

MASS CUSTOMIZATION 4.0 – INSIGHTS FROM SPECIFIC ANGLES

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Abstract: *This paper presents the output of the MC 4.0 INTERREG project devoted to enhancing Mass Customization 4.0 (MC 4.0) competencies in Small and Medium Enterprises (SMEs). It reports the results of four focus groups each one made with managers, entrepreneurs, and various academic and non-academic experts. The results show many MC-related issues that the current economic context and new technological opportunities bring to the attention of practitioners, academics, and policymakers.*

Key Words: *Mass Customization, Industry 4.0, SMEs, Focus Groups*

goods and services conceived with very differentiated and multidisciplinary knowledge and realised involving several different technologies. Finally, this sector is present everywhere, even though in different geographical areas this sector may present quite different peculiarities.

Many technological innovations are affecting the supply chains of the living sector. If we look at the manufacturing of materials, components, systems, and machines employed in these supply chains we can see that Industry 4.0 technologies are deeply changing the operational processes within and across companies. If we consider domotics we can see the possibility to equip our living spaces with functionalities not imaginable and foreseeable some years ago. Since living environments are responsible for a considerable impact on the environment (according to Cook [6] – private households are responsible for 40% of energy consumption), there has been a grooving of technological solutions for reducing this impact. This impact is significant both during the construction as well as during the use of living spaces. The combination of this environmental attention with the digitally enhanced functionalities of the living space is paving the way to smart living in smart homes.

However, a home environment is something unique, something designed for a specific person or for a specific family. The combination of objects, systems, and services is unique. Often it is unique even the single product/service used for such an environment [7]. This uniqueness and specificity frequently go up along the supply chains and tend to be influenced by geographical areas. This specificity structures the competency profile present and needed in a given geographical area and can become one of the aspects that characterize a given culture! Given the high degree of customization in the living sector, the provision of affordable customization is important in this sector.

But, how can this need for uniqueness and specificity be merged with the various innovations mentioned above? What are the potentials and challenges of the Industry 4.0-supported mass customization in the wide and long supply chains of the living sector? Are the

1. INTRODUCTION

We live in interesting times! This is because we are witnessing a lot of changes and innovations in regard to technologies, society, environment, companies, and individuals. Do these changes [1-3] relate to the mass customization (MC) approach, i.e. that approach that supports companies in surviving and growing by offering differentiated products and services with prices, in a quality and with a responsiveness that is not so different from companies that offer standardized products and services only [4]? This is the topic addressed in the present paper.

This issue affects many sectors, several geographical areas, and entire supply chains. However, one domain is currently of particular interest in this context - the living sector. This sector is important for individuals because in developed countries most of them spend the majority of their time at home [5], followed by workplaces, recreational facilities, and healthcare institutions. The way these different kinds of buildings are operating sets constraints and opportunities for an entire society that lives within, across, next, and around these buildings: they influence efficiency, well-being, social interactions, and personal relationships. All these types of buildings have important impacts on the environment both because of their use of unbuilt soil and because of their energy consumption, to mention only a few. The living sector is characterized by very complex supply chains that involve

human resources of companies ready to deal with Industry 4.0-supported mass customization?

Since we do not know whether we can have answers valid everywhere or whether we can have specific answers for specific contexts, we investigated these issues from different angles. We approach these questions in an exploratory way using focus groups that involve experts from different domains.

We performed 4 focus groups, one at international level and three at local level, to investigate the issues taking different views. We also used different methodological choices accordingly to the different preferences present in the specific focus group contexts. Our aim was to get different perspectives not to compare the perspectives adopted in different settings. So the limited comparability of methods was not an issue.

Our investigation ended up in a number of different hints that are very prolific in terms of research ideas. What emerges are also important issues to deal with in practice. A number of challenges emerge for policy making. So we think we opened a “Pandora’s box”!

2. METHOD

Focus groups were used as the method to collect data. The method of focus groups is frequently used as a qualitative approach across a wide range of disciplines and for different purposes such as research on decision making [8]. This method allows gaining an in-depth understanding of social issues by obtaining data from a purposely selected group of individuals rather than from a statistically representative sample of a broader population [8]. The focus group is a technique where a group of individuals is assembled to discuss a specific topic, aiming to draw from the complex personal experiences, beliefs, perceptions, and attitudes of the participants through a moderated interaction [e.g., 8, 9-11]. “Focus groups also draw upon the experiences of experts in a given field in order to pull together thoughts and ideas from individuals that have a high level of knowledge in the field. In this way, a great deal of information and knowledge can surface within the discussion among these experts. Reactions, discussion, and supporting and contrary points can all be brought to light and added into the discussion. This ‘expert panel’ is often used in forecasting the future and other concepts that require the involvement of knowledgeable individuals” [12: 3].

Given that the research aim is to explore opportunities and challenges for mass customization in the era of Industry 4.0, which is a very broad topic, four focus groups were carried out devoted to four specific topics. In each focus group, a panel of experts was involved as active participants in the discussion. More details on the characteristics of the experts are provided in the next subsections dedicated to the four focus groups. Besides these active participants, a group of silent participants assisted in the discussion by recreating a sort of two-way focus group where one group actively discusses a topic, whereas the other observes the first group [8, 9]. “Hearing what the other group thinks (or by observing their interactions) often leads the second group to different conclusions than those it may have reached

otherwise [13]” [8: 24]. The silent group was composed of representatives of the partners of the MC 4.0 INTERREG I-A project. This second group allows to enhance the validity of the results by collaborating and checking the results that emerged from the focus groups.

The discussion in a focus group can be guided or open. In the four focus groups we performed, the discussion was guided by a moderator by using open-ended questions. However, the moderator guided the discussion in a flexible way by leaving freedom to participants to discuss and interact with each other without interruptions if the emerged discussion was relevant and fruitful. To encourage the members to talk more freely, the moderator was committed to creating a relaxed environment that encourages active members to participate and share their views telling that divergent views are welcome. Topics to be discussed, aims and explanation of the procedure of the focus group were specified by the organizers in advance of the session along with the names and short biographies of the active participants (i.e., a short synopsis of who the participant is as an academic and/or professional). This allowed participant expectation-setting [14].

We used online focus groups [12] to overcome the pandemic restrictions that bring, in addition, the advantage to allow geographically diverse individuals to participate easily.

Due to the different contextual situations, specific methodological choices have been made for each focus group. In the following sections, the most significant methodological choices for each focus group are reported.

2.1. Focus Group 1

The first focus group was entitled “Global Trends in Mass Customization and Digital Transformation (Industry 4.0)” and was carried out online via the Zoom platform. Intended to address global trends, this focus group has been held in English with the participation of international experts mostly from Austria and Italy. This group composition was expected since the project within which this research has been done is intended to promote cooperation and business between these two countries. This focus group included 12 participants: a moderator, 8 experts with an active role, 1 rapporteur, and 2 silent participants from project partners to assimilate directly the information and subsequently control the final resume. The 8 experts with an active role included: 5 university professors (3 of them have also a role of entrepreneurs and 1 a managerial role), 1 SME entrepreneur, 1 general director, and 1 manager of a knowledge and technology transfer institution. To each participant, a short list of topics to be discussed has been sent with the invitation to participate. This list was intended to communicate precisely the general topics of discussion, but it did not include the detailed questions that would be posed. The focus group meeting lasted 3 hours.

The meeting moderator prepared a detailed list of questions. However, these exact questions have not been anticipated to participants and have not been shown to participants during the focus group. The moderator presented (i.e., provided orally) a question at a time

without forcing everyone to respond. He skipped some questions since sometimes the discussion dealt with the foreseen questions during the discussion of previous questions. To stimulate freedom of expression we decided not to record the entire meeting. Two researchers and the meeting moderator took notes during the meeting. Subsequently, two researchers shared their notes with the meeting moderator.

The meeting moderator compared his own notes with those of the rapporteur and another researcher participant, compared them, and created the final document in a form of a focus group report. The document was later provided to two other researchers and silent partners who in this way validated the contents of the report. Finally, we further synthesized the resulting messages for effective communication to a wide audience. The final synthesis is reported in the Results section.

2.2. Focus Group 2

The second focus group was entitled “Customization Management: Trends, Opportunities, and Threats for Veneto's SMEs” and was carried out online using the Zoom platform. This focus group included 18 participants: a moderator, 11 experts with an active role, and 7 silent participants from project partners to assimilate directly the information and subsequently control the final resume. The active participants included: 2 SMEs' entrepreneurs, 5 firms' managers from different departments, 1 temporary operations manager, 1 consultant with wide experience as an R&D director, and 2 managers of knowledge and technology transfer institutions. To each participant, a list of topics to be discussed has been sent with the invitation to participate. The focus group meeting lasted 3 hours.

The meeting moderator prepared a more detailed list of questions. He showed a question at a time without forcing everyone to respond. Deviations from the specific questions were allowed, however, participants kept very well the focus. The last question was focused on the most important and suitable Industry 4.0 technologies and related training therefore the list of training 4.0 topics and their definitions have been shown to facilitate discussion. To stimulate freedom of expression we decided not to record the entire meeting. Two researchers and the meeting moderator took notes during the meeting and subsequently shared their notes with the meeting moderator.

The notes taken by the researchers were sent to the meeting moderator who reconstructed all the talks that took place during the focus group. The aim was to keep any details of each point risen by each participant. The report build in this way contained 4.420 words. Subsequently, a short report of 1.816 words was created by rearranging results by content and synthesizing them. At this stage, a PowerPoint presentation report with 8 slides has been created to convey shortly the main results. These documents were circulated and checked by the project partners who participated in the focus group. All the feedback on these documents was discussed and implemented in the documents. Finally, we further synthesized the resulted messages for effective

communication to a wide audience. The final synthesis is reported in the Results section.

2.3. Focus Group 3

The third focus group was entitled “Mass Customization in Sustainable Buildings: Design the Performance of the New Construction Industry”. It was intended to contextualize mass customization in the South Tirol area, where the living section is very important and has very peculiar characteristics. In the focus group participated experts from construction companies, architects, HVAC engineers, experts in designing the performance of buildings, and managers of companies located in South Tirol but exporting to a wider market.

The focus group has been conducted in the format of a workshop. Active participants have been provided with questions before the meeting. The meeting moderator opened the meeting with a presentation that set clearly the focus of the discussion and recalled the questions that were to be addressed. Some of the speakers prepared one or a few slides to support their talk, but in general, they preferred a plain presentation.

The suggested questions were generally considered as a reference and not answered in detail. Each of the participants brought a peculiar perspective, experience, and underlining critical aspects. Participants usually referred to points made by some previous ones as well allowing some discussion after each short talk. The moderator stimulated some discussion and made some considerations after each main speech of each participant. In the end, recapped the emerged messages.

All participants showed a remarkable knowledge of the sector and valuable expertise on the subject, with a clear interest in techniques and approaches capable of improving the performance of the sector, overcoming the limitations, and taking the opportunities. The feeling was that they were animated by a shared commitment towards designing a development trajectory for the living sector in South Tyrol, joining the efforts and providing contributions from different backgrounds. Mass Customization as well as the new technologies of Industry 4.0 could be something appropriate but needing properly designed for the specific context and applicative field.

To stimulate freedom of expression we decided not to record the entire meeting. Two researchers and the meeting moderator took notes during the meeting and subsequently shared their notes with the meeting moderator. The notes taken by the researchers were sent to the meeting moderator who synthesised the messages by working in groups with some colleagues who participated as passive auditors. The main outcomes have been synthesised in a PowerPoint presentation report with 8 slides has been created to convey shortly the main achievements and to increase the communication effectiveness to a wider audience. The presentation was circulated and checked among the project partners who participated in the focus group. A synthesis is reported in the Results section.

2.4. Focus Group 4

The fourth focus group was addressing the specific challenges related to the development of domotics, smart devices in private home environments -from the perspective of specialists in the field. It was carried out online with a group of representatives from SMEs operating in the living sector, such as construction, renovation, furniture design, and electrical engineering in the program area of Carinthia/Austria. The focus group was attended by 10 participants, the majority representing the companies, complemented by representatives of the MC 4.0 consortium. The focus group consisted of two steps. The first was a keynote given by the moderator from the University of Klagenfurt emphasizing the main challenges in the field based on literature review and other information collected in the course of the project, which were, e.g.: compatibility/interoperability issues, the convergence of infrastructures (household appliances supporting utility on the one hand and entertainment devices on the other) and possibilities of integration of non-smart appliances. In the second asynchronous step, the participants were asked to summarize their thoughts on the raised questions, enhance them with aspects they consider relevant, and send them to the MC 4.0 Team (DEA) center in a written form.

The inputs were collected by Energieforum Kärnten as the main operator of the MC 4.0 DEA Center Klagenfurt, sent to the project members of the University of Klagenfurt, synthesized, and summarized in the paper's Results section.

3. RESULTS

The four focus groups have generated a number of messages. Hereafter, we present them by focus groups and not by common themes. We choose this way to present because it emerged that results have some context peculiarities and we think that it is important to consider these context characterization if we would like to delineate development paths for specific contexts.

3.1. Global Trends in Mass Customization and Digital Transformation (Industry 4.0)

Managers, experts, and researchers working both at the international level and with Italian and Austrian companies highlight that:

- The coalignment of MC 4.0 enablers is needed to successfully implement mass customization
- Configuration technology is crucial for future implementation of mass customization
- SMEs do not have a clear view of Industry 4.0 implementation and digital transformation
- SMEs could suffer a risk of a digital gap, in some sectors more than in others since disruptive technologies differ in their impact across sectors
- The disruption of international supply chains due to COVID and the need for more flexible supply chains is favoring the development of local competencies and re-shoring to Europe

- SMEs must consider sustainability in their strategies for the future
- In the living sector, domotics is a very complex issue with high uncertainties and with considerable sustainability and customization implications
- Domotics projects require high assessment efforts before starting because subsequent changes are hard to implement and costly.

3.2. Customization Management: Trends, Opportunities, and Threats for Veneto's SMEs

Entrepreneurs, managers, researchers, and experts working for Veneto SMEs highlight that:

- Variety and customization of the products and services offered by Veneto SMEs are constantly increasing
- This trend increases organizational complexity and costs and can become a threat if appropriate solutions are not implemented
- Customization is also an opportunity: for example, many Veneto SMEs were born and are born to satisfy specific customer personalization needs not satisfied by the market
- Technological innovation is also an important opportunity to be exploited both to offer innovative products and services and to improve business processes (for example by implementing Industry 4.0 solutions)
- Customization and technological innovation lead to the need for organizational change and adaptation
- In this context, human resources play a fundamental and critical role, for example in terms of individual competencies (both soft skills and technical-professional skills), resistance or not to change, acceptance of technology
- With reference to training for Industry 4.0, the topics most important and immediately applicable are cyber security, data analysis, and digital integration of processes.

3.3. Mass Customization in Sustainable Buildings: Design the Performance of the New Construction Industry

The main issues highlighted by experts involved both in international and Italian and Austrian projects are:

- In the building sector, the Mass Customization approach clashes with the customer's desire to have a unique product
- In the construction sector, standardization is more effective and replicable if applied to the process rather than the product
- The current trend is to customize the envelope components or finishes rather than the technical system. However, the reduction in energy systems capacity following an energy-efficient design leads to a widening of the possible configurations,

requiring a dedicated effort to standardize the solutions and increase the construction efficiency

- Small and medium-sized companies often find it difficult to share their know-how. Lack of industrialization prevents the firms from consolidating processes. Universities and Standards could play an important role in providing guidelines
- There is often a gap between the desire to outline a Mass Customization strategy and the ability to manage its developments and apply it in practice
- Having a holistic approach, designers have a fundamental role in the Mass Customization process and can increase their contribution
- For many small and medium-sized companies it is not economically viable to develop Mass Customization projects from scratch
- Mass Customization in the building sector should start with the industrialization of the construction site.

3.4. New developments in domotics at the private home: potential innovations and counterarguments

The main issues highlighted by experts involved both in international and Italian and Austrian projects are:

- The improvement of interoperability and compatibility of systems from different manufacturers is seen as very important from the perspective of the user, but also from the perspective of the supplier/installer. However, the representatives of SMEs identify different obstacles, e.g. market strategies/competition of manufacturers, warranty issues (which manufacturer is responsible in a heterogeneous system?). In regard to the integration of non-smart components/devices, the participants saw pros as well as cons: Not having to throw away functional devices supports sustainability aspects, however, old devices may not be optimized in terms of energy consumption and technical state-of-the-art. So the efforts to integrate such devices in a smart environment might make sense from the user's point of view, but maybe not from the supplier's perspective
- The convergence of appliances and entertainment devices is observed critically – technical possibility does not automatically mean that the features make sense
- Internet of things in the home environment: Smart Fridge / Integrated Grocery Procurement, "Predictive maintenance" is seen with scepticism. It would be nice if systems (such as the fridge) would be able to operate automatically. However, this involves dangers and other issues, such as data privacy and data security aspects
- The expansion of broadband (fiber optics) and the impact on the distribution of smart home systems – appropriate infrastructure is an important prerequisite of appropriately working superordinate systems, not only in the domain of smart homes.

Given the experiences and problems with currently separate systems (e.g. internet, mobile telecom network, power grid) it is important to invest efforts in stability, security, and reliability to keep the promises

- Technical support, e.g. for older people. Activity analysis, fall detection, nutrition support, reminder (forgot key, light corridor) – this seems to be interesting in the future, but the participants do not know or do not have experiences with systems covering these kinds of functionalities currently
- Customer self-service through the installation of intelligent home devices (e.g. light bulb sockets): specialist shops, electronics stores, hardware stores - the possibilities depend on objective as well as on subjective factors. The objective ones are costs – when self-services are more affordable/economic for user and supplier they will be accepted. The subjective ones are, e.g. the willingness or the ability to do those things yourself (e.g. computer literacy, technical skills), but also responsibility, and warranty aspects.

4. DISCUSSION AND CONCLUSION

Is Industry 4.0-supported mass customization relevant for the entire supply chain of the living sector? If yes, what opportunities and challenges does it bring? Fundamentally, this was our research question. And the answer has been: yes, no doubt it is potentially highly important, even though there are a number of challenges.

Customization is a competitive dimension for SMEs, but they need to keep high operative performances. In that respect, mass customization is a key approach and the new digital supports offered by Industry 4.0 are fundamental. However, SMEs have to face huge challenges: limitations in understanding Industry 4.0, lack of competencies, and constraints in resources may eventually lead to a competitive divide with respect to bigger companies.

The living sector in particular suffers from traditional customization approaches which are still far more diffused than mass customization ones. Established practices in the sector make MC 4.0 adoption not so easy. So, MC 4.0 offers huge opportunities, which are difficult to catch by SMEs of that sector.

Furthermore, there are some key peculiarities. For example, the customization of the HVAC systems suffers from some effects of the strong trend toward highly energy-efficient buildings. In particular, the role and size of HVAC systems have been reduced due to the increased performance of the envelope. At the same time, this opened an unprecedented range of possible configurations and combinations which makes the need for standardization more and more urgent, in both the solutions and their performance evaluation. The design of the building has become more and more challenging, due to the need of balancing contrasting objectives such as aesthetic features, energy and non-energy performance, and practical manufacturing, while maintaining a high level of customization.

Standardization, modularization, and their combination with the specialty and uniqueness are not as straightforward as an engineer from a mechanical context could imagine, but design can be supported by customization and configuration tools able to address multi-objective optimization problems.

Similarly, domotics poses new configuration issues. Interoperability of different systems or of systems of different producers, choice of technologies in a coherent way with budget and with the desired result are some of the problems to solve. So technology is offering huge possibilities, but how to deploy them in a customized home is something difficult to design.

We would like to conclude by highlighting that the main result is that a number of different specific issues have emerged. This result calls for focusing MC research on a number of specific differentiated problems in different contexts. There is a call for cases that illustrates new applications and that single out underlying problems. We need more examples well described. Examples are important for practice because practitioners learn from examples because examples make things believable and practically understandable. But also research needs examples. Facts are not theories, but facts are the base for theories. Study innovations require evidence of facts related to the studied innovations. Here we are plenty of innovations that melted together to design something that can be deeply different from what is currently available. More factual evidence is needed to base our foreseen potential future not only on something ideally possible but also on something that has been realised, at least in part. As a consequence, a research opportunity is to turn speculative imagination into greater factual evidence.

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