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Mass Customization and Sustainability

An Assessment Framework and Industrial Implementation

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Chapter 1
Introduction

The society of man has evolved from agricultural to industrial centered, and presently, is living through a digital era. But even in this digital-communication centered world, products still need to be produced, to be manufactured. Indeed the service sector, without manufacturing, could not exist. Manufacturing evolution is articulated in various paradigms, as described in Table 1.1. A key trend of the latest years is certainly "mass customization," a market paradigm where the consumer is placed once again at the core of the business (as it happened for craft production). In ancient times and in different cultures, the word "business" was related to the deep sense of life. The Swedish called it "naring liv" or "food for life" and the Chinese called it "meaning of life," when using the old characters. This ancient terminology identified with "business" an action to provide something (food or meaning) for the life of the customer. Mass Customization brings this old way to see "business" back, and changes the way consumer products are designed, manufactured, delivered, and recycled.

Figure 1.1 depicts manufacturing evolution through time in relation to product variety and volumes. Manufacturing started with an artisan making a single product for a single customer, and, as such, was recognized as craft production. Manufacturing continued to evolve in the late 1800s during the Industrial Revolution, pioneering mass production at the beginning of the twentieth century. Later the market demanded more and more variety, forcing manufacturing to move toward the paradigm of mass customization: as pointed out by many scholars, Mass Customization can be defined as the capability to produce personalized goods, with near mass production costs and efficiency (Chap. 2 will later address in greater detail Mass Customization definition). It is recognized that the current and future manufacturing challenges are returning to those of the original craft production age, with the added advantages and complexities of today's advanced manufacturing systems and technologies. Therefore, one view of mass customization could be as having the ideals of craft production expressed through modern industrial technology.

Additionally, lately manufacturing is growing beyond the economic context into a social and ecological phenomenon, motivating companies to move toward sustainable manufacturing.

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Table 1.1 Evolution of production paradigms

Paradigm	Craft production	Mass production	Flexible production	Mass customization	Sustainable production
Started	Long ago	1903	~1980	2000	2020?
Society needs	Customized products	Low-cost products	Variety of products	Customized product	Clean products
Market	Very small volumes per product, unique products	Demand > supply Steady demand	Supply > demand Smaller volume per product	Globalization Fluctuating demand	Environment
Business model	Sell-design-make-assemble	Design-make-assemble-sell	Design-make-sell-assemble	Design-sell-make-assemble	Design for environment-sell-make-assemble
Tech enabler	Know how	Interchangeable parts	Flexible production techs	Information technology	Nano/bio/material techs

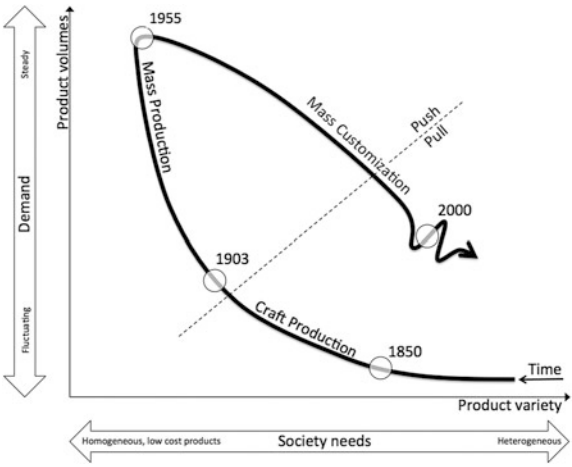

Fig. 1.1 Evolution of manufacturing

Manufacturing is, therefore, now confronted with many new "business goals" that are not only related to pure profit but also to the life and aspirations for future generations. The "company," that is the actor creating value for the consumer, has to go back to its etymological origin of the Latin word "cum + panis," or sharing the bread.

To adapt to global competitive pressures, modern industries must then develop methods and enabling technologies toward a *personalized*, *customer oriented*, and *sustainable* manufacturing. This statement is well understood by many companies, shared by policy maker at the European Commission (e.g., as per the "Factory of the Future" multi-annual roadmap), and empowered by the current and future funding programmes for industrial research (FP7 and Horizon 2020). Manufacturers are demanded to merge the need to be reactive toward customer needs and wishes (customized products), with the requisite to be proactive toward ecological and social impact (sustainable products).

This vision points out two key concepts whose impact on manufacturing is complex and interdepended: Customization and Sustainability. A key question to be addressed is whether Mass Customization can be regarded as one of the main driving forces to achieve effective Sustainability, and thus a key enabler to implement this envisioned personalized sustainable production, or a burden.

This new vision places a very strenuous challenge to the entire company organization, whose procedures and management approaches then require a thorough revision. This is certainly true for any product but in particular for shoe production, as footwear manufacturing is increasingly confronted with a progressive reduction in the size of production batches. Combined with the variability of styles, this tends to overstretch the traditional work organization and, with a demand for minimizing delivery times, manufacturing support systems do not as yet approach the levels of flexibility and quick response required for the production of mass customized products. However, since a noticeable demand for such

products is becoming evident among shoe consumers, footwear companies will soon have to confront these kinds of technical challenges.

This book is meant first to provide the theoretical background and a practical implementation roadmap to comprehend and apply Mass Customization. It will then provide a comprehensive handbook to understand and measure Sustainability. Eventually we will analyse the two concepts of mass customization and sustainability side by side, to lay a meaningful context toward the definition of a framework for their actual confrontation. The last chapter will portray the current efforts in RTD in this field.

The contents can be summarized as follows.

Chapter 2. Mass Customization theory applied to industry—Nowadays, Mass Customization is an established production paradigm in many manufacturing contexts, with remarkable application experiences in many industries. Here we provide a shared and acknowledged definition of "Mass Customization" and we explore its instantiations itemizing triggers, historical evolution, and vocabulary. Beyond the theoretical foundations of the concept, which are the real application examples in representative industrial contexts? How can we provide evidence of successful implementations? Significant case histories are here explored and major obtained results discussed, with the goal to identify future evolution paths.

Chapter 3. Sustainability and how to measure it—The label "Sustainable" is today a bottom-line requirement: as a matter of fact, Sustainability has become a common basic goal for many national and international organizations including industries, governments, NGOs, and universities. However, in spite of the nearly universal recognition that Sustainability has received, companies still struggle with the full understanding of the concept and, but just secondly, with its financial viability. This chapter provides a comprehensive handbook for the practical implementation of a sustainable assessment model, from concept understanding to indexes computation formulas.

Chapter 4. Assessment of sustainable Mass Customization—What are the performances of a mass customized production systems as far as sustainability is concerned? Which lifecycle phases raise the higher burden to "future generations willing to meet their own needs"? By applying the developed Assessment Model in a real case of mass customized production, we will highlight the intrinsic characteristics of the considered sectors when it comes to sustainability.

Chapter 5. The RTD contribution: Ideas and Future Trends—Several different EU research initiatives were meant to provide solutions to the aforementioned challenges. These experiences are here presented: their main findings, key concepts, and roadmaps are pointed out, grouped, and discussed.

Chapter 6. Mass Customization and Sustainability—This chapter addresses the link between Mass Customization and Sustainability. We will here propose a framework for the two concepts of confrontation.

By this book, the reader will familiarize with the concept of Mass Customization in theory and practice, being then capable to evaluate industrial realities and to propose roadmaps for a viable MC implementation. He will also acquire the capability to assess a product, process, and supply-chain configuration over several

sustainability indicators, which are realistically explained here with a clear guide for application. The reader will be also given hints on future trends and research ideas, to be held as inspiration for personal developments and implementation. In a nutshell, by this book, he will be able to answer to the following questions:

- What's Mass Customization and how can it be formalized?
- What's Mass Customization in practical terms?
- What's Sustainability and how can I measure it?
- What are the actual research initiatives and future trends?
- Is there a link between Mass Customization and Sustainability?

Chapter 2
Mass Customization Theory and Implementation Framework

2.1 Mass Customization Definition

The term "mass customization," abridged with MC, was anticipated by Stan Davis in the book, "Future Perfect," in 1987: "the same large number of customers can be reached as in mass markets… and simultaneously they can be treated individually as in the customized markets of pre-industrial economies" (Davis 1987). Pine in 1993 introduced an industrial perspective in the new-born concept and defined mass customization as "providing tremendous variety and individual customization, at prices comparable to standard goods and services" to enable the production of products and services "with enough variety and customization that nearly everyone finds exactly what they want" (Pine and Davis 1993).

In 2001, Tseng and Jiao provided a popular and intuitive definition: Mass customization corresponds to "the technologies and systems to deliver goods and services that meet individual customers' needs with near mass production efficiency" (Tseng and Jiao 2001).

In 2007 Pine was back again to his definition of mass customization and revised it as "the low-cost, high volume, efficient production of individually customized offerings" (Piller 2007a). To reach this efficiency requirement, a mass customization system should possess a stable although still flexible and responsive set of processes, that are capable to deliver a finite number of customization options. As a result, the costs associated with mass customization should lead to a price level similar to the mass produced product.

Finally Piller, who devoted consistent efforts in MC related research, provided his definition of mass customization, focusing on key concepts that really distinguish mass customization from similar approaches. While taking into account the previous approaches to Mass Customization concept definition, we choose to start from the work done by Frank Piller. "Mass Customization refers to customer co-design process of products and services, which meet the needs of each individual customer with regard to certain product features. All operations are performed within a fixed solution space, characterized by stable but still flexible and responsive processes. As a result, the costs associated with customization allow for a price level that does not imply a switch in an upper market segment." (Piller

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2004; Boër and Dulio 2007). Following Piller's argument and work, this definition can be further decomposed into four statements (Piller 2004):

2.1.1 ITEM 1: Customer Co-design

Customers are integrated into value creation by defining and configuring an individual solution. Customization is about the concretization of the end-user needs and desires into concrete product specifications. A tool is then needed: whether a paper catalog, listing variants and combinations, or a digital configuration software, the co-design is empowered by a proper mean. The footwear sector offers several examples of web-based tools meant to provide these functions: Mi-Adidas, Converse, Footjoy, Keds, Left, Morgan Miller, Nikeid, Otabo, Ryz, Vans, Preschoolians, Timberland.

2.1.2 ITEM 2: The Needs of Each Individual Customer

The co-design procedure, mentioned in ITEM 1, is an action that concretizes the customization potential, expressed by all the possible products configurations (the degree of customization offered by the manufacturer), into a single customized product. The goal is then to correctly identify the customization options and dimensions meant to satisfy the customer needs. To better express the level of customization offered, three dimensions are highlighted: fit, style, or functionality (Piller 2004, Boër and Dulio 2007) (Fig. 2.1). *Style* (*aesthetic design*) relates to modifications aiming at sensual or optical senses, i.e., selecting colors, styles, applications, cuts… Many mass customization offerings are based on the possibility to co-design the outer appearance of a product. This kind of customization is often rather easy to implement in manufacturing, demanding a late degree of postponement. *Fit and comfort* (*measurements*) is based on the fit of a product with the dimensions of the recipient, i.e., tailoring a product according to a body measurement or the dimensions of a room or other physical objects. In the case of footwear, this means to measure the two feet in 3D and extract the necessary information to choose the best fitting last or even to make the personalized one. It is the most difficult dimension to achieve in both manufacturing and customer interaction, demanding expensive and complex systems to gather the customers' dimensions exactly and transfer them into a product. *Functionality* addresses issues like selecting speed, precision, power, cushioning, output devices, interfaces, connectivity, upgradeability, or similar technical attributes of an offering. These dimensions of customization offered may be plotted on a three-branch radar graph, as shown in the picture above. By grading the three axes with a given customization scale, by then evaluating the level of personalization offered in each dimension, and by eventually connecting the resulting points, we obtain different

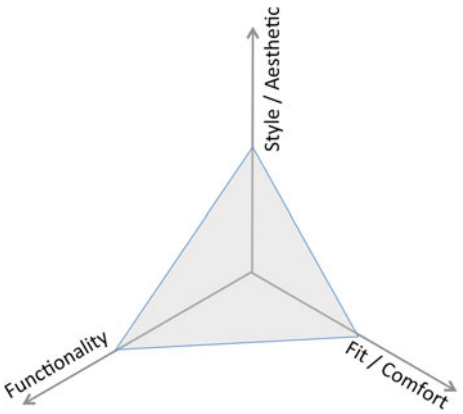

Fig. 2.1 The customization axes

triangles describing different customization scenarios. Each triangle represents the offer proposed to the customer, i.e., the degree of customization he will be able to take advantage from (Fig 2.1).

It is important to highlight that the final customer, as a single entity, differently from what happens within the co-design in ITEM-1, does not individually impact the company choices in defining the customization dimensions of the product: those options are defined eliciting the "needs of the many" by market research, surveys, and anticipation of trends.

2.1.3 ITEM 3: Stable Solution Space

The term solution space represents "the pre-existing capability and degrees of freedom built into a given manufacturer's production system" (Piller 2004). A successful mass customization system is characterized by a stable while flexible processes distributed along the whole supply network, used to deliver high variety goods, with "near mass production efficiency." This generally implies that the customization options are limited to certain product features. Customers perform co-design activities (ITEM-1) within a list of options and predefined components, that were chosen, thanks to surveys and analysis (ITEM-2), before their customization activity. Those options were defined trying to meet the needs of the individual customer, by analyzing the needs of the many. There is a strict link among (1) the "needs of the many," that define a potential solution space from the desires and point of view of the customers, (2) the "capability and degrees of freedom built into a given production system," that defines a potential solution space coping with technological and economical consideration of the manufacturer, and (3) the "company specific strategy and policies," that may limit the customization offer due to tactical considerations (this is the case of a shoe company that limits the combination of colors to given pre-accepted sets, to

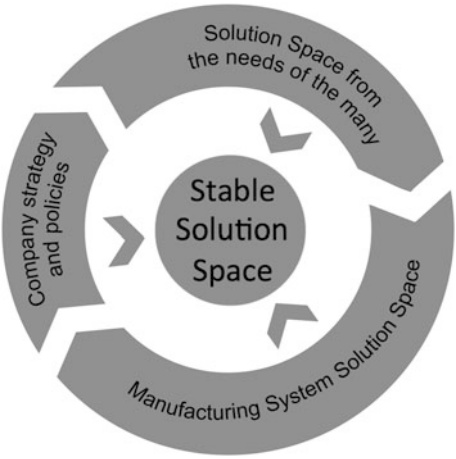

Fig. 2.2 The recursive design of the stable solution space

preserve the brand style, or do not give the possibility to move along the "aesthetic dimension," again to preserve brand name, but are eager to promote fitting). Thus the stable solution space (SSS) is the result of an interaction of those three elements (see Fig. 2.2), whose KPIs (Key Performances Indicator) may significantly differ from one another.

Once defined, the SSS represents: (1) the yet undifferentiated product blueprints (that is the sum of all the potential customization options for the MC product); (2) the capability and degrees of freedom of the production system; (3) the adequate supply chain capable to support the product variants.

Figure 2.3 shows the mapping of the SSS onto the four ITEMs of the Mass Customization definition: the SSS is defined thanks to the interaction of the desires of the customers (mapped on MC ITEM 2) and of the potential solution space coping with technological and economical consideration of the manufacturer (mapped on MC ITEM 3).

The SSS, as mentioned before, represents the potential product configurations, the production system and the supply chain meant to manufacture the final product (again Fig. 2.3). The potential product configurations are the starting points used by "customer co-design tools," ITEM-1, in order to define the specification of the final goods (e.g., the "product configurators" for the personalization available in the websites for shoe personalization aforementioned). Figure 2.3 anticipates also the relation with the MC ITEM 4, hereinafter described: the adequate price.

2.1.4 ITEM 4: Adequate Price

Mass customization practice and studies (see for example Piller 2013) show that consumers are frequently willing to pay a premium price for customization to reflect the increment of utility they gain from a product that better fits their needs

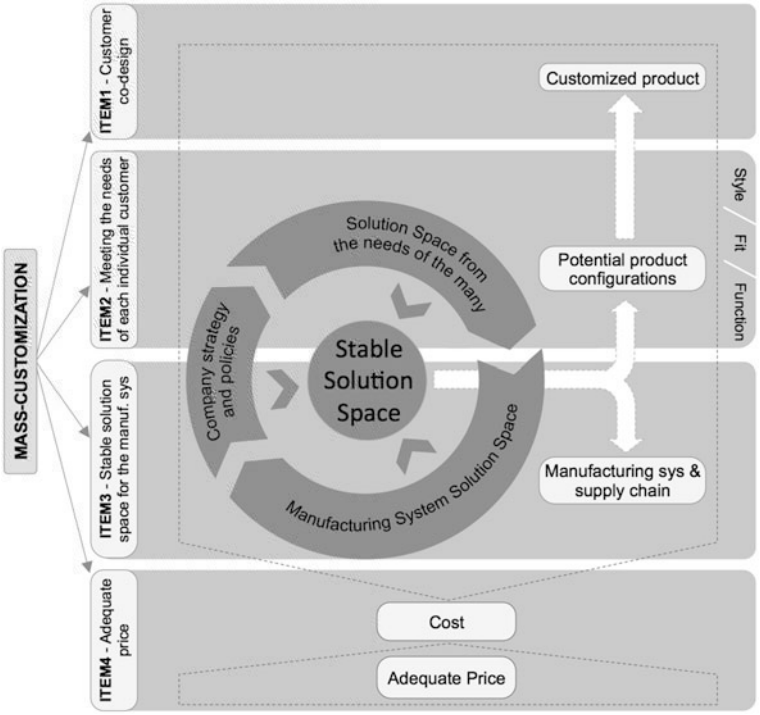

Fig. 2.3 The stable solution space mapped on the mass customization items

than the standard product. Mass customized goods are targeting the same market segment that was purchasing the standard goods before, but with adequate price increase.

The SSS is then subject to another constrain, as again shown in Fig. 2.3 by the large arrows with dotted lines. The number and type of product options, the related manufacturing system and the adequate supply chain contribute to define the cost for the final customized product. This cost must be compatible with an adequate price so that the customized product does not target a different market segment, if compared with the standard one. The EUROShoE project (Boër and Dulio 2007) demonstrated, by relevant consumer analysis, that in footwear a premium price for customized shoes of 20–40 % is acceptable… It is worth noticing that if we consider the premium price percentage, a luxury brand with a small number of products asks for a higher profit margin (per product) than a cheap brand where the overall "premium" profit is distributed on wider (also mass) volumes. This is still a debate in the MC community if a luxury brand like Ferrari, with its all personalized cars, can be taken as an example of MC or if it is more pertinent the Fiat 500, where customization is at a much lesser degree, but much closer to the "mass" concept (especially considering the low premium price asked for these, few, customizations). The same applies in the footwear sector, of course.

2.2 A Template to Jump in

This book has a predominantly applicative attitude: providing actual, practical, and intuitive tools to entrepreneurs aiming at implementing MC within their businesses is one of the main goals pursued. The template here presented (Fig. 2.4) and the following discussion and examples are meant to enable prospective (but also current) MC adopters to identify MC implementation procedures suitable for their businesses, and to qualitatively investigate and assess their approaches in comparison to others'.

In the last 15 years, many researchers have approached the MC theme from a wide spectrum of points of view (see the four research domains cited in Fogliatto et al. (2012)) and many industrial case studies have also been cited as relevant examples of MC implementation in real industrial environments. This notwithstanding, it appears to be difficult for an apprentice entrepreneur to understand the best path he can follow in order to actually implement MC within its business. Many times an entrepreneur asks: "How can I *adopt* MC within my business?" With the hereinafter-discussed methodology, this chapter aims at supporting this businessman in finding valuable answers to this question. For this reason, the point of view of this chapter is different (and probably complementary) from others' approaches in the literature. Three are the elements the proposed methodology is composed of:

1. a template with seven blocks chosen as the building elements of an MC company business environment (Fig. 2.4). A good starting point to successfully implement an MC transformation is the exploitation of a roadmap, that it is here actualized with a conceptual template that everybody can understand and that

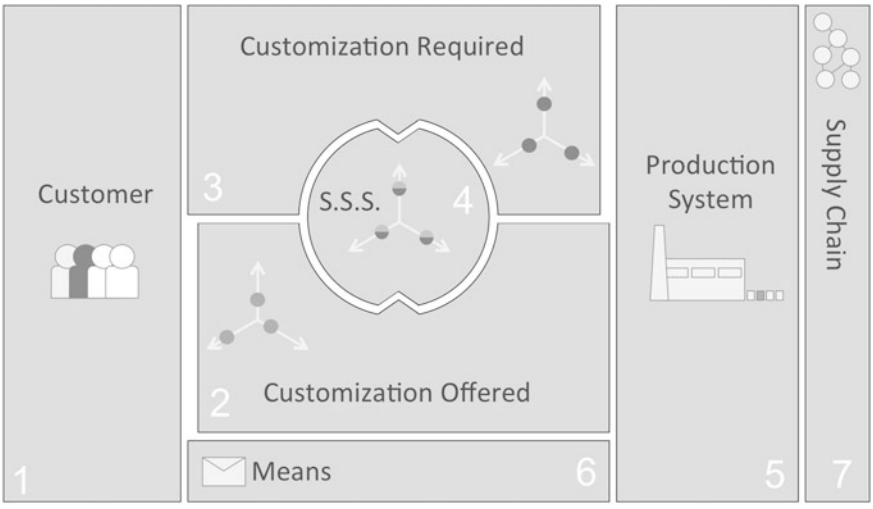

Fig. 2.4 The mass customization implementation template

facilitates discussion. In the following paragraphs we propose such a template (MCIT—Mass Customization Implementation Template), which allows to describe and to think through the MC options and implementation issues;
2. a set of questions supporting the entrepreneur in understanding the key elements to be considered for each block of the MCIT. Specific topics and challenges have to be faced for each building element while implementing Mass Customization. Answering to these will support in taking a step closer to the actual implementation of MC;
3. real-case examples providing actual answers that existing MC businesses gave to these questions.

The MCIT template is thus meant to describe different situations where any company can jump-in into the most appropriate block, to easily describe and explore different alternatives. There is not a correct starting block, or an exact time or logical sequence to walk through the blocks. Each MC implementation will have different genesis, needs, and paths: the template will support the implementer by providing inspiration and making the right questions, not to forget essential aspects. Examples taken from the literature are finally meant both to provide concrete responses and to suggest applicable implementation paths.

Block* 1—*CUSTOMER: Customers are at the core of any production paradigm, not just MC. Without customers, no production system may work for long. We have to carefully address the following questions, to pave the way for a sound MC business implementation:

What's the Target Market? This deals with the identification of a group of customers that we decide to aim toward. A well-defined target market is a key element to successful MC implementation. Different segmentation approaches may apply.

E.g., different segmentation dimensions can be taken into account in order to identify the target customers of an MC offer. Adopted elements are the same of traditional marketing approaches: age, sex, location, spending power, sector-specific categories,… It is important to notice that the relevance of the segmentation elements is usually different in traditional and MC businesses (attitude toward customization is often correlated with products contexts of application, but also with the spending power). In some cases, segmentation has allowed to define a path from pilot to large-scale MC applications. The **mi adidas** customization initiative (Seifert 2006) was structured in four sequential phases. Segmentation allowed to identify a promising market context where to test the pilot service (2001) on 300 customers from six European countries (geographical segmentation), all athletes (activity-related segmentation) interested in customizing soccer footwear (sector-specific element of segmentation). In phase 2 (late 2001), other segments were explored relaxing some of these constraints: not only athletes but any sportive customer, not only European, but also from U.S., not only soccer,