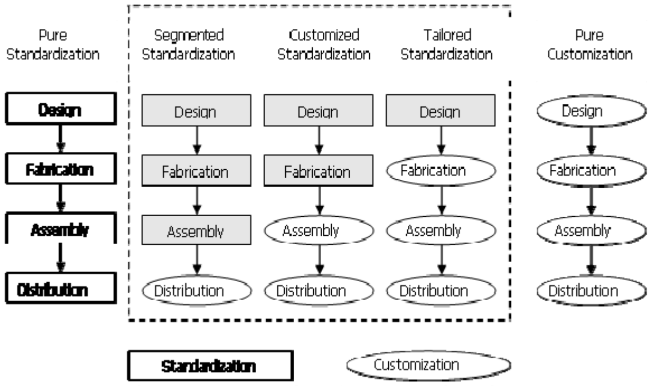

Figure 2. Levels of Customization

Marellimotori (electric motor manufacturer) manufactures all kinds of electric motors and delivers them to their customers in accordance to their demands. Motors are used for different purposes so the need for their adaptation is great. By using mass customization Marellimotori have managed to achieve greater diversity of produced motors at competitive prices. Standard motors or their adaptations can be chosen as well.

MC IMPLEMENTATION

The idea of MC – to offer customers the product they want– is commercially fully justified. However, the very MC implementation is a problem and many companies have been disappointed (Levi Strauss' custom jeans) Even today many executives consider that MC, although enchanting, is an impractical idea that can be used in a limited number of cases (DELL).

A research [3] done in over 200 different companies from over 8 different countries has shown that if MC is correctly understood and implemented it represents a strategic mechanism that can be applied in most types of businesses. MC will not take the company and its trade into an idealized state where it will know what a customer wants and what goods to produce in order to satisfy the individualized customer requirements and all that at the mass production price. MC is about moving targets by developing a set of organizational capabilities which in time will supplement and enrich present business.

A company has to fulfil three fundamental MC requirements:

1. A possibility to identify product attributes within customer requirements.
2. A possibility to re-usage and
3. A possibility to offer customer support in order to identify and construct solutions according to their demands.

There is not only one, best way leading to MC and improving competitiveness; every single company and its mangers need to adapt their approach and methods according to their specific business.

Past practice has confirmed that diversity of needs and requirements constitutes a problem that has to be minimalised. Requirements have to be unified in order to create a product that satisfies everyone (one size fits all) or no one (mass production).

MC does not represent a single, definite business strategy to be adhered to strictly but it is a set of organizational capabilities that can enrich any business.

Every approach to MC must take into consideration different product or industry specific factors.

The three basic common requirements that need to be defined in order to do business in accordance to principles of MC are:

1. Solution space development
    a. identifying particular customer needs attributes (product attributes where customer wishes diverge the most)
    b. defining solution space that determines what is offered and what not

Creating offer possibility framework is a complex and expensive procedure that can be helped by several approaches, such as creating an interface that is easy to use, analyzing customer feedback

2. Robust process design implies
    a. customized products delivery accompanied by efficacy and reliability of mass production
    b. flexible automation, although a contradiction in itself is nowadays common in auto industry, as well as in pharmaceutical, food and other industries
    c. process modularity –fast adaptation to changes in customer demands
    d. investment in knowledge – staff required to have wide spectrum of knowledge, not only specialized
3. Choice navigation
    a. offer help
    b. when dealing with extremely large, complex products it is really necessary to create a fast tool that will enable multiple iteration, learning from errors and giving fast quality answers
    c. it is possible to save by avoiding later errors
    d. Croatian shipyards are valued because of tailor made approach to shipbuilding and this is a characteristic that can be incorporated in an overall MC process.

MC implementation in itself does not represent a change over from one to other destination but it is a non stop way in which the motion is in the continuum whose ends are determined by MP and MC, and the company position in this spectrum is determined by three criteria. A company can implement MC through improving all three criteria or only some of them; it all depends on technology and competitiveness of a given market.

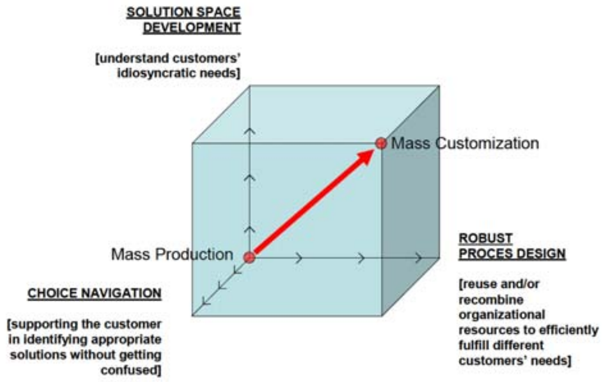

Figure 3. The Mass Production - Mass Customization Continuum [3]

Products, processes, organisation all represent one aspect of this complex system. In order to understand better how this system operates it is good to model it in several different ways [4]: by breaking it into subsystems in which it is easier to encompass all relevant date and information pertinent to every distinct subsystem; by recording relationships between subsystems that together give an integrated system behaviour and by analysing system entries and exits and determining their influence on the system (it is important to set system limits as they define 'the inside' of the system).

System segmentation [5] of production system can be done by using axiomatic design procedure where it has to be said that companies usually start a project with the already existing production structure and they view it as a certain restriction. Axiomatic design [6] suggests mapping among four basic domains and encourages designers to define the capabilities and limitations of the system first.

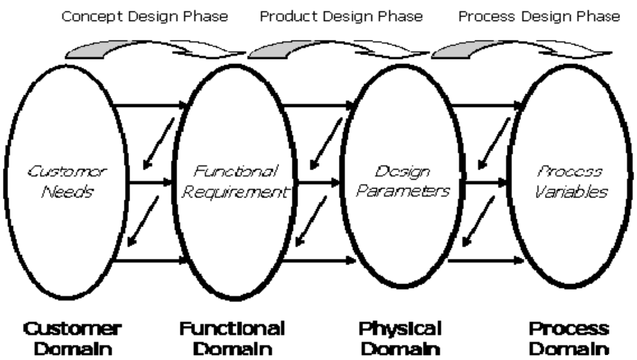

Figure 4. Axiomatic Design Domains

Companies use product platform in order to increase number or variants and shorten product delivery time, lower expenses and satisfy customer needs. The key to successful product family lies in creation of a platform. There are a major number of papers that deal with possibilities, tools and methods of implementation families and product platform of various forms. Scientists, as well as industrial experts have to try to span the gap occurring between planning and creation on one side and use of product platform on the other side. The impact of developing products based on families and platforms on the initial definition, project and manufacturing processes has also been studied.

Certain authors advocate modular product implementation and analyze product development process, modular project, Design for modularity (DFM), design for manufacture and assembly, flexibility and cellular manufacturing system [7].

Creating a basic unit into which different components (modules) can be fitted thus enabling different variants of the same product to be produced is considered to be one of the most important aspects of modular production.

Basis has to be capable of supporting, with its structure and use, all expected product variants, and individual components must bear characteristics which put together create complex products [8].

In this way modularity can shorten project development time, enable customization – adaptability and product expansion, increase quality, create certain standards and shorten time to delivery.

MC OF LARGE, COMPLEX PRODUCT

Complex management [9] represents a development of a framework that will allow designer to customize product to customer requirements easily. The main complexity source in the whole product plan is represented by a large number or information and interdependencies that affect or not only product variants, but all product aspects. The authors study complexity for the very beginning of the project when it is still possible to analyze later consequences.

System complexity is determined by many factors:

- time change
- number of interrelationships and interconnections, both positive and negative
- non-linear behaviour and interactions
- small entry changes can be the cause of huge consequences (butterfly effect)
- systems are adaptable – they can learn
- systems can evolve to even greater complexity in order to achieve even better performances
- stochasticity.

PRODUCTION SYSTEM COMPLEXITY

Production system complexity of a given product derives from many sources:

1. Product complexity derives from:
    a. Product size (large number of components, large number of work hours, large supply order demands).
    b. Product plan (calculation of large number of components produced out of different materials, different designer from different department are interdependent, different regulations and standards have to be met)
    c. Product diversity that is simultaneously produced by the company (number of products, variants, storing)
2. Production process complexity derives from:
    a. Required spatiality (large space needed to process materials, make product and store it; coordination of large number of employees, and large quantities of equipment)
    b. Process (complex early operations flow, complex changes, constant quality checks, need to outsource).
    c. Supply (large number of suppliers and orders, quality control of delivered products, delivery times).

Other sources that increase the complexity of the whole system and as such have to be taken into consideration are complex informatics system and greater ecological demands throughout the whole production process.

CHARACTERISTICS OF SHIPBUILDING PROCESS

For the purposes of complex product production the final product is seen as a single, unique product. Globally seen all complex products of some company have common characteristics (in a shipyard – every ship is a unique product) Certain researches (interviews with Greek ship owners who intend to modernize their fleets with newly built ships [10]) have shown that the most valued shipyards are in Japan (Hitachi, Mitsubishi, Misui) and South Korea (Hyundai Heavy Industries, Daewoo, Samsung) and Korean shipyards are considered to provide best value for money. However, the same researches have shown that the ship owners want ships built in accordance to their specific wishes which indicates a need for flexible shipyards when it comes to cooperation between the ship owner and the shipyard regarding the changes in the project.

Modern ship designers face many demands that regard more complex ship structures, increasing safety demands and higher ecological standards. Ecology standards have mainly been regulated by IMO standards and regulations (International Maritime Organization) – a set of conventions to which everyone involved in maritime traffic (from ship designers and ship owner to recycling plants) have to comply.

Soon, a new convention on ship recycling will take effect („Hong Kong International Convention for the safe and Environmental Sound Recycling of Ships"). In order to implement this convention well a green passport has been developed. It is a document that will follow a ship during its whole life span – from the plan to aging and will contain all information about material use to construct it, as well as materials – waste generated during its use. Green passport will be used for both new constructions and already existing ships and will be subject to approval and inspection.

Complex ship structure contains a large number of variables and limitations. In the early project phases a large number of precise dates is lacking so the whole process is iterative with a spiral flow of approaching the final result. Bulk, load bearing capacity, stability, strength, length of welding on a specific ship can not be determined precisely and as one characteristic changes the others change to in conformity.

It is necessary to preserve light weight in order to increase load bearing capacity, but without impairing the needed strength; retain the required ship speed and minimal fuel consumption; ensure ship stability in all sea conditions and against damages...

Shipbuilding process with all its features is considered to be a highly complex production business system. A complex product requires a complex production process which in turn requires unique and special shipbuilding organisation structure. Uniqueness and specificity of organisational structure is seen in its 'width', i.e. a large number of business and production functions, as well as in its 'depth' i.e. a large number of organisational and management levels. Moreover, shipyards have developed relationships with numerous partners that participate in vessel building, as well as in preparatory and production part of shipbuilding process. Shipyards, at the same time, perform their activities on more than one object at different production or preparatory phases, so a complex matrix planning organisation structure dominates.

Table 1.: Comparison of characteristics of shipbuilding process with characteristic of mass production

Shipbuilding	Mass production
- low volume	- high volume
- complex, non repetitive on product level	- standardized and repetitive products
- production in loose network	- integrated production system
- handcraft	- automated process
- long throughput time	- short throughput time
- customization	- no customization
- product is partly designed and engineered to order	- no design and engineerig changes are allowed

Table 2. Comparison of characteristics of shipbuilding process with characteristics of mass customization

Mass customization	Shipbuilding
- medium to low volume	- low volume
- repetitive on process level but not on product level	- 80% repetitive on process/product level, 20% is engineerd and produced to order
- automated when beneficial	- production in loose networks
- integrated production system	- manual processes
- customization within certain constrains	- custom within certain constrains
- short throughput	- long throughput
- product is design for customization	- modular design where some modules are standardized and other are customized
- customization to order	- customization to order

The whole shipbuilding process at its first level is divided into shipbuilding preparatory processes and shipbuilding production processes. Main characteristics of these processes are [11]:

- *multi stage development i.e. intermittency with a large number of inter products*
- *considerable interactivity and technological process inter dependence*
- *most part of these processes are non repetitive process with different activity length*
- *the process is implosive, as there is a large number of components – raw materials at the start, and a small number of different final products in the end*
- *processes happen in numerous parallel or consecutive flow, with small or large time overlapping*
- *processes are technologically different and different equipment is used*
- *processes are mainly work intensive*
- *in production processes there is a 'movement of product through the process' as well as 'movement of process through the product',*
- *different inputs and resources, both proper and external, are needed for the process to take place*
- *buyer is present from the very beginning of the process (a known buyer).*

The following tables show comparison of shipbuilding characteristics to characteristics of mass productions and mass customization [12].

AN EXAMPLE OF MC IMPLEMENTATION IN PRODUCTION OF LARGE, COMPLEX PRODUCTS

Today F.L. Smidth covers over 30% of world market for cement producers' equipment. The company has to implement a configuration system that enables a fast drafting of initial customer offer. Prior to implementing configurators the company needed from 3 to 5 weeks and 10 to 15 experts from various sectors to form an offer. All this knowledge is now stored in a configurator and by using it any offer can be compiled in about 2 days. The system enables fast simulation of various solutions, and all in concordance with customer requirements. Moreover, facility optimisation is done by using standard company modules or standard equipment purchased from the supplier. This approach leads to further lowering of price, as time needed for calculations, project documentation and individual production of separate parts is saved. The amount of information transferred from one department to another is also diminished thus diminishing the error possibility, as well.

The most important customer requirements for cement factories can be summarized as: price and financing conditions, delivery time, operational costs (running costs as workforce, energy, transport, maintenance are critical for the cement factory's overall rentability) and energy consumption and environmental load (emissions). In recent years, there has been an increasing focus on minimazing energy consumption and emission from cement factories.

Product configuration at F.L. Smidth is done is seven phases: analysis of specification processes, product *analysis, object-oriented analysis, object-oriented design and choice of software, programming, implementation and maintenance and further development.*

Cost incurred by creating configuration system derives from configuration team, model development, information finding and operation and maintenance. The advantages are, however, manifold and superior in relation to costs. They are a new way of working, new opportunities, greater use of modularisation, high efficiency in producing offers, ease of access to knowledge and information and transparent solutions [13].

CONCLUSION

More and more companies meet with the increasing customer demands that require delivery of custom made products that are customized according to unique needs of each individual customer, and at the same time delivery times, pricing and quality have not changed significantly from mass produced products.

This development of manufacturers can be achieved by implementing a concept known as 'mass customization' or production of customized products where advantages of mass production are still retained.

In the last few decades it has been difficult to forecast the market needs, the offer is greater than ever, and production possibilities more incontestable, so many companies search for the way out by reducing prices, enriching the product choice and offering unique, quality products.

Large, complex products constitute a specific problem as there is no possibility to standardize the product or its production process.

This paper gives an overview of past implementation of mass customization in different industries and through three different implementation possibilities

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AUTHORS & AFFILIATION

Ivica VEZA[1],
Natasa JURJEVIC[2]

[1-2] UNIVERSITY OF SPLIT, FACULTY OF ELECTRICAL ENGINEERING, MECHANICAL ENGINEERING AND NAVAL ARCHITECTURE, SPLIT, CROATIA

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