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ANALYSIS AND DESCRIPTION OF MASS CUSTOMIZATION AS A SYSTEM – A REVIEW

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RESUMO: A customização em massa é um termo cunhado há quase quatro décadas e, apesar da sua maturidade, o conceito ainda é controverso. A falta de homogeneidade da sua definição dificulta o avanço das pesquisas sobre o tema e sua adoção. Nesse sentido, o presente trabalho busca mapear as definições de customização em massa com uma clara divisão dos seus subtemas, a partir da sistematização das contribuições de autores de diferentes campos de conhecimento, dentre os quais Design e Arquitetura, que forneceram uma definição conceitual de customização em massa e seus aspectos internos. Em seguida, com base nas informações coletadas, utiliza-se o recurso gráfico do diagrama como ferramenta para análise e representação do conceito de customização em massa enquanto um sistema composto por diversos subsistemas conectados. O trabalho resulta em uma coleção de definições e um sistema de classificação que pode ser usado para análise e definições de trabalhos existentes e futuros.

PALAVRAS-CHAVE: customização em massa; sistema; classificação; análise

ABSTRACT: Mass customization is a term coined almost four decades ago, and despite its maturity, the concept is still controversial. The lack of its definition of homogeneity hinders the research progress on the subject and its adoption. Therefore, the present work seeks to map the definitions of mass customization with a clear division of its subtopics based on the contributions of authors from different fields of knowledge, including Design and Architecture, who provided a conceptual definition of mass customization and its internal aspects. Then, based on the information collected, the diagram's graphic feature is used to analyze and represent the concept of mass customization as a system composed of several connected subsystems. The work results in a collection of definitions and a classification system that researchers can use to analyze and define existing work and future contributions.

KEYWORDS: mass customization; system; classification; analysis

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Introduction

Mass customization (MC), a term coined by Davis (1987) almost four decades ago, has been extensively studied in the building sector as a housing strategy for approximately three decades (Avalone and Fettermann, 2020). Despite its long history, MC remains contentious, lacking a universally accepted definition and clear differentiation of its internal research subjects. This lack of consensus and the complex interfaces between these subtopics can slow the advancement of research in this area.

Therefore, this work aims to map the definitions of MC and the subthemes within its scope. The article reviews several literature contributions that provide a conceptual definition of MC and its internal aspects. We sought contributions from different disciplines, such as architecture, products, and business, so it was possible to avoid a biased view of the theme and map it from a traversal perspective. In sequence, we proposed a deeper analysis of the concept of MC and its unfolding in subthemes. This analysis occurs by understanding MC as a system composed of interdependent subsystems. This understanding is valuable because it enables the theme analysis through specific sub-themes and their interfaces within a network. As functions describe systems (MITCHELL, 2008), the actions toward a particular goal of the MC strategy delimit its subthemes.

We organized the work into the following sections: section 2 presents the methodology used in the literature review and the analysis of the subsystems; section 3 presents several definitions of MC and its internal subdivisions and proposes a proper definition of the concept based on the literature review; section 4 presents the analysis of MC as a system and description of its subsystem; and section 5 presents the conclusions.

Methods

We selected the papers in three stages: planning, development, and publication (KITCHENHAM, 2004). The identification of the documents started with titles familiar to the author due to previous research, and that served to define keywords.

Table 1 shows the grouping and combination of keywords. The databases chosen for the search were Scielo, Web of Science, and CAPES journal portal. We filtered the first selection based on title and abstract relevance analysis. Then, we selected and classified the titles based on predetermined criteria: title, abstract or summary alignment, duplicated articles, recognized author in the subject, and publication of the same author with similar dates or results.

Table 1: the combination of keywords used in the search strategy. Source: Authors.

OR		OR
Mass customization: Mass customization	AND	Elicitation; Data extraction; User requirements
		Project; Design; Technology; Method
		Production; Fabrication; Building systems; Building technologies
		Logistics; Supply Chain; Transportation; Information flow

For the system's description, we chose the diagram as a tool for representation and analysis. We understand that it is an appropriate tool for the study of systems since the diagram is "[...] an icon that makes intelligible the relations, especially spatial, between the parts that constitute an object" (MONTANER, 2017, p. 9) and that, moreover, "[...] does not exhaust attempts to reveal unexpected and unpredictable relationships" (MONTANER, 2017, p. 10). We adapted the graphic notation for the definition of systems introduced by Freeman and Newell (1971 apud MICTHELL, 2008).

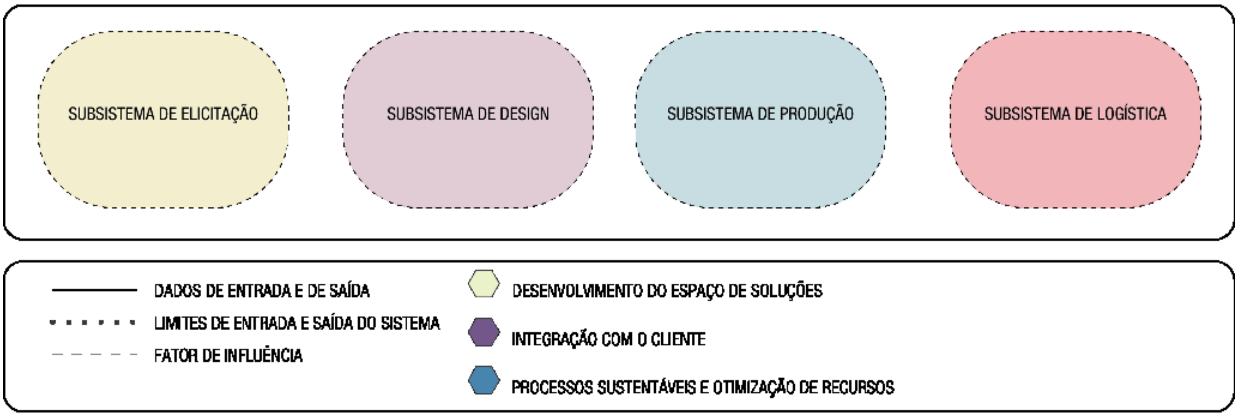

Figure 1: Graphics and symbols used in the analysis. Source: Authors.

Mass Customization Definitions

There are divergences within the literature on the definition of the term. Some close definitions with subtle differences proposed by relevant authors illustrate this divergence. Pine II (1993) defined it as the ability to develop, produce, and sell affordable goods and services with variety and customization so that anyone can find exactly what they want. Later, Gilmore and Pine II (1997) state that customization can occur after delivering the product to the end-user. In Zipkin's (2001) view, conditions related to monetary price are not strictly assigned, considering a business strategy based on a company's ability to offer tailored products or services. Salvador, Holan, and Piller (2009) also do not make cost specifications, defining a strategic mechanism through specific capabilities for a manufacturer's alignment with the end-user needs. Later, Piller (2019) attributes cost accessibility as the inherent property of MC. The author also states that customization can occur after product delivery and not only in the operational phases. Finally, Kolarevic and Duarte (2019, p.3) define it as "[...] contemporary business and marketing capacity that is aimed at meeting the unique needs of individual consumers."

Kaplan and Haenlein (2006) state that three questions underlie the main divergences around the concept. (1) Does MC apply only to products or services? (2) What is the value chain point where the end-user customizes their product? (3) Should customized goods' production and sale price be close to standard mass-produced goods? After answering the three questions mentioned above, Kaplan and Haenlein (2006) propose two definitions for MC: working and visionary. The usefulness of the visionary definition lies in serving as a parameter for the continuous improvement of the company's operations. Thus, MC is described as:

Working definition — a strategy that adds value through consumer and manufacturer interaction during the operational stages of manufacturing and assembly to create customized products such as production costs and monetary value similar to mass-produced goods. (KAPLAN e HAENLEIN, 2006, p.176)

Visionary definition — a strategy that adds value through consumer and manufacturer interaction during the operational design stage to create customized products, following a hybrid approach that combines cost leadership and differentiation. (KAPLAN e HAENLEIN, 2006, p.177)

It is possible to observe that for Kaplan and Haenlein (2006), mass customization (1) applies only to products and not services, (2) customization only happens during the operational phases of the product, that is, during the Design (visionary), or manufacture, or assembly (working), and finally, (3) the monetary price and the cost of mass custom products should be similar to that of standardized mass products.

Processes and capacities

According to Pine II, Victor, and Boynton (1993), for a mass customization strategy to be successful, the production cycle must be based on a dynamic network between relatively autonomous operational units. Its effectiveness depends on the communication capacity between these units being instantaneous, economically viable, flexible, consistent, and compliant. After Pine II, Victor, and Boynton (1993), other authors proposed an explicit definition and classification of the units and capacities that describe MC as a system. Hart (1995) defines four necessary groups for an MC strategy: (1) a marketing team dedicated to formulating communication strategies with potential users and end-users for the extraction of their needs and sacrifices (2) a design team capable of creating a scope of possible solutions based on the data extracted from potential users and convert the needs of end-users into products; (3) a production team responsible for manufacturing and assembly; (4) a distribution team responsible for the supplies and delivery of the product. The capabilities necessary for the strategy's success are the effective communication between the marketing and design teams for the definition of the scope of solutions, the interactivity between the design team with the end-user and the production team for product development based on the needs and evaluation of the user and, finally, the alignment between production and logistics.

For Zipkin (2001), although the author does not formally define responsible teams or groups, three basic capabilities depend on the connection between some types of processes. The first, called elicitation, depends on the communication between the data extracted from the end-user, conversion into a product, and capturing its reaction. The second, defined as flexible processes, involves the materiality capabilities of the generated product. In other words, the communication between the product design and the company's production system consists of manufacturing and assembly. The third capacity, defined as logistics, concerns the entire flow of information between the previous steps and the product for the supply chain's elaboration and distribution.

The third classification, elaborated by Salvador, Holan, and Piller (2009), has been commonly accepted in the literature and used directly or indirectly by other authors. The authors define the first capability as developing the universe of solutions. It depends on capturing the end-user needs and sacrifices to specify which product components will be customized and their level of customization. The second capacity, a robust process project, involves optimizing the company's resources to sustainably materialize products generated from the universe of solutions through flexible but stable production and logistics processes. The authors classify the latter capability as choice navigation. It involves efficient interaction between the company and the end-users for product formulation based on their needs, with real-time evaluation and manufacturing information for production generation.

Finally, Duarte (2019) defines MC as a system comprising three main parts. The first is a design subsystem capable of capturing and using external end-user data to generate design solutions—and the second is a production subsystem capable of materializing the generated project. The last is a computer subsystem that processes context data, communicating and developing unique solutions fast enough to meet mass demands.

For Duarte (2019), the activities within the design subsystem depend on extracting contextual data. Therefore, an internal subsystem must be capable of removing this data. Duarte (2019) does not mention activities related to logistics.

Figure 2 shows the analysis of the capacities defined by the cited authors, comparing them with the definition given by Pine II, Victor, and Boynton (1993) and with subsystems defined based on the descriptions of the processes. In most cases, the allocation of the capabilities is at the interface between these groups of processes. The functional connections between these subsystems comply with what Pine II, Victor, and Boynton (1993) described, as well as the description of the system and function proposed by Mitchell (2008). Hence, based on this analysis, we define MC as a system composed of four semiautonomous subsystems. By describing them through their functionalities, we illustrate that the first subsystem must extract the data of potential users and other contextual information. The second subsystem must be able to develop product designs based on user needs and assessments. The third subsystem must be able to materialize the product. The fourth subsystem must be able to supply the manufacturing and distribute the product to the end-user. In addition to the internal functions of each subsystem, the success of the system as a whole lies in three capabilities related to the functional connections of the subsystems to each other and with the end-user: (1) the connection between the data extraction subsystem and the design subsystem for the production of a universe of solutions; (2) the interaction between the design subsystem with the end-user for the consideration of their needs and their evaluation; (3) the stability between the design, production, and logistics system. The configuration and results of the system will vary depending on the following: the characteristics of the product and its intrinsic qualities, the point at which interaction with the end-user occurs, and the means of production used, such as organizational technologies and methods. Next, the subsystems will be analyzed in greater depth so that the internal structures of each one, the interface between them, and possible variations can be understood.

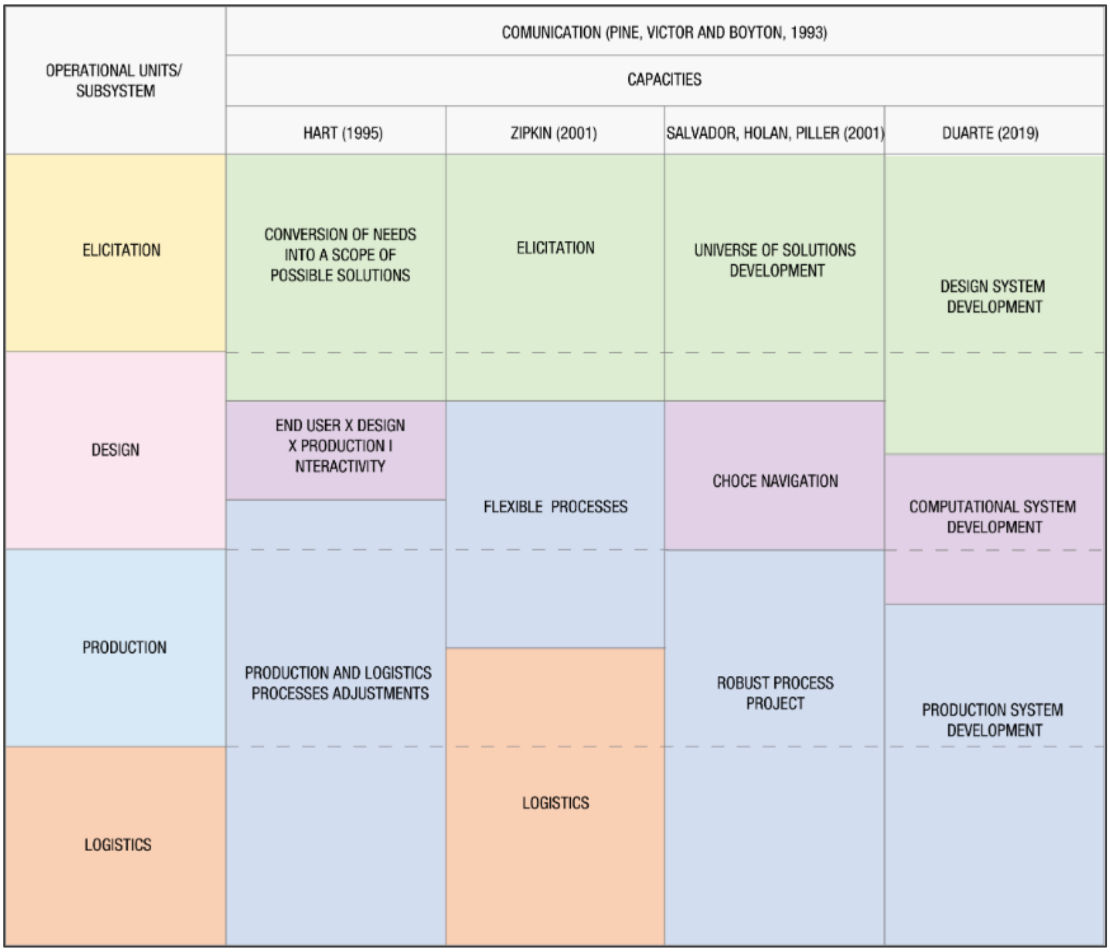

Figure 2: Schematic representation of the comparison of capabilities for MC (HART, 1995; ZIPKIN, 2001; SALVADOR, HOLAN e PILLER, 2009; DUARTE, 2019), with the identified subsystems and the terms used by Pine II, Victor, and Boynton (1993).

Analysis and Description of the Subsystems

Elicitation

According to Piller (2019), one of the main challenges of MC is identifying users' distinctive needs. These are the product attributes where there is a greater need for customization. Therefore, the elicitation system aims to communicate with the group of potential users to identify their needs and desires, besides being able to read contextual data necessary for design formulation. The output data of this subsystem will serve as input to the design subsystem. (DUARTE, 2019; PINE II, 2019)

This subsystem may have different configurations according to the method and research technique adopted to identify and analyze this data. Piller (2019) states that conventional data extraction and analysis techniques, such as interviews and questionnaires, can be used. However, according to the author, these are not the most suitable for MC, as they identify homogeneous characteristics rather than the heterogeneity necessary for customization. Consequently, the mere extraction of objective data may not understand the complexity required for formulating the architectural product and its variations. This system has different techniques and technologies to perform its complex function, ranging from manual data collection and analysis of face-to-face activities to physical models using interactive platforms and artificial intelligence (PILLER, 2019; AVALONE e FETTERMANN, 2020). Regardless of method and technique, the subsystem must always be able to extract, read, and convert external data into useful information to be interpreted by the design subsystem.

Design

According to Duarte (2019), the design subsystem must be able to generate the project using the data received from the elicitation subsystem. It may have different configurations according to the design method and technology employed. Despite its configuration, unlike standardized products, the design process must be explicit in all cases, as the logic behind design decisions must be known and systematized so designers can replicate it in different contexts. As Piller (2019) states, MC depends on a flexible but stable process that generates various results sustainably, unlike the traditional model where each new project is associated with a new implicit process, with a greater or lesser degree of variation.

In this case, it makes sense for the design subsystem to work from a computational perspective that, according to Oxman (2006, p.243), explains cognitive processes based on the architect's ability to "[...] formulate, represent, implement and interact with explicit and well-formulated representations of knowledge." From this, we can draw two conclusions: first, the correct functioning of the MC design subsystem should be suited to a digital context. Second, if the design subsystem depends on computational processes and digital technologies, its input data, generated by the previous subsystem, must be objective data that can be quantified and computed.

Oxman (2006) and Duarte (2019) identified five internal components in the design subsystem. Oxman (2006) defines four necessary components: representation, generation, evaluation, and performance, and Duarte (2019) adds a formulation component. The following are the functions of each of them:

1. **Formulation** (Duarte, 2019): Read, interpret, and convert the needs of potential users into project needs to formulate a universe of possible solutions based on a system of rules.
2. **Generation**: generate a universe of design solutions, with rules and restrictions responsible for setting forms and material characteristics of the generated results.
3. **Evaluation**: analyzes and compares the performance and adequacy of design alternatives generated according to the end user's needs.
4. **Performance**: seek and find the most appropriate solution to the end user's needs based on the programmatic and contextual evaluation.
5. **Representation**: represents the solutions generated in its most varied aspects (form, space, monetary value of production sale, and others).

The subsystem may use different generation approaches according to the operating method and technology. These factors will change the interaction settings between the abovementioned subsystems, defining the design subsystem's configuration. It is not part of the scope of this work to present an in-depth discussion about possible design approaches. However, the generative, formative, and performance-based models are worth mentioning, as Oxman (2006) defined. The generative model is a computational form generation mechanism (OXMAN, 2006). For example, shape grammar, evolutionary algorithms, and L-systems (CAETANO, SANTOS e LEITÃO, 2019). The formative model is a mechanism based on the logic of the design process for creating shapes by interaction and operation with a logical and non-deterministic formal generation environment from digital techniques (OXMAN, 2006). The most common example is parametric design systems, an approximation of Design characterized using parameters to describe groups of design results (CAETANO, SANTOS e LEITÃO, 2019). Performance-based models are similar to generative models but based on generating solutions according to the desired performance and behavior (OXMAN, 2006). Finally, some composite models associate all the functions of the models mentioned above.

Production

The production subsystem materializes the generated design solution (COSTA, DUARTE e BÁRTOLO, 2017; DUARTE, 2019). In the case of the production process, the main factor influencing its configuration is the technology employed (COSTA, DUARTE e BÁRTOLO, 2017, p. 957; DUARTE, 2019, p. 131), followed by the operational method allowed by such technology. In addition, it will also be responsible for defining the interface between the production and design subsystems, where production can influence the design process or even total dependence between both.

We identified three technologies: (1) artisanal production, (2) mechanical industrial production, and (3) digital industrial production. The first allows high flexibility in production but with low stability and performance. It is not the most suitable for MC (DUARTE, 2019), except in cases where cultural aspects favor its choices, such as when there are traditions of community engagement and the use of local materials in the execution of the MC product (KOLAREVIC e DUARTE, 2019). The second technology is associated with a modular production strategy, which ensures flexibility and stability while having the advantage of the economy of scale (SMITH, 2010; PILLER, 2019). The third technology is controlled by digital information from a computational model, allowing high flexibility and efficiency. The manufacturer can produce objects using techniques that influence the subsystem's configuration, classified as additive, subtractive, and conformation (PUPO, CELANI, and DUARTE, 2009).

Manual artisanal production does not directly influence the interface between the design and production subsystems due to the linear processes associated with this type of production (SMITH, 2010). On the other hand, in mechanical industrial output, the correct synchrony of its horizontal processes depends on coordination or compatibilization between design and production. Therefore, the design subsystem needs to receive direct input data from the production subsystems, which will generate design constraints. In digital industrial production, manufacturing occurs directly from the computational model; thus, design and manufacturing are interdependent, and the manufacturer cannot treat them separately. Hence, the connection between the systems is so close that, eventually, one subsystem overlaps. (PAOLINI, KOLLMANNSBERGER e RANK, 2019). Finally, the production subsystem will consist of fabrication, assembly, and occasionally subassembly components, with different configurations according to the technology, method, and location.

Logistic

Logistics is the process required to supply and store raw materials, and information flows through the production process, packaging, storage, and distribution (BARMAN and CANIZARES, 2015). Therefore, the logistics subsystem is responsible for correctly functioning the supply chain and distribution.

According to Piller (2019), two factors increase the cost of producing customized goods: (1) increased complexity and (2) increased uncertainty of business operation. On the first factor, increased variability requires a more significant number of parts, processes, suppliers, and distribution channels. In other words, a more complex flow of information to manage throughout the entire production chain. In the second case, the increase in uncertainty occurs due to surprises arising from the different demands of the end-user, the point of the production chain at which it will happen, and its effect on the cost of manufacturing and distribution (PILLER, 2019).

Therefore, Piller (2019) states that two strategies can be applied to increase the certainty and stability of production. The first is the implementation of computational technologies of production automation that allow a high level of variability with low human interference in production. However, in some areas, such as the AEC industry, such technologies have yet to reach their full potential or are not economically viable (KOLAREVIC e DUARTE, 2019). The other way is manipulating the insertion and influence of the end-user on the supply chain. It can delay the end user's involvement to a later final phase in industrialized production. In this case, the manufacturer can stabilize the supplies and achieve savings of scale from storing preassembled parts and, based on specific demands, form a particular product to be distributed to the end-user (SMITH, 2019).

In this context, the logistics subsystem will most often present three components. The first, supply, refers to the raw material needed for production. The second is storage, which will appear when there is a stock of preassembled elements to supply the final assembly. And finally, distribution to the end-user. However, storage may not occur in some cases, as products fabricated with additive manufacturing technology are delivered directly to the end-user. The distribution subsystem may not appear when production occurs at the end user's address. For example, this is the case of buildings produced in loco.

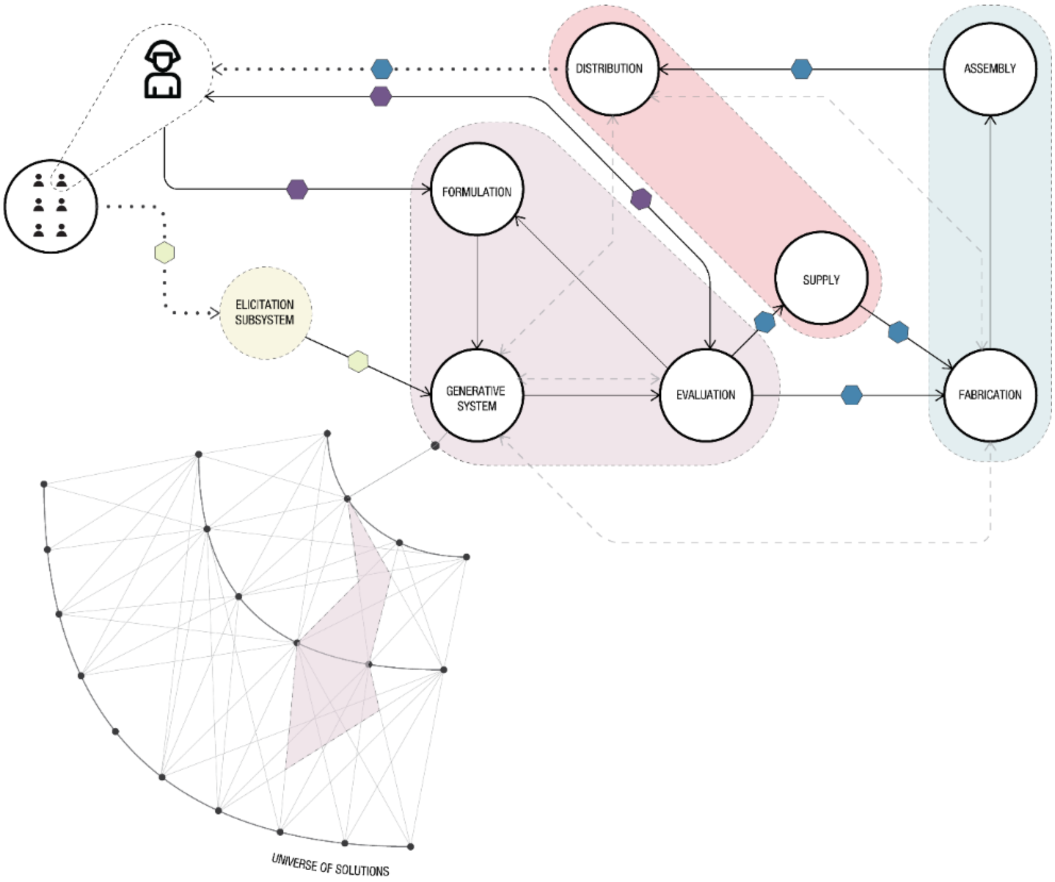

Figure 3: Representation of a system for mass-customized production of a generic product. Source: Authors

Conclusions

This work aimed to deepen the knowledge about MC systems by analyzing and describing their definitions and functions as a system. It was possible to identify that MC depends on a system composed of four semiautonomous subsystems: elicitation, design, production, and logistics. In addition to the subsystems' internal functions, the system's success lies in three capabilities specific to the functional connections of the subsystems to each other and with the user.

This classification contributes to formally defining the subthemes of MC, thus allowing the analysis of future studies on the subject from a clear perspective according to the subsystems addressed in the research and their respective interfaces. It also contributes to a classification system that helps to allocate existing and future research on the theme.

It was possible to realize that there is no single model for MC. However, there are essential guidelines to consider when elaborating a specific strategy according to the singularities of each case, where its choices will configure a single system with particular components and internal relationships. It was possible to notice that detecting the participants' idiosyncrasy in MC is more critical than detecting their homogeneities. Finally, we perceived that there is no hierarchical relationship between the subsystems but rather a network of overlaps and functional connections, where the success of the MC will depend on the quality of communication between its subsystems.

This research does not present a pragmatic analysis of actual case studies or scientific papers and their respective classifications according to the subsystems described. Therefore, we recommend that future works use the classification to analyze previous scientific and industry works. We also encourage new and more specific conceptual reviews of the described subsystems to further enrich our understanding of MC systems.

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References

AVALONE, Marianne C.; FETTERMANN, Diego D. C. **Customização em massa de edifícios residenciais:** uma revisão de literatura. Desafios da Engenharia de Produção no Contexto da Indústria 4.0. Bauru, SP, Brasil: XXVI Simpósio de Engenharia de Produção. 2019. p. 1-13.

AVALONE, Marianne C.; FETTERMANN, Diego D. C. Demandas de customização em edifícios residenciais no Brasil: uma análise de agrupamentos empírico-qualitativa com base no sistema Skeleton/Infill. **Ambiente construído**, Porto Alegre, v. 20, n. 2, p. 489-503, abril-junho 2020. ISSN 1678-8621.

BARMAN, Samir; CANIZARES, Alejandra E. A Survey of Mass Customization in Practice. **International Journal of Supply Chain Management**, v. 4, n. 1, p. 65-72, março 2015.

CAETANO, Inês; SANTOS, Luís; LEITÃO, Antonio. Computational Design in Architecture: Defining parametric, generative, and algorithmic design. **Frontiers of Architectural Research**, v. 12, n. 8, p. 2-14, 2019.

COSTA, Eduardo C. E.; DUARTE, José P.; BÁRTOLO, Paulo. A Review of Additive Manufacturing for Ceramic Production. **Rapid Prototyping Journal**, v. 23, n. 5, p. 954-963, Agosto 2017.

DAVIS, S. M. **Future Perfect**. Boston: Addison Wesley, 1987.

DUARTE, José P. Customizing mass housing: Toward a formalized approach. In: KOLAREVIC, Branko; DUARTE, José P. **Mass customization and design democratization**. Abingdon: Routledge, 2019. Cap. 11, p. 130-142.

FETTERMANN, D. C.; TORTORELLA, G. L.; TABOADA, M. Mass Customization Process in Companies from the Housing Sector in Brazil. In: ROBLES, Guillermo C.; ALCARAZ, Jorge L. G.; HERNÁNDEZ, Giner A. **Managing Innovation in Highly Restrictive Environments**. Heidelberg: Springer International Publishing, 2019. Cap. 5, p. 99-118.

HART, Christopher W. L. Mass customization: conceptual underpinnings, opportunities, and limits. **International Journal of Service Industry Management**, West Yorkshire, v. 6, n. 2, p. 36-45, 1995.

KAPLAN, Andreas M.; HAENLEIN, Michael. Toward a Parsimonious Definition of Traditional and Electronic. **The journal of product innovation management**, 2006. 168-181.

KITCHENHAM, Barbara. **Procedures for Performing Systematic Reviews**. Keele University. Staffordshire, p. 33. 2004.

KOLAREVIC, Branko; DUARTE, José P. From massive to mass customization and design democratization. In: KOLAREVIC, Branko; DUARTE, José P. **Mass customization and design democratization.** Abington: Routledge, 2019. Cap. 1, p. 1-12.

LARSEN, Maria S. S., et al. **Mass Customization in the House Building Industry**: Literature Review and Research Directions. Frontiers in Built Environment, 5, Outubro 2019. 1-12.

MITCHELL, William J. **A Lógica da Arquitetura:** projeto, computaação e cognicação. Tradução de Maria Gabriela Celani. Campina: Editora da Unicamp, 2008.

MONTANER, Josep M. **Do diagrama às experiências, rumo a uma arquitetura de ação**. Tradução de Maria Luisa de Abreu Lima Paz. São Paulo: Gustavo Gili, 2017.

NIELSEN, Kjeld, et al. Utilization of Mass Customization in the Construction and Building Industry. **Managing Complexity:** Proceedings of the 8th World Conference on Mass Customization, Personalization, and Co-Creation (MCPC 2015). Montreal: Springer. 2016. p. 115 - 125.

OXMAN, Rivka. Theory and Design in the First Digital Age. **Design Studies**, v. 27, n. 3, p. 229-265, Janeiro 2006.

PAOLINI, Alexander; KOLLMANNSBERGER, Stefan; RANK, Ernst. Additive manufacturing in construction: A review on processes, applications, and digital planning methods. **Additive Manufacturing**, v. 30, p. 1-13, 2019.

PILLER, Frank. T. Creating a sustainable mass customization business model. In: KOLAREVIC, Branko; DUARTE, José P. **Mass customization and design democratization**. Abington: Routledge, 2019. Cap. 3, p. 30 - 40.

PINE II, B. J. Customering: the next stage in the shift to mass customization. In: KOLAREVIC, Branko; DUARTE, José P. **Mass customization and design democratization**. Abington: Routledge, 2019. Cap. 2, p. 13-28.

PINE II, B. J.; VICTOR, B.; BOYNTON, **A. Makin Mass Customization Work. Harvard Business Review**, Boston, p. 107-116, Setembro 1993. ISSN 93509.

PIROOZFAR, Amir E.; LARSEN, Olga P. Customizing Building Envelopes: Retrospects and Prospects of Customization in the Building Industry. In: PILLER, Frank T.; TSENG, Mitchell. **Handbook of Research in Mass Customization and Personalization**. [S.l.]: World Scientific Publishing Company, v. I, 2009. Cap. 3, p. 869-891.

PUPO, Regiane; CELANI, Maria G.; DUARTE, José P. Digital materialization for architecture: definitions and techniques. **Proceedings of the 13th Congress of the Iberoamerican Society of Digital Graphics**. São Paulo: SIGraDi 2009. 2009. p. 439-442.

SALVADOR, Fabrizio; HOLAN, Pablo M. D.; PILLER, Frank. **Cracking the code of mass customization. MIT Sloan Management Review**, Cambridge, 2009. 70-79.

SMITH, Ryan E. **Prefab Architecture**: a guide to modular design and construction. Nova Jersey: John Wiley & Sons, 2010.

SMITH, Ryan E. Mass Prefabrication: Investigating the Relationship Between Prefabrication and Mass Customization in Architecture. In: KOLAREVIC, Branko; DUARTE, José P. **Mass customization, and Design Democratization**. Nova York: Routledge, 2019. Cap. 14, p. 175 -184.

TAUBE, Jaqueline; HIROTA, Ercília H. Customização em massa no processo de provisão de Habitações de Interesse Social: um estudo de caso. **Ambiente Construído**, Porto Alegre, v. 17, n. 4, p. 253-268, outubro-dezembro 2017. ISSN 1678-8621.

ZIPKIN, Paul. **The Limits of Mass Customization**. MIT Sloan Management Review, Cambridge, 2001. 80-87.