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MASS CUSTOMIZATION TECHNIQUES – STATE OF THE ART

Nikola Suzic[1], Cipriano Forza[2], Zoran Anisic[3]
[1]University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Republic of Serbia / University of Padova, Department of Management and Engineering, Vicenza, Italy
[2]University of Padova, Department of Management and Engineering, Vicenza, Italy
[3]University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Republic of Serbia

Abstract: *Mass Customization (MC) had its beginnings in 80's and 90's. Today, Mass Customization has became a mainstream paradigm in modern production as witnessed by a plethora of on-line configurable products. Much of its current success MC owns to variety of its techniques which are used to obtain needed results in production, product development and sales. Yet, there is still a question of what are the techniques that can be called MC techniques. In other words what are main techniques that enable implementation of MC into ones company. The paper gives an overview of the main MC techniques as well as the effects that are to be expected from their implementation. Furthermore, some relationships between different MC techniques are discussed as an important factor of implementation of these techniques.*

Key Words: ***Mass Customization, MC techniques, State of the Art, Implementation of MC***

1. INTRODUCTION

Mass customization strategy is today more important than ever. Development of markets dictate that new products entering the market must be different from existing ones and meet customer needs more completely [1]–[4]. Customers are given more buying options on daily basis. Today, mass customization is present in all types of industry, from production of muesli*, beverages, shoes, apparel [5] to furniture [6], cars and industry equipment [7]. Hence, mass customization has gained on its importance in last two decades bringing many companies to produce customized products on the mass scale.

Never the less, there are still many companies that strugle with implementation of needed MC concept and have failed to implement it [8]†. In order to help companies to implement MC we must be more effective in communicating what are the MC techniques, what is the contribution of each one, and how do theey relate each other. A better knowlede on these aspects will help companies in selecting the MC techniques to implement and in planning their imprementation.

The present paper tries to contribute in the above mentioned clarification effort by investigating which MC techniques have been more frequently adopted in MC implementation and for what purpose do they have been adopted.

Many techniques and concepts are supposed to enable implementation of MC [9]. However sometimes techniques fequently mentioned by academic article do not find equivalent attention in practical applications. To limit this kind of potential bias the present article concentrate its literarure review on case based research.

More specifically the present paper reports the results of a literature review of techniques used in MC trough cases of MC implementation recorded in literature.

2. MC TECHNIQUES – STATE OF THE ART

2.1. MC Techniques in Cases from Literature

In order to analyse variety of techniques that are available in literature and to make summary at the end, a number of cases from practice has been gathered and overviewed. Main criteria for taking a case into account was that:

- case is well documented in reliable literature source,
- company's name and basic company data are available to reader and
- potential MC technique is presented in a way that there is no doubt that company has been using it, at least in experimental purposes or pilot programmes if not fully implemented.

Obviously, as concequence of using presented criteria some cases were discarded at the beggining.

Table 1. presents an overview of all collected literature cases. Overview gives information about the technique used, company in which the technique was used, company's country of origin, product assortment and finally the reference from which it was taken.

Overview gives all together 46 cases, from 12 countries, mainly from Western Europe, Scandinavia, North America and Japan. Number of used references is 35 all together. Gathered cases present eight MC techniques that have been successfully used in practice for the purposes of MC concept implementation.

* http://www.mymuesli.com/
† Walcher & Piller (2012) report around 20% failures in MC startups during first year of business

Table 1. *Overview of MC techniques use from literature cases*

	Used MC technique(s)	Company (country of origin)	Product(s)	Reference(s)
1	-Form postponement	Daimler Chrysler (Germany)	cars	[10]
2	-Form postponement	Xilinx (USA)	computers, integrated circuits	[11]
3	-Form postponement	Zara (Spain)	clothing	[12]
4	-Mixed model assembly line	BMW (Germany)	cars	[13]
5	-Part standardization -Product modularization -Form postponement -Product Configurator	Dell Computers (USA)	computers	[14] [10]
6	-Part standardization	Intel (USA)	computers	[4]
7	-Part standardization -Product modularization -Product families	Migatronic (Denmark)	welding machines	[15]
8	-Product configurator	Sideco S.p.A. (Italy)	pipes & tubes, fittings, flanges, valves, plates	[16]
9	-Product configurator	Demex Electric (Denmark)	electronic switchboards	[17]
10	-Product configurator	Fritz Hansen (Denmark)	furniture	[18]
11	-Product configurator	FLSmidth (Denmark)	cement	[18]
12	-Product configurator	Niro (Denmark)	process equipment	[18]
13	-Product configurator	APC (USA)	power supplies, servers, electronics	[18]
14	-Product configurator	Novenco (Denmark)	marine air handling units, fan products...	[19]
15	-Product configurator -Product platforms	Grundfos (Denmark)	circulator pumps, submersible pumps, electric motors and Injection molding equipment.	[20]
16	-Product configurator	Paris Miki (Japan)	eye glasses	[2]
17	-Product families	Philips (Netherlands)	healthcare, consumer lifestyle and lighting	[15]‡
18	-Product modularization -Form postponement	Hewlet-Packard (USA)	computer equipment	[21] [22]
19	-Product modularization -Form postponement	Autoliv (Sweden)	airbags, seatbelts and other automotive parts	[23]
20	-Product modularization	Lutron Electronics Company of Coopersburg (USA)	house and office lightning	[2]
21	-Product modularization	Hyundai (South Corea)	cars	[24]
22	-Product modularization	Atlings AB (Sweden)	steady rests for turning	[25]
23	-Product modularization	Scania (Sweden)	cars	[25]
24	-Product modularization	Whirlpool (USA)	home appliances	[25]
25	-Product modularization	Sony Ericsson (Japan-Sweden)	mobile phones	[25]
26	-Product modularization -Product platforms -Product families -Mixed model assembly line	Volvo (Sweden)	cars	[26] [27]
27	-Product platforms -Component standardization -Form postponement	Shermag Inc. (Canada)	furniture	[28]
28	-Product platforms -Product families	Kodak (Japan)	cameras	[29]
29	-Product platforms -Product families	VolksWagen (Germany)	cars	[30]
30	-Product platforms -Product families	Black&Decker (USA)	power tools and accessories	[31] [32]
31	-Product platforms -Product families	Honda (Japan)	cars	[33]
32	-Product platforms -Product families	Rolls Royce (Great Britain)	planes	[34]

‡ NOTE: In some cases, like in the case of [15] and [18] original references have not been available to authors, but reference was made for the purpose of techniques overview. For further information please search cited reference for the original ones.

33	-Product platforms -Product families	Boeing (USA)	planes	[35]
34	-Product platforms -Product families	Sony Walkman and HandCam (Japan)	audio and video technology	[36] [15]
35	-Product platforms	Minolta (Japan)	cameras, camera accessories, photocopiers, fax machines, and laser printers	[37]
36	-Product platforms	ASML (Netherlands)	machines for the production of integrated circuits	[38]
37	-Product platforms	Skil (USA)	power tools	[38]
38	-Product platforms	Stork Digital Imaging - SDI (Netherlands)	systems for digital print and pre-print applications	[38]
39	-Product platforms -Product families	NASA (USA)	spacecrafts	[39]
40	-Product platforms	Danfoss (Denmark)	solenoid valves	[20]
41	-Product platforms	Aker Solutions (Norway)	drilling equipment for oil and gas exploration	[20]
42	-Virtual Build To Order -Product configurator -Product families	Orangebox (Great Britain)	furniture	[40]
43	-Virtual Build To Order	U.S. Filter (USA)	reverse osmosis systems, filters, dispensers, purifiers	[41][§]
44	-Virtual Build To Order	IBM (USA)	servers	[41]
45	-Virtual Build To Order	3Com (USA)	computer network infrastructure products	[41]
46	-Virtual Build To Order	American Standard (USA)	air-conditioning systems, bath-tubs, anti-lock braking systems	[42]

The note should be given on a number of cases from literature available for every technique presented. Simple overview of the given table (Table 1.) shows that mostly used, or at least mentioned, techniques in literature are *product platforms* and *product families*. After them there are *product configurators* and *product modularization.* Less cases have been found on *form postponement* and *virtual build to order* techniques. At the end, least number of cases have been found for *part standardization* and *mixed model assembly lines*.

Nevertheless, we must take into account that some of the techniques are substantially "younger" than others. For example *virtual build to order* is representative of these techniques. This technique has been named only in last ten years.

Even some "old" techniques are represented with small number of cases. For example *part standardization* is presented only in three cases and it is doubtable that this is a real state of application of this technique in practice. It is most likely that part standardization is presumed to be a "solved" question and it is of lesser interest for researchers of MC concept.

Some of the techniques, like *mixed model assembly lines* are used for a long time, but interest in them is growing substantially in last years because of the lower volume/high variety production characteristic – MC characteristic of the markets, which this technique is solving successfully [43].

In analysis it was also concluded that MC technique *product platforms* is almost always treated as a part of larger technique together with *product families*. In the conclusion we can say that it is justified to treat them as one technique in this paper and in the future research.

2.2. Definition of MC Techniques

All presented MC techniques from Table 1. do have substantial attention of available literature. In order to make needed basis for future research these techniques are defined as follows:

- *Product platforms and product families*[**]

  Product platform is a set of common components, modules, or parts from which a stream of derivative products can be efficiently created and launched[22].

  Product family is a group of product that are "partially (if not fully) substitutable in their demands, possess underlying similarities in their functionality, and further have the potential to share components, subassemblies, production process, and sometimes even a common concept and/or architecture [44].

- *Product modularization* can be defined as an "activity in which the structuring in modules takes place" [45].

- *Product configurator "*is a tool which supports the product configuration process so that all the design and configuration rules which are expressed in a

[**] In this overview product platforms and product families have been put together as a result of being treated as one technique in the literature – Table 1., references [15] [29] [30] [31] [32] [33] [34] [35] [36] [39]

[§] NOTE: In the moment of paper publication use of VBTO was in experimental phase in mentioned companies. Although in given years (1998, 1999) technique was not called Virtual build to order, but „Delayed differentiation using vanilla boxes“

product configuration model are guaranteed to be satisfied.” [46]

- *Form postponement* “is an organizational concept whereby some of the activities in the supply chain are not performed until customer orders are received” and afterwards output is finalized in accordance with customer preferences with avoiding of finished goods inventories building up in anticipation of future orders [10].
- *Virtual-build-to-order (VBTO)* “is a form of order fulfillment system in which the producer has the ability to search across the entire pipeline of finished stock, products in production and those in the production plan, in order to find the best product for a customer.” [47]
- *Part standardization* “generally refers to an approach in manufacturing in which two or more different components for different finished products are replaced by a common component that can perform the functions of those it replaces“ [48].
- *Mixed model assembly lines* are assembly lines able to accept different products in terms of size, color, material, used equipment etc. Main characteristic of these lines is that when changing to next work peace (next product) there is no setup time needed. [43]

2.3. Underrepresented MC Techniques and their Definition

Besides seven MC techniques defined in previous part of the paper, there are other techniques that need to be addressed in future research. These techniques are mainly less attractive for researchers since they represent a part of existing know how. But, although these techniques are used by many companies, we argue that for a considerable number of enterprises they still represent “terra incognita”.

Examples of these techniques are *group technology (GT)* and *single minute exchange of die* (SMED). We did not find these techniques openly addressed in the case based articles on MC we analyzed in our literature review.

Incidentally, we can also notice that *part standardization* is represented only in three cases, although many authors agree that part standardization is a must in order to successfully manage product variety [49].

We take the following definitions of group technology and SMED techniques:

- *Group technology* “is a method of organization for factories in which the machine tools, other processing facilities, and people, are divided into groups.” [50] Machine groups complete all the parts they make and groups of machines are laid together.
- *Single minute exchange of die* (SMED) is a tool for shortening of setup times on technological systems. Technique strives to reduce setup time to single digit on every technological system in production [51].

These two techniques have been in use for last half of the century, and have brought many benefits to companies using them. They represent backbone of shop floor improvements in a company, and it can be argued that without the use of these “classical” techniques MC approach can not work properly.

3. EFFECTS OF THE MC TECHNIQUES

In order to better understand positive effects that can be expected from implementation of every presented MC technique, an overview of techniques and their effects has been done (Table 2.).

Given overview of MC techniques with positive effects of their implementation (Table 2.) shows that there is a vast number of improvements that can be expected from implementation of these techniques.

Some of the effects obviously overlap. There is a need to analyze these overlappings and potential connections of MC techniques that can be essential for successful implementation of MC.

Table 2. *Overview of MC techniques with positive effects of their implementation*

	MC technique	Effects of the MC technique
1.	Part standardization	-reducing the development and research costs -speeding up introduction of new products to markets -reducing the administrative cost because there are fewer components to manage -reducing the manufacturing through economies of scale [52] -reduces the level of safety stock required to meet service level required [53] -favors the introduction of the PULL concept with reducing of variety in production [4]
2.	Product modularization	-task specialization -platform flexibility -increased number of product variants -economies of scale in component commonality -cost savings in inventory and logistics -lower life cycle costs trough easy maintenance -shorter product life cycles trough incremental improvements such as upgrade, add-ons and adaptations -flexibility in component reuse -independent product development -outsourcing -system reliability due to high production volume and experience curve [54]

3.	Product platforms and product families[††]	-efficient development of differentiated products -increase of flexibility and responsiveness of the manufacturing system -concurent advantage over companies who develop their product one at a time -shorter product development -reduction of product's cost -reduction of manufacturing system's complexity -reduction of cost for product development -increase in possibility for product upgrade [55] -favor the implementation of MC because of the possibility to develop large number of product fast [1] -reduction of the time needed for testing of complex products [35]
4.	Form postponement	-lower stock obsolescence [56] -less work-in-process [57], [58] -shorter lead- and delivery times [59] -enables economies of scale [58] -improves customer satisfaction [60], [61] -allows companies to react to short-term changes in customer specific demand [59]
5.	Product configurator	-shorter lead times -reduction of needed resources to produce specifications -fewer errors in specifications -makes choice of product variants easier for the customer [9]
6.	Virtual build to order	-shortening of lead time in the system -reduction of inventory size [62]
7.	Group technology	-shortening lead times -reducing large setup times -decrease in Work-In-Progress inventories -reduction of large inventories of finished goods -gaining better part quality -lower costs of produced unit of the product [63], [64]
8.	Mixed model assembly line	-increased volume flexibility -increased mix flexibility -reduced product dedicated costs -more consistent quality -shorter tact time -one assembly flow is a driver for commonality and common product architecture [27]
9.	Single minute exchange of die (SMED)	-setup time reduction -reduction of stocks, and as a consequence :increase of capital turnover rates, more efficient use of plant space, increase of productivity with stock handling operations eliminated, unusable stocks arising from model changeover or mistaken estimates of demand is eliminated etc. -increase of machine work rates and productive capacity -elimination of setup errors -improved product quality -increased safety due simpler setups -lower expenses -lower skill level requirements -reduction of production time -increased production flexibility [65]

4. LOGICAL CONNECTIONS BETWEEN MC TECHNIQUES

Every technique and her effects can not be analyzed separately. Done in this way it will bring only limited results. Thus, there is a need for holistic view [66]. Unfortunately this is a difficult analysis for companies since the interactions between MC techniques are very complex. We do not deep this point since it deserve a lot of space, but we highlight this as a interesting issue to research on.

[††] in this overiview product platforms and product families have been put together as a result of being treated as one technique in literature – Table 1., references [15] [29] [30] [31] [32] [33] [34] [35] [36] [39]

With overview of the cases we can conclude that in large number of them techniques are mentioned together and are treated almost as one, like in the case of product platforms and product families. In other cases connections are not so strong, but they still exist. Many of these connections are confirmed in the literature.

For example, literature presumes that part standardization should be done before product modularization [14], [49], [67], before introduction of product platforms [67], product configurator [16] and form postponement [14], [68]–[70].

Many authors agree that product modularization is a basic technique for acquiring product platforms [67], [71], product configurator [16] and form postponement [14], [21], [49], [68], [69].

Also, authors see product platforms as precondition for product families implementation [9], [22], [67]

Further more, product families are seen as necessity for introduction of form postponement [4], [68], [70] and product configurator [16].

As we can see from this short overview, connections between MC techniques are a complex issue. Off course this is only a part of the analysis. Whole scope of nine presented techniques is more complex and more difficult for the analysis.

5. DISCUSSION

In this paper MC techniques have been gathered trough published case studies, and then defined and analyzed trough positive effects they produce in industry when applied.

But analysis of individual technique is not always sufficient. That is why paper gives also a short analysis of logical connections between some of the analyzed techniques. Based on this short analysis, we can argue that it is sometimes difficult to make boundaries of some of the techniques. Therefore it is not always clear where one technique stops and another one starts.

This complexity is the reason to take holistic approach in the future research, based on these nine techniques. This approach must also have a certain degree of flexibility in order to counter complexity of the problem.

These are crucial observations for MC concept implementation. We can argue that not understanding of techniques and connections between techniques, as well as not taking holistic approach is the reason for many of unsuccessful MC cases. Even if understanding of some technique is on the high level in the company, it can be the case that company lacks understanding of some other technique that is crucial for success of the project. It is expected that this is especially true for SMEs who lack human, time and capital resources for studying of every technique. For SMEs this will be one of the main restrictions for implementation of the MC concept.

It must be noted that present study has its own limitations. One limitation is that paper has dealt only with positive effects of presented MC techniques. In the future works negative sides of every technique should also be taken into account. Another limitation is that logical connections between MC techniques have been only superficially considered. Ideally analysis should be done more thoroughly and it should include all the MC techniques.

6. CONCLUSIONS

This paper tried to bring us closer to answers on four questions important for future research in MC concept implementation:

- What techniques can be called MC techniques?
- What are effects of these MC techniques?
- What are logical connections between MC techniques?
- What should be future direction of research in the field of MC concept implementation?

Paper pointed out to nine MC techniques that until now received different attention of MC researchers. Authors argue that these techniques can be treated as basis for MC concept implementation.

Off course, not all of the techniques need to be implemented in order to get a MC system. As we can see in the literature overview (Table 1.), implementation of the MC techniques will depend of industry and types of products that are produced. Also we can presume that type of MC techniques applied will depend on company’s size, market type and size as well as of consultants (experts) experience previous to the implementation of some technique in company.

Based on this study some of the future direction for research are:

- Logical connections between different MC techniques should be more deeply explored in the future.
- Importance of Group technology and SMED as MC techniques is still to be researched.
- Research should be further focused on SMEs. It is assumption that these companies are the ones that will benefit the most from this kind of study.

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CORRESPONDENCE

Nikola Suzic
University of Novi Sad - Faculty of Technical Sciences, Novi Sad, Serbia
University of Padova - Department of Management and Engineering, Padova, Italy
nikolasuzic@gmail.com

Dr Cipriano Forza, Full Prof.
University of Padova
Department of Management and Engineering,
Stradella S. Nicola, 3,
36100 Vicenza, Italy
cipriano.forza@unipd.it

Dr Zoran Anisic, Prof.
University of Novi Sad
Faculty of Technical Sciences,
Trg Dositeja Obradovića 6
21000 Novi Sad, Serbia
anisic@uns.ac.rs