Universidade Federal Do Rio Grande Do Sul
Escola de Engenharia
Programa de Pós-Graduação em Engenharia Civil: Construção e Infraestrutura

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A METHOD FOR CAPTURING CUSTOMERS' PREFERENCES FOR HOUSING CUSTOMISATION

Porto Alegre
2021

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Thesis presented to the Postgraduate Program in Civil Engineering: Construction and Infrastructure at Universidade Federal do Rio Grande do Sul, Brasil, in Fulfilment of the Requirements for the Doctoral Degree in Engineering

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This Doctoral Thesis was assessed regarding the requirements to obtain the title of DOCTOR IN ENGINEERING, research area Construction, and its final form was approved by the Supervisor and the Postgraduate Program in Civil Engineering: Contruction and Infrastructure from Universidade Federal do Rio Grande do Sul.

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To my beloved family, Guido, Marilene, Matheus, Marceli,
Cristiano, and Summer.

ACKNOWLEDGEMENTS

Firstly, I would like to thank the Coordination for Improvement of Higher Education Personnel (CAPES) for sponsoring this investigation, and ERASMUS Plus, for financially supporting my research exchange at the University of Huddersfield.

I would like to express my deepest gratitude to Professor Carlos Formoso, my supervisor, for his support, patience, and valuable discussions to elevate the quality of the research, and wisdom shared during these years. My most profound appreciation to Professor Marcia Echeveste, my co-supervisor, for sharing excellent knowledge in statistics, engagement in the research, and encouraging me during this process. I would also like to thank Professor Patricia Tzortzopoulos, for supervising my work during the research exchange at the University of Huddersfield, for welcoming me with open arms, for all the support and guidance.

My acknowledgements to my dear colleagues and friends from the Building Innovation Research Unit (NORIE, Brazil). A special thanks for Daniela Dietz Viana, Juliana Parise Baldaluf, Lucila Sommer, Guillermina Peñaloza, Raquel Reck, Manoela Conte, Giulie Baldissera, Fernanda Brandalise, Fernanda Bataglin, Jordana Bazan e Natalia Ransolin, for the research discussions, friendship and company for “coffee and therapy sessions”. Thank you to Luciana Gheller Amorim, for the collaboration in the initial year of the empirical study in company P. My deepest gratitude to Manoela Conte, for the insightful discussions about mass customization and the development of empirical studies, and friendship. Thanks to my friends, research team, and “foreign family” in Huddersfield, UK: Juliana, Eduardo and Marina Baldauf, João Soliman Junior, Barbara Pedó, Josana Wesz, Tecia Duarte, Manuela Fazzan, Danilo Gomes, Yreilyn Cartagena. In addition, thank you to Cibeli Leão and Érica Dall'Asta, for their sincere friendship and support since our master degree.

I would like to thank Company P for two years of research collaboration, especially the company representatives who contributed in the development of the empirical study. My special appreciation for Karine Hoffmann and the architects from the customisation team who provided priceless contributions for the research, for their willingness to discuss and motivation to implement change.

I am deeply greatful to Eduardo Pricladnitzki and Enio Pricladnitzki from Company W, for their vote of confidence in the research team and openness in showing the company processes and vision and especially willingness to discuss to develop solutions further. Also, my sincere gratitude to Mariana Verçoza, brand and marketing consultant from Bcode, who was an active representative of Company W in this study, for her collaboration and contributions to the discussions. Also, my acknowledgements to other representatives and partners that colaborated in the research.

In addition, my most profund gratitude to my parents, Guido e Marilene, for their unconditional love and support, always inspiring me to improve as a person and a professional. Thanks to my brother and sister-in-law, Matheus e Marceli, for the incentive and happy distractions. Finally, my deepest appreciation to my loves, Cristiano and Summer, for the love, patience, unwavering support and belief in me and my work.

“Isn’t it odd, we can only see our outsides, but nearly everything happens on the inside.”

(Charlie Mackesy)

ABSTRACT

HENTSCHKE, C. dos S. **A method for capturing customers preferences for housing customisation.** 2021. Thesis (Doctor of Philosophy in Civil Engineering) – Programa de Pós-Graduaçãp em Engenharia Civil: Construção e Infraestrutura, Escola de Engenharia, Universidade Federal do Rio Grande do Sul, Porto Alegre, 2021.

The housebuilding sector has used mass production systems and reduced portfolios for many decades in different countries, countering the constant changes in society, resulting in neglecting the increasing diversity of customers' requirements. Housebuilding companies should be able to meet this requirement's diversity by offering a higher product variety and at the same time maintaining costs within market expectations. Mass customisation strategies have been presented as efficient alternatives to keep the balance between fulfilling clients' specific needs and maintaining reasonable prices in housing by focusing on value generation. Moreover, there are limited ways of increasing value generation in housing considering its trade-off with product cost, emphasising the need for the delimitation of a set of options (i.e.: solution space) adequate to customers' preferences. Some research opportunities highlighted in the literature for adopting mass customisation in housing include solution space clear definition and the need for methods to explore the value perceived in product alternatives and reduce trade-offs between preferences and choice complexity. Accordingly, the main aim of this investigation is to propose a method for capturing customers' preferencess and supporting customer integration in mass customisation strategies for housing. The design science approach was used as methodological underpinning for building the solution in this investigation. This thesis was structured in three academic papers. The first paper provides an overview of the available practices in house building and focuses on developing a framework of customer integration and core decision categories that support the definition of mass customisation strategies. In the second paper, a method for identifying customers' preferences and support solution space definition was proposed, based on preference modelling and willingness-to-pay approaches regarding customer value and its balance with operations costs. In paper 3, another method is presented by adapting menu-based choice for housing and its implementation in an empirical study. The main contributions of this thesis include the method for capturing customers' preferences, a framework of decision categories, and approaches for modelling customers willingness-to-pay for customised housing.

Keywords: Mass Customisation. Solution Space. Customers. Stated Preference. Willingness-to-Pay. Housing

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1 INTRODUCTION

1.1 RESEARCH CONTEXT

Over the last decades, society is evolving rapidly, resulting in different lifestyles and a growing diversity of housing customer needs and expectations (JANSEN, 2014, 2020). This means that customers are becoming more demanding, and making their housing choices based on their preferences, economic and social contexts (JANSEN, 2014; JUN et al., 2020; OLANREWAJU; WONG, 2019). By contrast, many housing developers still adopt the mass production paradigm as a key strategy for delivering affordable housing, especially in developing countries, like Brazil, Mexico and Ecuador (MARTINEZ; TOMMELEIN; ALVEAR, 2017; NOGUCHI; HERNÁNDEZ-VELASCO, 2005). By using traditional strategies for cost reduction and a standard product, the sector neglects the changing lifestyles and different household profiles, resulting in requirements not being fulfilled (FORMOSO, 2015; KOWALTOWSKI; GRANJA, 2011; NOGUCHI; HERNÁNDEZ-VELASCO, 2005), making value generation ineffective in this sector (BONATTO; MIRON; FORMOSO, 2011). The frustration with housing units motivates dwellers to make several changes after occupation (FORMOSO; LEITE; MIRON, 2011; HENTSCHKE, 2014; OLANREWAJU; WONG, 2019).

According to Jansen (2014) and Jun et al. (2020), housing developments must be based on both customers preferences and project constraints (e.g. price, market, regulations). Nevertheless, achieving different stakeholders' expectations and considering the trade-offs related to product cost is challenging (BONATTO; MIRON; FORMOSO, 2011; KOWALTOWSKI; GRANJA, 2011). Previous research, such as Leite (2005) and Noguchi and Hernández-Velasco (2005), suggest alternative ways for reducing costs, such as using standardised components, industrialised construction systems, strategies for lead time reduction and application of Mass Customization (MC). MC is a business strategy that aims to offer products that fulfil customers' specific requirements, potentially adding value, through flexible process and structure, with costs and delivery time similar to mass production (Hart, 1995; Jiao, Ma, & Tseng, 2003; Pine, 1993; Fogliatto, da Silveira, & Borenstein, 2012).

The MC concept was born in manufacturing, and several successful application examples have been reported in the literature (KUMAR; GATTOUFI; REISMAN, 2007; PILLER, 2007; SUZIĆ et al., 2018). Although MC has been a success in different sectors, several authors consider that this strategy still is challenging to be implemented in manufacturing due to context particularities (FETTERMANN; ECHEVESTE, 2014; PILLER; MÜLLER, 2004; SUZIĆ et al., 2018). Piller, Moeslein, & Stotko (2004) argue that using the concept of value creation in different production systems and strategies, such as agile, lean and MC, has the common goal of increasing cost-effectiveness and ability to react to heterogeneous and constantly changing market demands. However, even implementing those alternative strategies to increase value generation can be challenging due to limited market and requirements' understanding, technology availability and production system constraints (FETTERMANN; ECHEVESTE, 2014; SALVADOR; HOLAN; PILLER, 2009; WIKBERG; OLOFSSON; EKHOLM, 2014). Therefore, understanding and considering customers' requirements in developing customised products is essential for the success of the MC strategy in manufacturing (FOGLIATTO; DA SILVEIRA, 2008; FRANKE; PILLER, 2004; HART, 1995; OGAWA; PILLER, 2006).

The application of MC has been suggested as an alternative for balance fulfilling clients' specific needs and maintaining controlled costs in housing (NOGUCHI; HERNÁNDEZ-VELASCO, 2005; ROCHA, 2011; SCHOENWITZ; NAIM; POTTER, 2012; SHIN et al., 2008). This strategy has been applied in housing production in different countries such as Brazil (ROCHA, 2011; TILLMANN, 2008), Mexico (NOGUCHI; HERNÁNDEZ-VELASCO, 2005), Ecuador (MARTINEZ; TOMMELEIN; ALVEAR, 2017), Germany (SCHOENWITZ et al., 2017), UK (BARLOW et al., 2003), Korea (SHIN et al., 2008) and Japan (LINNER; BOCK, 2012). Its adoption in housing can bring several benefits, such as increasing dwellers' degree of satisfaction (FRUTOS; BORENSTEIN, 2004; LEE et al., 2018; MARTINEZ; TOMMELEIN; ALVEAR, 2017); increasing market share (SCHOENWITZ et al., 2017); establishing long-term customer relationship and improving loyalty (BARLOW; OZAKI, 2003; KAUR SAHI; SEHGAL; SHARMA, 2017); and creating competitive advantage (SHIN et al., 2008). Additionally, some studies have suggested that customers are willing to pay a premium price in order to obtain a customised product that better fulfils their needs instead of purchasing a standard product (FETTERMANN; TORTORELLA; TABOADA, 2019; FRANKE; HADER, 2014; LARSEN et al., 2019).

The main challenges to housebuilders to apply MC are capturing customers' requirements (BARLOW; OZAKI, 2003; FETTERMANN; TORTORELLA; TABOADA, 2019; FORMOSO, 2015; MARTINEZ; TOMMELEIN; ALVEAR, 2017) and keeping the balance between offering variety and maintaining housing affordability (MARTINEZ; TOMMELEIN; ALVEAR, 2017). Additionally, MC in housing can be bounded by the regulatory and funding boundaries (BARLOW; OZAKI, 2003; FORMOSO, 2015), additional costs and extending construction time (MARTINEZ; TOMMELEIN; ALVEAR, 2017; SHIN et al., 2008), and use of integral product architecture and structural restrictions (FORMOSO, 2015).

When considering the increasing product variety, companies should be able to manage additional costs, keeping benefits similar to mass production, and maintaining a level of competitive advantage (FETTERMANN; TORTORELLA; TABOADA, 2019; MARTINEZ; TOMMELEIN; ALVEAR, 2017; SCHOENWITZ et al., 2017). With that aim, companies should plan their processes and design their MC strategies effectively, considering their target market and most value-adding product attributes for customers (FETTERMANN; TORTORELLA; TABOADA, 2019).

Customer integration is often achieved during the product configuration and design phases, but its extent depends on the level of customisation[1] offered, varying from a simple configuration of predefined options, to genuine co-design (PILLER; MOESLEIN; STOTKO, 2004). It initially relies on companies´ abilities to identify market segments and explore customers' needs and preferences to translate these trends into requirements and product specifications that support the development of customised goods (FOGLIATTO; DA SILVEIRA; BORENSTEIN, 2012; FRUTOS; BORENSTEIN, 2004; PILLER; MOESLEIN; STOTKO, 2004). Therefore, in this

[1] The level of customization or taxonomies of customization refer to the strategy that companies adopt for satisfying different markets through the value chain (FOGLIATTO; DA SILVEIRA; BORENSTEIN, 2012), and it is closely related to the customer order decoupling point (CODP).

investigation, the definition of customer integration includes different types of customer-company interactions enabled by different practices such as modular design and configurators (Kummar et al., 2008) and capturing customers preferences and needs to define such interactions and practices.

Furthermore, customer involvement in new product development (NPD) is critical to MC adoption and can also be regarded as a value-adding source and cost-saving potential, so-called "economies of integration" (PILLER; MOESLEIN; STOTKO, 2004). According to those authors, besides the possibility of charging premium prices, the economies of integration enables companies to acquire deeper market knowledge and enhance value generation, reducing waste along the value chain and potentially identifying sources and opportunities to counter-balance MC additional costs.

Information about customers' preferences, confronted to customisation costs and customers' willingness to pay, can be used for the definition of the solution space, as it involves establishing the connection between requirements and customisable attributes so that viable products can be proposed (PILLER; MOESLEIN; STOTKO, 2004; SALVADOR; HOLAN; PILLER, 2009). The solution space is a set of customisation units[2] and rules for combining them to be offered to customers, which is crucial to define product variants in a MC strategy (ROCHA, 2011; SALVADOR; HOLAN; PILLER, 2009). Some authors (FERGUSON; OLEWNIK; CORMIER, 2014; PILLER, 2007; VON HIPPEL, 1998) argue that MC's economic feasibility depends on a clear solution space definition by establishing limits within production capabilities and a range of product alternatives from which customers can choose according to their preferences. Furthermore, the solution space's definition involves a series of decisions, which should balance the variety of customisation units for the customers, based on their needs and the need to minimise operational costs (FOGLIATTO; DA SILVEIRA, 2008; SCHOENWITZ; NAIM; POTTER, 2012).

Companies should understand what generates value to customers to support the solution space definition and offer the customised product, according to economic limitations, to increase perceived value (FERGUSON; OLEWNIK; CORMIER, 2014; HART, 1995; PILLER, 2004). Moreover, a large number of options can confuse and overwhelm customers, creating the so-called "burden of choice" and leading to a postponement in purchase decisions (HUFFMAN; KAHN,

[2] The customization units are the customizable attributes of the product and their range of options to be choose by the customers (ROCHA,2011)

1998; SALVADOR; HOLAN; PILLER, 2009; SCHOENWITZ et al., 2017). Thus, companies should reduce choice complexity and guide customers to define products that better suit their needs (PILLER; MOESLEIN; STOTKO, 2004; SALVADOR; HOLAN; PILLER, 2009), for example, by using choice menus[3]. They are transitional devices to guide customers through the customisation process by capturing information regarding their requirements and making them available to operations (PILLER, 2004; SLYWOTZKY, 2000). Customisation units are presented to customers through a choice menu, defining what can and cannot be customised in the product, based on the solution space (ROCHA, 2011; SALVADOR; HOLAN; PILLER, 2009).

1.2 RESEARCH PROBLEM

Although there are several successful MC adoption examples in the literature, its body of knowledge still disperse and growing (KUMAR; GATTOUFI; REISMAN, 2007). Even though there are many mechanisms to reduce complexity, counterbalance additional costs, and solve other MC challenges, companies still struggle to implement those practices[4] and generate value (ECHEVESTE; ROZENFELD; FETTERMANN, 2017). Some gaps between research and practice have been pointed out in the literature: (i) lack of in-depth understanding of implementation strategies (PILLER, 2004; SUZIĆ et al., 2018), (ii) difficulty of identifying, selecting and incorporating MC practices in NPD (FETTERMANN; ECHEVESTE, 2014), and (iii) the shortage of prescriptive research and guidance for adopting such practices (FETTERMANN; ECHEVESTE, 2014; ROCHA, 2011).

MC strategies' success depends on the coordinated efforts of Marketing, Product Design and Operations (FERGUSON; OLEWNIK; CORMIER, 2014; ROCHA, 2011). Such areas should collaborate towards a common goal of satisfying customers by effectively capturing customer requirements to deliver what the market expects while also focusing on the internal processes (SCHOENWITZ et al., 2017). Therefore, some authors (FERGUSON; OLEWNIK; CORMIER,

[3] The choice menu can be also called choice boards, configurators, toolkits and catalogues.
[4] Practices are the methods, tools and techniques, successfully used in real-life situations to solve problems and support the performance of activities during NPD (FETTERMANN; ECHEVESTE, 2014), that can be adapted to other companies facing similar challenges (KAHN; BARCZAK; MOSS, 2006).

2014; FETTERMANN; ECHEVESTE, 2014; PILLER; MOESLEIN; STOTKO, 2004) suggest the combination of different practices and strategies to deliver mass custom goods and propose the use of IT tools to facilitate some phases of the customisation processes. In fact, several studies related to customer integration have focused only on the development of digital tools, such as choice menus and configurators (FERGUSON; OLEWNIK; CORMIER, 2014; FETTERMANN; ECHEVESTE, 2014; PILLER, 2007). Still, achieving success through MC strategies requires an organisational context and processes that foster continuous improvement, learning, and knowledge creation, besides technologies and tools (KOTHA, 1995). Thus, a strategy focused approach is needed (PILLER, 2007).

MC's adoption in housing is still latent (LARSEN et al., 2019), focused on operations and enhancing productivity (FETTERMANN; TORTORELLA; TABOADA, 2019; JENSEN; NIELSEN; BRUNOE, 2018; LARSEN et al., 2019). Furthermore, many research opportunities related to customer integration have been mentioned in the literature, such as defining a solution space and providing support for customer decision-making during product configuration (JENSEN; HAMON; OLOFSSON, 2009; KHALILI-ARAGHI; KOLAREVIC, 2016; LARSEN et al., 2019).

The choice menu can be regarded as a strong source of information about customers' requirements and potential basis to refine the solution space and NPD (PILLER, 2004; SALVADOR; HOLAN; PILLER, 2009; SCHOENWITZ et al., 2017; SLYWOTZKY, 2000) but there is still a gap on how to design, implement, and manage choice menus (PILLER, 2005; FOGLIATTO; DA SILVEIRA, 2008). Khalili-Araghi and Kolarevic (2016) point out that there is a need for new methods and tools for customer integration that reduce trade-offs between customer perceived value and complexity resulting from customisation. Furthermore, the definition of the solution space and customisation units based on customers' perceived value is not a common practice in either manufacturing or housing (FOGLIATTO; DA SILVEIRA, 2008; HENTSCHKE et al., 2014; ROCHA, 2011). According to Schoenwitz et al. (2017), identifying consumers´ preferences and the impacts of considering them during housing NPD seems to be a fruitful research opportunity.

Ogawa and Piller (2006) state that the primary source of failure on the launch of new products is the faulty understanding of customers needs and preferences. To avoid this risk, companies should understand customers' perceived value, meaning the trade-off between benefits and sacrifices of customisation, for defining which customisation units to offer in the solution space (HART, 1995; HUFFMAN; KAHN, 1998; PILLER, 2004; SILVEIRA; BORENSTEIN; FOGLIATTO, 2001; SQUIRE et al., 2004; SVENSSON; BARFOD, 2002; WILLIAMSON; WESTBROOK, 1993). Furthermore, it is necessary to find ways for systematically translate clients' requirements into product specifications, according to the market segment (WIKBERG; OLOFSSON; EKHOLM, 2014) and to understand the economic impact of considering this information as a key enabler to MC (PILLER; MOESLEIN; STOTKO, 2004). Ferguson, Olewinik and Cormier (2014) suggest that companies should establish their solution space aiming to minimise the trade-off between the customers' ideal product and the ones available in the menu by systematically considering customers preferences.

Some authors have suggested the use of stated preference (SP) techniques to support decision-making towards essential elements in MC strategies, such as defining a choice menu (FOGLIATTO; DA SILVEIRA, 2008), and outlining product platforms (COLOMBO et al., 2020; TAN et al., 2020). SP techniques focus on measuring customers preferences and purchasing intentions regarding hypothetical products through surveys (ORTÚZAR; WILLUMSEN, 2011). According to Fogliatto and Da Silveira (2008) and Schoenwitz et al (2017), new methods based on SP can help companies redesign their products, change business strategies, and reconfigure processes and reconsidering their market position.

In housing research, SP techniques can be used to describe and predict customers' choices based on their responses to a specific set of hypothetical multi-attributes alternatives and on the choice of the housing solution that offers major utility (Louviere & Timmermans 1990; Molin et al. 2001). It also enables house building companies to forecast return of investment (Molin et al. 2001), and estimate WTP (MOLIN, 2011). Moreover, the identified customers preferences can provide support for housing design and development (JANSEN, 2020; JUN et al., 2020; KAM et al., 2018). Recent developments have been reported in housing research to support decision making related to MC, such as: (i) the solution space refinement (HENTSCHKE et al., 2020); (ii) definition of the product and component´s level of customisation (SCHOENWITZ et al., 2017); and (iii) proposition of recommendation systems (JUN et al., 2020). Nevertheless, there is still a need to understand further how customers preferences and other information can support decision-making regarding essential elements of the MC's strategy, such as the solution space and interfaces with customers.

1.3 RESEARCH QUESTIONS

Accordingly, the main research question of this doctorate thesis is:

“How to identify customers needs and preferences for mass customised housing projects and consider such information to support solution space definition?”

The specific research questions are:

- How to define a mass customisation strategy that integrates customers into development of mass customised housing projects?
- How can stated preference techniques be used to identify customers needs and preferences regarding housing attributes and target the customisation offer according to market segments?

1.4 RESEARCH OBJECTIVES

The main aim of this research is:

- **“Devise and evaluate a method for capturing customers’ preferences for mass customisation of housing projects and support solution space definition”.**

The specific aims of this doctorate research are:

- Propose a framework of decision categories for customer integration and for devising the scope of customisation to support the definition of housing MC strategies;
- Devise a method to capture customers’ demands for customisation of housing projects, by combining a choice-based experiment, a WTP approach, and estimation of operations costs;

- Propose a method for capturing customers’ demands for housing customisation based on MBC.

1.5 THESIS STRUCTURE

This doctorate thesis is divided in six chapters: (i) introduction, (ii) research method, (iii to v) three journal papers, and (vi) conclusion. The first chapter presents the research context, problem, questions and objectives. In the second chapter, the adoption of DSR and the connection between the papers is explained. The development of the thesis was divided into three journal papers, respectively chapters 3 to 5, from which two have been published, and the third one is soon to be submitted to an international journal.

Paper 1 involves the development of the framework for customer integration and devising the scope of customisation. Paper 2 presents a method for identifying customers’ housing preferences to support the solution space definition by balancing it with operations costs, based on stated choice. In Paper 3, a method for identifying customers preferences for customised housing is developed based on MBC, which is implemented in an empirical study in a residential building company. The last chapter contains an overview of the research contributions and suggestions for future work.

2 OVERVIEW OF THE RESEARCH METHOD

2.1 METHODOLOGICAL APPROACH AND RESEARCH OUTCOMES

Design Science Research (DSR) is a methodological approach that has been largely applied in several fields of knowledge such as information systems, management, operations management, engineering (HOLMSTROM; KETOKIVI; HAMERI, 2009), information technology (MARCH; SMITH, 1995), medicine (KASANEN; LUKKA; SIITONEN, 1993). It aims to build an innovative solution for a real-world problem class and, at the same time, make a scientific contribution to a specific field of knowledge (KASANEN; LUKKA; SIITONEN, 1993; LUKKA, 2003). According to Holmstrom and Ketokivi (2009), the artifact devised is a mean to solve practical or ill-structured problems. Thus, DSR often addresses managerial and theoretical questions about decision making situations in which goals are uncertain, conflicting or unknown by decision-makers and require a solution design (HOLMSTROM; KETOKIVI; HAMERI, 2009). This investigation has adopted DSR to address the question of how to manage customer integration into the development of mass customised housing. More specifically, how customer integration practices can support decision-makers to define a MC strategy and improve value generation for customers.

Differently from traditional sciences that seek to explore, explain, and describe natural phenomena, in DSR the focus is on prescribe, propose and design artifacts to tackle classes of problems (DRESH; LACERDA; ANTUNES JUNIOR, 2015). The prescriptions made along the investigation are embodied on an artifact (MARCH; SMITH, 1995) or a solution concept, the main outcome of this research type. According to Kasanen, Lukka and Siitonen (1993); Dresh, Lacerda and Antunes Junior (2015), the artifact must have a strong connection with a real problem, showing its practical relevance. Holmstrom, Ketokivi and Hameri (2009) argue that both solution and problem are built during DSR process instead of discovered. Additionally, is essential to demonstrate the innovation and utility of the proposed solution and point out its contribution towards the advancement of theoretical knowledge (KASANEN; LUKKA; SIITONEN, 1993). In summary, solution building is both an exploratory process, involving proposing, testing and refining the solution, and an explanatory process, as the theoretical relevance of the solution must be assessed (HOLMSTROM; KETOKIVI; HAMERI, 2009).

The solutions for managerial problems resulting from DSR can be organisational procedures, models, diagrams and plans (KASANEN; LUKKA; SIITONEN, 1993). March and Smith (1995) suggested four categories of outcomes: models, constructs, methods, and instantiations. Constructs are specific language terms used to characterise problems and describe solutions, while a model refers to a set of constructs and their relationship statements which are used to describe situations, problems or solutions (MARCH; SMITH, 1995). Methods are set of steps to perform a task targeting a goal, usually associated with how to apply constructs and models (MARCH; SMITH, 1995), and their application enables the transformation and improvement of a context (DRESH; LACERDA; ANTUNES JUNIOR, 2015). The same authors mention instantiation as an operationalisation of constructs, models and methods that display their feasibility and effectiveness. Moreover, they can also guide the artifacts utilisation and indicate an implementation time. Table 1 presents the main outcomes of this investigation according to the DSR outputs.

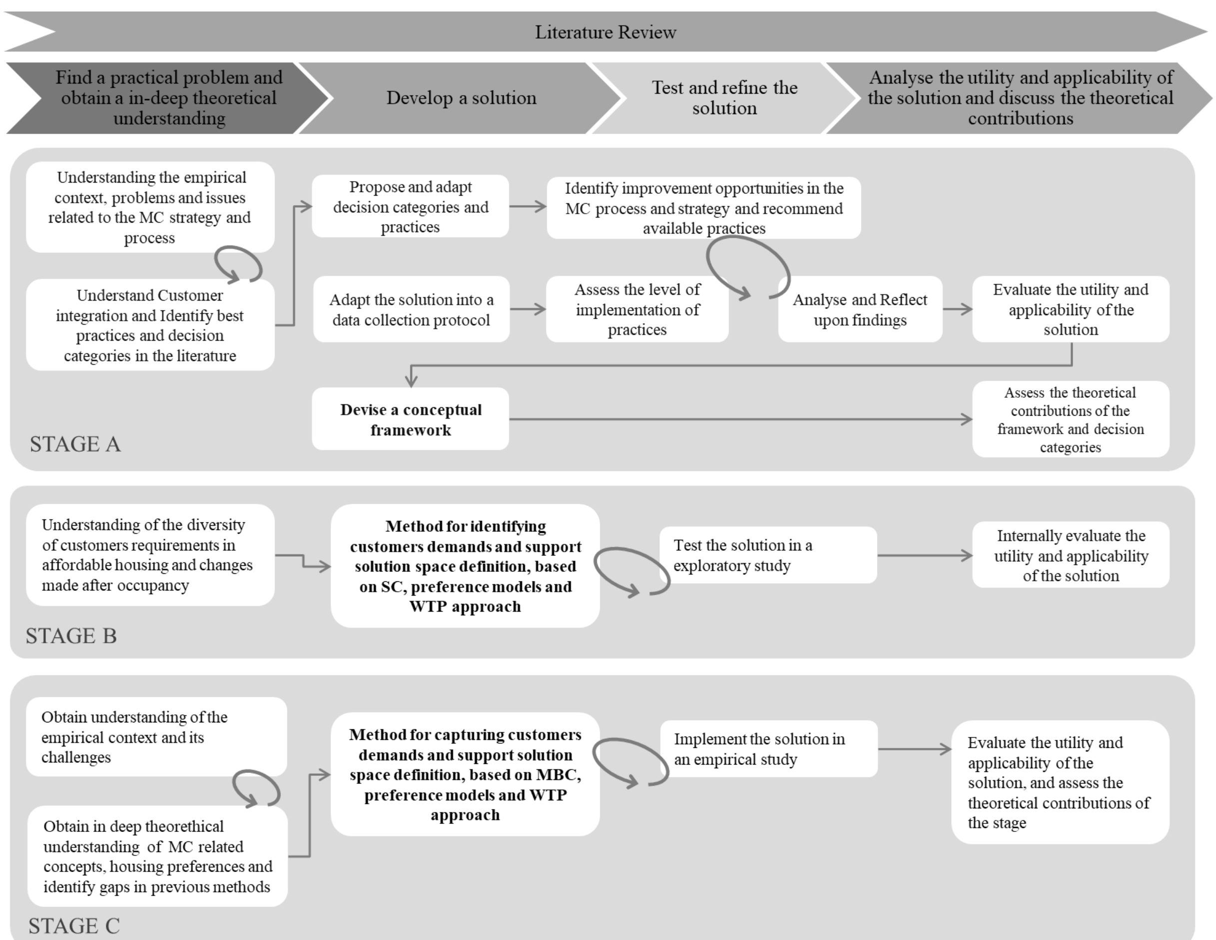
Table 1 Research outcomes

DSR Outputs	**Research Outcomes**
CONSTRUCTS	Proposed and refined customer integration and core decision categories list of practices for customer integration and for defining the scope of customisation
MODEL	A framework for customer integration and customisation scope definition to support devising MC strategies
	A hierarchical model for housing attributes
METHOD	Method to capture customers' preferences for mass customised housing projects and support solution space definition, based on choice-based experiments, preference modelling and willingness to pay approach
	Method for capturing customers' demands for mass customised housing projects and support solution space definition, based on menu-based choice and willingness to pay approach
INSTANTIATIONS	Instantiation of the first method in an exploratory study
	Instantiation of the second method in an empirical study

2.2 RESEARCH DESIGN AND PAPERS

The development followed the main steps of DSR proposed by Kasanen, Luka and Siitonen (1993) and Lukka (2003), as depicted in Figure 1. These were: (i) find a relevant real-world problem to be solved, with investigation potential, and obtain an in-depth understanding of the topic; (ii) Build an innovative solution to address the problem; (iii) Implement the solution to test its practical applicability; (iv) Reflect upon the scope of applicability of the solution and identify and present the theoretical contribution to the research field. A literature review also supported this investigation. This investigation was divided in Stages A, B and C. The DSR steps occurred iteratively during the research stages, as suggested by Vaishnavi and Kuechler (2007).

Figure 1 Research Design



Stage A encompasses all four steps of DSR, and is closely related to the development of an empirical study in Company P. The empirical study was part of a research collaboration project between UFRGS and the House Building Company P, within a 2 year time frame. The aim of the project was propose and refine mass customisation practices and tools to improve the management of residential building projects. During the initial stages of collaboration, semi-structured interviews were carried out to understand the empirical context and identify the practical problem related to the MC strategy and process.

A literature review on customer integration and MC practices was carried out to understand the topic deeply and resulted in the main research question of how to manage customer integration to support the MC strategy definition and improve value generation for customers. Initial developments of the solution included identifying the relationship between practices and decision categories and refining some decision categories.

More intense discussions with Company P customisation team were carried out to test and refine the solution by assessing the use of practices and decision categories and further understand their underlying ideas. Diverse documents analysed, nine semi-structured interviews with different company representatives and one meeting were considered sources of evidence to identify MC practices used during the NPD process. Simultaneously, a list of MC practices for customers integration compiled from the literature was compared to the ones adopted by the company, and improvement opportunities were identified. These improvement opportunities were discussed with company P's representatives in two meetings, motivating company P to implement some of them.

A year later, another assessment of Company P's MC strategy was carried out based on a refined list of core and customer integration decision categories and practices. The customisation team of Company P accessed each practice by rating it according to a 5 point scale, from not applicable to fully applied, during three meetings. The utility of the solutions was assessed by the customisation team and manager during meetings and discussions. The main outcome of this stage was a conceptual framework of decision categories for customer integration and for devising the scope of customisation, which can also support MC strategy definition. Further details about Stage A and its outcomes are given in Paper 1.

Stage B was the first cycle of development of the method, and it started by obtaining an in-depth understanding of customers' requirement diversity in housing, which may cause many product changes after occupancy, based on a literature review. It also included a more specific analysis of former studies to identify key customisable attributes in housing. SP was identified as a potential set of techniques to understand and measure customers' preferences in housing. The solution was developed based on stated choice, preference modelling and WTP approaches, resulting in a method for identifying customers' demands and supporting solution space definition for mass customised housing projects. This method is divided into four phases: (i) Context understanding, (ii) Experiment Planning, (iii) Customers preference modelling (iv) Balancing customer preferences and operational costs. The method was applied in an exploratory study, including all four phases to a small sample of potential customers of the My House My Life program from Brasil. Finally, an internal assessment of the method's utility was carried out. Thus, stage B encompasses the solution incubation and refinement phases of Holmstrom, Ketokivi and Hameri (2009), focusing in the exploratory part of the research.

Stage C of the research was the second cycle of development of the solution, which resulted in the second method. It was developed in close collaboration with company W, in a second empirical study, which was carried out during the COVID 19 pandemic. This stage started with a further understanding of the practical problem of how to identify customers demands and preferences for housing customisation and consider this information in NPD and MC strategy definition. It was based on a literature review and semi-structured interviews with company W's representatives.

The second method emerged from the further understanding of the practical problem, custom design of the solution for Company W's context and attempted to address limitations identified in the first version of the solution. As suggested by Kasanen, Lukka and Siitonen (1993) the artifact not only solve problems but also can make new ones to emerge, which was a motivation for refining the solution in this investigation. One of the structural changes proposed was the adoption of Menu-Based Choice instead of SC, which shifts the focus from limited product alternatives into a larger group of attributes available for individual configuration. Additionally, the extended housing product is considered and structured from a hierarchical perspective in the second version. Finally, this version of the method was applied to a sample of Company W's potential customers through an online survey.

The practical contributions of Stage C were assessed in meetings with company W's representatives. In Chapter 5, the outcomes of Stage C are presented, as well as the theoretical implications.

The results of this thesis are presented in three academic papers. Each academic paper has been produced with a particular aim by using different sources of evidence and focusing on different topics of literature review, as shown in Table 2.

Table 2 Papers structure summary

	Research objectives'	**Sources of Evidence**	**Literature Review**
Chapter 3 (Paper 1)	Propose a framework of decision categories for customer integration and for devising the scope of customisation to support the definition of housing MC strategies;	Semi-structured interviews; Document analysis; Discussions;	-Mass customisation; -MC decision categories and Practices; -Customer Integration.
Chapter 4 (Paper 2)	Devise a method to capture customers' demands for customisation of housing projects, by combining a choice-based experiment, a WTP approach, and estimation of operations costs;	Secondary Data Analysis; Online Survey;	-Mass customisation; -Stated Choice; -Willingness to Pay; -Solution space;
Chapter 5 (Paper 3)	Propose a method for capturing customers' preferences for housing customisation based on MBC.	Semi-structured interviews; Document analysis; Discussions; Online Survey;	-Mass customisation; -Menu-Based Choice models ; -Solution space;

3 A Customer Integration Framework for the Development of Mass Customised Housing Projects (Paper 1)

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Published in Sustainability, 27 October 2020.

Link: https://www.mdpi.com/2071-1050/12/21/8901 *sustainability*

MDPI

Article

A Customer Integration Framework for the Development of Mass Customised Housing Projects

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Received: 23 September 2020; Accepted: 22 October 2020; Published: 27 October 2020

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Abstract: Mass customisation is a business strategy that aims to deliver a variety of products that fulfil customer requirements and, at the same time, keep price and delivery time within acceptable limits. It has been adopted in different sectors to increase value generation, including house building. A major challenge in mass customisation is customer integration, i.e., how to improve value generation by understanding and considering requirements from different customers, and defining their involvement in product development. Most studies on this topic tend to be technology-focused, often being limited to methods and digital tools to generate and display product alternatives. The aim of this paper is to propose a framework of decision categories for customer integration and for devising the scope of customisation to support the definition of mass customisation (MC) strategies. Design science research was the methodological approach adopted in this investigation. It was based on a literature review about mass customisation practices and also on an empirical study developed in a residential building company from Brazil. The main contribution of this paper is a framework for customer integration, which contains a set of decision categories related to the definition of the scope of customisation and customer integration, and a list of practices that are applicable to house building. A secondary contribution of this investigation is a set of constructs that have been used to describe the decision categories and their relationships.

Keywords: mass customisation; customer integration; residential; practices

1. Introduction

In the current scenario of the house building industry, there is a fierce market competition in different countries, primarily concerned with costs, demanding strategies to increase productivity [1,2] and, at the same time, to consider customers heterogeneous demands [3]. Understanding customers' needs and preferences is a challenge due to their changing lifestyles and different family structures [4–6]. Therefore, customer requirements must be appropriately understood and communicated to decision-makers, such as investors, developers and designers; otherwise, value generation may be compromised [4]. The progressively increasing diversity of customer requirements has created business opportunities related to product customisation in several different sectors [7,8], including house building [9]. According to Wang et al. [10] this shifting focus from company to customer demand is a driving force in industrial innovation.

Mass customisation (MC) is a strategy that aims to fulfil customer requirements [11–13], and, at the same time, achieve high efficiency and competitive advantage [2,11], through flexible processes and supply chain integration [1,14]. Therefore, companies combine elements of mass and craft production to improve value generation for specific market segments [15–17]. In the house building industry, besides contributing to competitive advantage, the adoption of MC can provide benefits related to environmental and social sustainability, by avoiding waste caused by product changes made after occupancy by users, as well as by increasing their perceived value and sense of ownership [5,18].

Several successful applications of MC in the manufacturing industry have been reported in the literature [7,19,20]. However, its body of knowledge is dispersed and is still growing [7]. According to Piller [21] and Suzic et al. [20], there is a lack of in-depth understanding of the strategies for implementation. Other authors [22,23] argue that the further expansion of the field depends on the development of models and tools to support companies in new product development (NPD). A major challenge in MC is customer integration, i.e., how to improve value generation by understanding and considering requirements from different customers, as well as defining their degree of involvement in NPD [22,24]. Most studies on this topic tend to be technology-focused [19], being often limited to methods and digital tools to generate and display product alternatives, such as configurators and choice menus [22].

In the house building industry, the implementation of MC is still latent [1,25], sparse and more focused on operations [1]. A critical challenge for the adoption of MC in housing is capturing customers' requirements [3,14,25–27], and establishing a balance between offering variety and achieving efficiency and, consequently, housing affordability [1,9,25,27]. Several research opportunities on this topic have been pointed out in the literature, such as the definition of solution spaces, and the support to customers' decision-making during the configuration process [1–3,22,25]. However, Khalili-Araghi and Kolarevic [3] suggest that new methods for customer integration are needed to reduce the trade-offs between customers perceived value and the complexity that results from customisation. Kotha [17] argues that technologies and tools alone are insufficient to achieve MC goals, as the adoption of this strategy requires an organisational context that fosters continuous improvement, learning and knowledge creation.

Some studies have associated the use of MC strategies with prefabricated or industrialised construction methods (e.g., [1,28,29]). However, this strategy has also been explored by companies that adopt traditional construction methods (e.g., [6,9,25,26]). In fact, some of the potential improvements related to MC are not directly related to the type of technology used, such as understanding customer requirements, customer interaction, and visualisation approaches [2,6,25,30]. Rocha [30] suggests that the definition of an MC strategy can be divided into decision categories, and should start by making some core decisions related to the scope of MC, and then move to other areas, including customer integration. Wikner [31] defines decision categories as ways to classify decisions and support the segmentation of complex decision problems into a structured and relatively independent way to facilitate decision-making.

A possible starting point to understand key decision categories is to analyse practices implemented in the industry [20,32,33]. Those practices can be regarded as methods, tools or techniques that have been successfully used in real-life situations for improving performance or solving problems [32]. By understanding the underlying ideas of those practices, they can be adapted to other companies facing similar challenges [33]. This research seeks to further understand practices as an expression of tacit knowledge that can be applied for learning, working, innovating and organising [34].

Therefore, this research study aims to answer the question: How can customer integration in the NPD of mass-customised house building projects be managed? The main outcome of this investigation is a framework of decision categories for customer integration and for devising the scope of customisation to support the definition of MC strategies. It is based on practices identified in the literature and also on an empirical study carried out in a house building company. The framework is meant to be used by companies to support the definition of MC strategies. A secondary contribution of this investigation is a set of constructs that have been used to describe the decision categories and their relationships.

This paper is structured into six sections, including the introduction. In the theoretical background section, MC is discussed, emphasising its core concepts, especially the ones related to customer integration. In the third section, the research method is presented, including the methodological approach and research design. Then, the results of the empirical study are presented in the fourth section. In section five, the framework for customer integration is presented and evaluated. Finally, in section six, the main conclusions and opportunities for future research are presented.

2. Theoretical Background

2.1. Mass Customisation and Related Concepts

According to Silveira et al. [35], the success of MC strategies relies on several internal and external factors, such as customers demand for customisation, market and value chain readiness, technology availability, and knowledge sharing. Other studies [22,28,30] point out that the implementation of MC depends on the coordinated efforts from three different areas of the company: customer integration, product design and operations management. After requirements are captured, the design area must focus on developing product alternatives by translating those requirements into specifications. Finally, operations management is concerned with producing and delivering customised goods, by managing resources and the supply chain to achieve time and cost-effectiveness [22,30].

MC depends strongly on the company's ability to translate customers' demands into new products and services, in which knowledge creation and information sharing play a key role [22,35]. According to Kotha [17,36], knowledge creation in the MC strategy has two primary sources of information: (i) external, from customers, and (ii) internal, related to internal processes and workers' experiences.

Customers inputs into NPD can be communicated in different ways, such as desires and needs, suggestions towards product solutions, and even insights that may lead to radical innovations [37]. According to Piller et al. [24], by translating customer preferences and needs into product requirements, companies are able to transform subjective information into explicit knowledge. This knowledge can be used to understand customer demands and inspire new developments [17,24,36]. Besides, feedback from customers and previous choices can be used by companies to introduce innovations and also provide guidance on whether to limit or expand product variety [17,36]. Furthermore, Wang et al. [10] discuss emerging methods for collection and storage of customers inputs based on "Big Data" and other IT tools to support decision-making. Therefore, different practices can be used to capture such knowledge [37].

The level of customisation is concerned with the range of customisation options to be offered in order to satisfy different customers [13]. However, this decision needs to be based on the analysis of trade-offs between the company's capabilities and customers' demands [7,35,38]. Moreover, customisation can occur at various points in the value chain, from a minor product adaptation to full customisation defined at the design stage [35,39]. Each one of these points may be related to a specific level of customisation, and requires the definitions of how and when customers' needs are translated into product specifications. A number of taxonomies of customisation types have been proposed in the literature based on the level of customisation, such as the MC generic levels proposed by Silveira et al. [35]: design, fabrication, assembly, additional custom work and services, package and distribution, usage and standardisation. Another example is Barlow et al.'s [40] set of strategies for the house building industry (Table 1), which is based on Lampel and Mintzberg [15].

Table 1. House building strategies.

MC Strategies in House Building [40]	Description of the Customisation Level
Pure standardisation	Standardised product. No possibility of changing products
Segmented standardisation	Limited choice focused on aesthetic elements and or based on aggregate knowledge regarding customers' requirements
Customised standardisation	Balance between cost, lead time and choice, associated with postponement and modular practices
Tailored customisation	High variety or availability of choice. The product is fabricated by combining a set of standardised design elements
Pure customisation	Infinite choice, relatively high costs and lead time

Source: adapted from Barlow et al. [40].

The location of the customer order decoupling point (CODP) is essential to define the customisation level [41,42]. It divides the value chain in processes based on forecasts (mostly standardised) and on customer demands (customised according to orders) [24,38,39] (see Figure 1). The CODP also defines which activities are postponed until the customer's specific requirements are captured, and an order is placed [24].

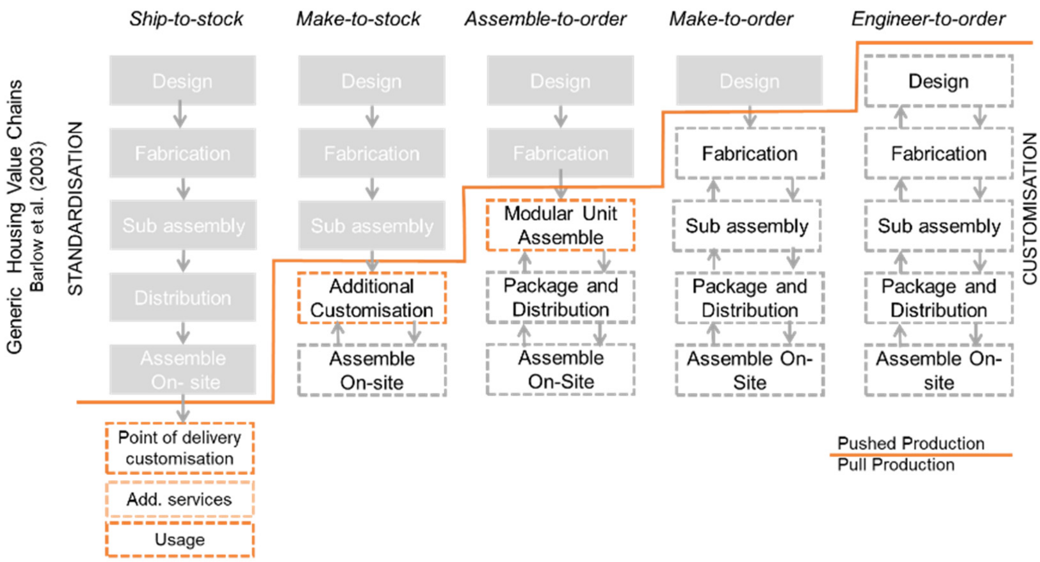

Figure 1. Customer order decoupling point (CODP) in housebuilding. Source: adapted from Barlow et al. [40] and Silveira et al. [35].

Therefore, the extent of customer integration is closely related to the level of customisation [24] and the CODP definition [39]. In fact, the level of customisation usually defines the intensity of customer–company interaction during NPD [24,38]. Moreover, a high customisation level should rely on collaboration with customers from early design stages, while a low one requires less intense participation of customers [38].

When defining the level of customisation, companies should bear in mind that offering too many options not only can make operations inefficient, but also cause customers frustration and confusion, the so-called burden of choice [43,44]. Thus, the definition of a limited solution space plays a key role in MC. The solution space consists of a combination of different customisation units (i.e., customisable attributes and their available options) and rules to combine them, limiting the set of possible product alternatives [30,44]. However, even if there is a limited number of flexible processes, a large number of features and product alternatives may be generated [7,19,21].

Previous studies [14,23,28,30] have pointed out that devising a solution space must be based on the identification of customers' needs and preferences for product customisation, and decide whether and how those will be meet [2,28,44]. It must also be highlighted the importance of post-occupancy evaluations (POE) to capture requirements and provide feedback for the NPD of future house building projects [14,26].

Rocha [30] proposed three core decision categories to define the scope of an MC strategy in house building: (i) the solution space; (ii) customisation units; and (iii) classes of items, which are specific properties of options offered in the customisation units [30]. Additionally, Amorim [45] proposed a decision category named communication of customisation information that defines how the information is made available, when and for whom. This is strongly supported by previous studies [9,25–27,45–47], that highlight the need to improve the effectiveness of information flows between different sectors of the company, in order to facilitate collaboration and improve value generation.

Rocha [30] suggests that the level of customisation should be considered as an operations management related decision category, as it is related to the definition of when and how customisation units are defined. However, Schoenwitz et al. [28] suggest that customers' preferences play a key role in the definition of the customisation level, indicating that there is an interaction between customer integration and operation management decisions. The same authors also pointed out that the definition of a single CODP neglects the possibility of choices to be made separately for different components and attributes, which are made feasible by prescribing multiple decoupling points.

2.2. Customer Integration

According to Franke, Keinz and Schreier [48], the value delivered by mass customised products is driven by the fit, style and functionality, or utility perceived by customers, and the uniqueness of a product. Customers are often willing to pay extra to obtain customised goods [1,21,38]. Furthermore, Piller [21] argues that the willingness-to-pay (WTP) reflects the value perceived in the increment of utility that they gain from a product that better fits their needs rather than the best standard product available. Therefore, customer integration should start from capturing needs and preferences, and estimating the WTP for a customised good [22].

Kumar et al. [7] argue that customer integration embraces not only co-design but also other types of interactions between companies and customers, which can be enabled by modular design, configurators, and elicitation of needs. It means that customers can have an active role in product definition, configuration or modification within a given solution space [19,21]. Thus, premium prices are charged to cover additional costs resulting from customisation, such as higher costs of sales [17] and operations [24]. Moreover, customer integration can also bring some cost-saving results from collecting consistent market information and establishing a close customer–company relationship [24].

In this context, new relationships must be established between customers and companies [3]. Thus, companies can benefit by expanding the use of traditional customer relationship management (CRM) tools [49] to relational marketing ones [50]. These are means to build long-lasting relationships with customers, by improving value generation through interactions, creating trust and increasing loyalty [49–51]. According to Tommaso [50], relational marketing is based on a logic of exchange and learning. It can potentially improve customer experience, which refers to the combination of a number of personal impressions (considering cognitive, affective, behavioural, physical and social aspects of the response), resulting from interactions between a customer and a product or service [50].

According to Silveira et al. [35], the customer–company interface must be tailored to each unique context. Fetterman et al. [25] proposed a set of steps to outline a customer–company interface for the house building industry, which is built on a proposition by Silveira et al. [35]: (i) defining a solution space to be offered to customers; (ii) collecting and storing information on customers choices; (iii) transferring data from retail to production; (iv) translating customers choice into product design features and manufacturing instructions; and (v) delivering customised products and offering post-occupation customisation. In step two, effective ways to present the solution space for customers are needed [30,35], enabling them to deal with the variety of alternatives, avoiding the burden of choice [43].

Rocha [30] suggested two decision categories for customer integration, namely, configuration sequence and visualisation approaches. These are concerned with how the customisation units are presented to customers and how they engage in creating the product. The first one involves defining a sequence of decisions to be made by customers when configuring their product alternatives [30]. The visualisation approaches decision category defines how the customisation units will be displayed and to whom (i.e., customer, company or both), being divided into three types: collaborative, transparent and do-it-yourself [30], similar to the approaches proposed by Gilmore and Pine [16]. For example, in the collaborative approach, both customers and companies are aware of the customisation process and can be applied through choice menus and or a dialogue between the company and customers [30]. However, Rocha [30] only proposed a broad definition of those three approaches, without discussing how to implement or combine them for effectively presenting the solution space to customers.

3. Research Method

Design science research (DSR) was the methodological approach adopted in this investigation. This approach typically involves the development of innovative solution concepts, named artefacts, to solve classes of practical problems, and at the same time contribute to the development of mid-range theories, i.e., theoretical models that apply to a limited range of situations [52,53]. The main reason for choosing DSR is the prescriptive, rather than descriptive character of this investigation. The practical problem addressed by this research work is how house building companies can use customer integration concepts to support the definition of MC strategies and improve value generation for customers.

There are different types of outcomes in DSR, such as models, methods, constructs, instantiations [54] and technological rules [55]. The artefact proposed in this research is a conceptual framework which prescribes a set of core and customer integration decision categories that can be used to support the definition of MC strategies in house building companies. This research work also proposes new constructs and adapts existing ones, which are useful for describing those decisions categories.

Figure 2 provides an overview of the research design, in which the activities are organised similarly to the DSR steps proposed by Lukka [53]: (i) identify a practical problem and understand it from a theoretical perspective; (ii) devise the solution; (iii) test and refine the solution in an empirical study; (iv) analyse the utility of the solution and discuss the theoretical contributions of the investigation.

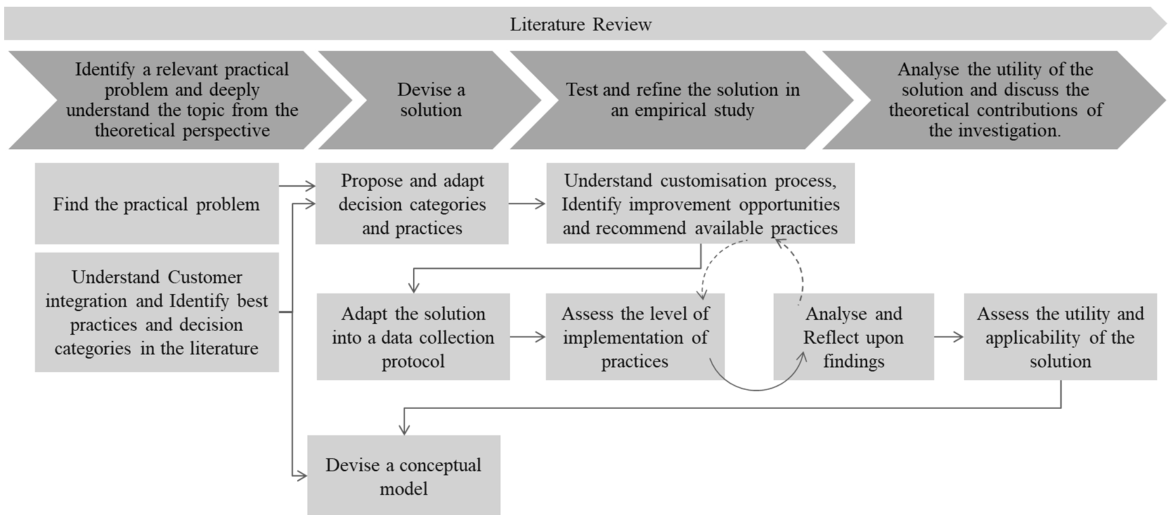

Figure 2. Research design.

A literature review on customer integration and MC practices was carried out in order to obtain a deep understanding of the topic, in the first step of the research (Figure 2). The aim was also to find descriptions of practices that were successfully used for customer integration, by using the snowballing technique, complemented by an advanced search in the Scopus repository. The search was undertaken in journal and conference papers, from 1998 to 2018 and its results were limited to areas relevant for house building such as engineering, management, and environmental science, from which 24 papers were selected. As a result, two sets of practices were identified, one related to the MC core decision categories and the other to customer integration. Information about those practices was stored and further categorised in a database, according to authors, and country of adoption.

In the second step of the research, the selected practices were associated with decision categories (Figure 2). Some of the decision categories considered were identified in the literature review (see Section 2), such as solution space, visualisation approaches, and configuration sequence. Furthermore, the processes of classifying practices into decision categories available in the literature brought to light some gaps, which resulted in the proposition of some additional decision categories.

The third step of the research consisted of the development of an empirical study in a house building company, named Company P, in which the implementation of MC practices and decision categories was assessed (Figure 2). The aim of this study was to understand further the underlying ideas of practices and to test the utility of the proposed decision categories. It was part of a broader research project, in which the MC strategy of the company was assessed, and some improvements were implemented by the company, which took approximately two years.

Company P was founded in the 1970s as a family company, being currently one of the largest construction companies of the South Brasil, with 252.312 m^2 built so far. They have over 20 years of experience in delivering customised residential building projects for upper-middle and middle-class customers. Their products are made from a combination of traditional methods of construction with industrialised components, such as internal drywall partitions and precast façades. This company was chosen because its business strategy was strongly based on the customisation of products to obtain market differentiation. Moreover, the company was willing to take part in this project and had a department entirely dedicated to customising residential projects. The customisation team (CT) had six architects, including a coordinator.

The focus of the empirical study was on a relatively new market segment explored by the company in which a limited solution space was offered to customers. Within this context, the productivity–flexibility trade-off had to be managed carefully in order to increase the perceived value for customers without substantially increasing costs and lead time.

The empirical study started by assessing and analysing the customisation process adopted by Company P, based on multiple sources of evidence (see Table 2). Several semi-structured interviews were carried out with representatives of different departments of the company. These interviews were divided into three sections: (i) company's general information (e.g., business model, customers, competitors, history); (ii) description of NPD and customisation practices; (iii) description of products and customisation options. Additionally, one open-ended interview was carried out with the customers and customisation manager about the role of the customisation department and the MC strategy. Based on the interviews and documents analysis, a customisation process map was devised by researchers and discussed with the CT. Simultaneously, the existing customer integration practices were compared to a preliminary list of practices extracted from the literature, and a gap analysis was then carried out, resulting in the identification of some improvement opportunities. Those improvements were discussed with Company P's representatives in two meetings. Then, the company decided to implement some of the suggested improvements.

Table 2. Sources of evidence used to understand the customisation process and identify improvement opportunities.

Source of Evidence	Details and Participants	Duration
Open-ended interview	Customers and Customisation Manager (civil engineer)	1 h 6 min
Semi-structured interview	Customisation Coordinator (architect), and Customisation Architect	1 h 6 min
	Customisation Architect	58 min
	Project Coordinator (architect), Project Analyst (civil engineer)	1 h 2 min
	Product Development Analyst (architect)	34 min
	Production Manager (civil engineer)	50 min
	Product Intelligence Manager (civil engineer)	40 min
	Marketing Manager (administrator)	53 min
	CRM department coordinator (marketing)	40 min
	Customisation Architect in charge of "point of delivery customisation"	53 min

Table 2. *Cont.*

Source of Evidence	Details and Participants	Duration
Document analysis	Proposed solution space	
	Product catalogues	
	Presentation of customisable attributes for customers	
	Company web site	
	Contracts	
	Post-occupation evaluation questionnaire	
	Project customisation management spreadsheet (containing dates for decision making, residential units customised by customers, customisation units chosen, etc.)	
	Customisation status on-site communication	
Observations	Participant observations of the interaction between the CT and customers during the construction site open day promoted by the CRM department	1 h 30 min
Meetings	One meeting with the CT to discuss their processes, identified practices and improvement opportunities	1 h 22 min
	One meeting with the CT to discuss research findings	1 h
	One meeting with the CT, manager and professionals from other departments of Company P to discuss research findings and the utility of the artefact	1 h 30 min

Approximately one year later, after the implementation of some improvements by the company, a data collection protocol was used to assess Company P's MC strategy regarding core and customer integration categories. This data collection protocol was based on the final set of decision categories and on the full list of practices, being used as a reference to discuss the adoption of practices with the CT (Table 3). This assessment was based on a 5 point scale. Besides, data about the perspective of customers were captured qualitatively during three open days in construction sites, bringing another perspective to the discussions.

Table 3. Sources of evidence used on the assessment of the level of implementation of practices.

Source of Evidence	Details and Participants	Duration
Document analysis	Customised units database	
	Simplified choice menu	
Observations	Two participant observations of the interaction between the CT and customers during the construction site open day promoted by the CRM department	4 h
		5 h
Semi-structured interviews	Ten interviews with customers during events promoted by the CRM department regarding the customisation service, interaction, visualisation tools and customisation units	Approx. 15 min each
	Four interviews with architects from the CT regarding core and customer integration practices and decision categories	During the discussions
Meetings	One meeting with the CT to discuss core decision categories and related practices, and their utility	1 h 56 min
	One meeting with the CT to discuss core decision categories and related practices and their utility	1 h 45 min
	One meeting with the CT to discuss customer integration decision categories and related practices and their utility	1 h 39 min

Analysis and reflection of the research findings were carried out in the fourth step of the research study. The utility of the research outcomes, i.e., decision categories and MC practices, was assessed based on the following criteria: (i) provide underpinnings to the assessment and monitoring of core and customer integration decision categories; (ii) provide support to understand MC related concepts and its underlying ideas; (iii) support decision-making for defining the MC strategy, particularly in terms of integrating customers in customisation processes. The assessment of utility was carried out in six meetings with representatives of the customisation department, as shown in Tables 2 and 3. Finally, the conceptual framework of decision categories for customer integration was devised.

4. Results

4.1. Identification of Practices from the Literature

Table 4 presents the 44 MC practices that were identified in the literature review concerned with core and customer integration areas, organised according to decision categories. It is noteworthy that 35 of those practices were discussed in up to three different papers out of the twenty four reviewed. The maximum number was seven papers per practice. Therefore, this investigation provides a much broader view of customer integration practices than previous studies. Furthermore, these practices do not overlap with each other, so they can be combined to formulate strategies. Some of the practices provide support to decision making regarding the definition of strategies, while some other practices support the operationalisation of the strategic decisions undertaken.

Table 4. List of Practices.

n°	Description of the Practice	Authors
	Decision Category: Knowledge Management	
1	Present effectively customisation options	[30,45]
2	Establish a protocol to register and manage customer order changes	[25,26,45]
3	Carry out routine construction site visits to check customers' orders compliance by the design team.	[26,45]
4	Use product prototyping to test and communicate technical and design solutions to stakeholders	[45]
5	Create a database of customers orders for housing units customisation shared within departments	[30]
6	Standardise project documentation and communication between customer and developers from the company	[6,30]
7	Use specialised information systems for managing production management of customised products	[9,11,27,45,56]
8	Carry out post-occupation evaluation to understand customers' needs, capture new requirements and feedback the new product development	[14,57–59]
9	Establish a complaint management system and definition of continuous improvement procedures	[14]
10	Adopt methods for identifying the demand for customisation and consumers preferences to define solution spaces	[2,25,28,30]
11	Manage information about customisation orders to create knowledge for the company	[2,30,47,58,59]
12	Carry out product and service research to understand which factors contribute to customers satisfaction regarding the housing unit and customisation process	[14,46]
13	Use choice menus as a learning tool, to understand customers' needs and preferences and provide feedback to new product development	[2,3,27]

Table 4. *Cont.*

n°	Description of the Practice	Authors
14	Map the customisation process to find improvement opportunities and potential areas of economy	[28,30]
15	Create metrics that can be used to analyse the trade-offs between flexibility–productivity	[18,25,46]
16	Share information about the customisation sales and profitability performance within different departments	[46]
	Decision Category: Level of Customisation	
17	Define different levels of customisation according to customers' preferences, distinct market segments, and projects	[25,26,28,46,59]
18	Offer of different customisation units and level of customisation according to the project stage, i.e., a multiple customer order decoupling point approach.	[28,59]
19	Use modular components that allow product variations according to customers' requirements	[6,40,46,60]
	Decision Category: Solution Space	
20	Assess the alignment between the solution space and customer demands to improve the cost-effectiveness of the mass customisation strategy	[27,28,60]
21	Define customisation units based on the region and local needs for the projects and their target customers	[46,58]
22	Define a limited solution space to achieve economies of scale	[6,14,30,40,60]
23	Offer of additional services related to the built environment	[14]
24	Offer extra customisation units at the product delivery	[11,14,40,46]
25	Offer innovative customisation units, such as related to sustainability and automation	[58]
26	Promote multidisciplinary discussions, among different stakeholders, for defining the solution space and level of customisation	[46,60]
27	Refine the solution space according to previous experience in other projects	[25]
28	Define the customisation units based on the balance between the potential value-adding to customers and its feasibility and operations costs	[25,28,57,59,60]
29	Adopt information technology tools or a choice menu to support customers' choice and product configuration, which is well integrated into the new product development	[3,6,11,25,27,40,56,61]
30	Offer additional customisation units post-occupancy or substitution of previously chosen components according to customers emerging needs	[25,58]
	Decision Category: Customer Interaction and Relationship	
31	Advertise the possibility of customisation to customers as a competitive differentiation in the market	[26,59]
32	Co-design	[6,40,46,58]
33	Define interactions with customers and display them in a customer journey representation	[14,25,61]
34	Identify potential customers for new projects to establish effective communication with the target audience	[47,59]
35	Have meetings with clients for product configuration and cost estimation	[30]

Table 4. *Cont.*

n°	Description of the Practice	Authors
36	Offer customers precise product specifications and information regarding the customisation status	[59]
37	Establish a dialogue between customers and the company's representatives for configuring the product according to their needs	[6,27,40,61]
38	Adopt methods and tools to collect customer orders in a standardised and systematic way	[11,25–27,45,46]
39	Promote customer interaction with product prototypes to learn about them, their needs and capture requirements	[6,40]
40	Use product catalogues for advertising and informing customers about the product and customisation process	[6,25,40]
	Decision Category: Visualisation Approaches	
41	Use tools, lists, databases of that communicate additional costs for customisation to support customer decision-making during configuration, enabling negotiation and increasing transparency	[6,11,30,45,61]
42	Build a prototype or showroom for showing the customisation units available to customers	[26,30,58]
43	Present standard product specifications through images and information	[30]
44	Use virtual prototyping, e.g., building information management (BIM) models, to show product alternatives to customers	[2,3,11,56]

The descriptions of the decision categories proposed in this investigation are presented in Table 5. Some of them were subdivided into sub-categories or decision domains that characterise sets of processes that depend on similar preconditions [31].

Table 5. Decision categories, source and research contributions.

	Categories	Source	New Definition or Adaptation
Scope of Customisation (Core)	Solution Space	Adapted from Rocha [30]	The solution space decision category was adapted to consider both customisation units and classes of items due to the interdependency among those decisions. They can be regarded as decision domains.
	Level of Customisation	Adapted from Rocha [30]	This decision category is concerned with the definition of the levels of customisation to be adopted by the company. It is closely related to the customer order decoupling point, customer integration and product variants definitions.
	Knowledge Management	Proposed in this investigation	This new decision category addresses how to manage knowledge created by the company, considering customers, processes and workers information, as suggested by Kotha [17], including the communication of information and knowledge created. It allows companies to continuously update competencies, apply practices and routines, promoting organisational learning and continuous improvement [17,36].

Table 5. *Cont.*

Categories		Source	New Definition or Adaptation
			Customer based knowledge decision domain: it aims to define approaches to assess customers demand for customisation to establish a solution space and to evaluate the delivered products for understanding emerging and evolving requirements. Additionally, it is necessary to establish how is this information will be used to feedback the new product development. It is strongly related to customer integration and value generation.
			Organisational knowledge decision domain: it is concerned with how to make explicit tacit knowledge from workers and processes, and translate it into practices to be adopted. It also encourages the reflection upon practices for disseminating them and refining the MC strategy.
			Communication of customisation information decision domain: it embraces practices that promote transparency and continuous improvement by making relevant customisation information available to stakeholders during new product development. In this research, it is considered as a way to disseminate information and knowledge created, and not limited to the interface between product design and operations, explored by Amorim [45].
Customer Integration	Visualisation Approaches	Adapted from Rocha [30]	Further than just defining who is aware of what is happening in the customisation process, visualisation approaches decision category regards the definition of how the solution space and the customisation units will be presented to customers. Therefore, the "visualisation tools" decision domain was proposed with that aim, specifically for defining tools that portray the solution space.
	Configuration Sequence	Proposed by Rocha [30]	
	Customer Interaction and Relationship	Proposed in this investigation	It regards the definition of approaches to interact with clients during the new product development and develop a close relationship with them throughout their entire journey, for achieving loyalty [49–51]. This decision category is closely related to planning the customer experience [50].

Four core decision categories for MC in house building were defined in this investigation (Table 5). In relation to the previous literature, a new core decision category related to knowledge management was proposed, which is concerned with how to establish a knowledge-creating system to support MC. This decision category was based on contributions from several authors [17,22,24,35,36]. Three decision domains were proposed within the knowledge management category: customer-based knowledge, organisational knowledge, and communication of customisation information.

Three customer integration decision categories were defined, including "visualisation approaches" and "configuration sequence", based on Rocha [30]. The "customer interaction and relationship category" was proposed to address decisions regarding how companies interact with customers, when and for which purpose, and establish a trustworthy relationship, during NPD. By contrast, the decision categories proposed by Rocha [30] were focused on defining the customer–company interface, by broadly specifying who visualises what during the customisation process, and the sequence of decisions to be made by customers when configuring a product. The adapted version of visualisation approaches decision category includes the decision on whether to use visualisation tools for displaying the solution space. Additionally, there seems to be a gap in the literature regarding configuration sequences, since no practices for the house building industry have been found.

4.2. Empirical Study in Company P

4.2.1. Understanding the Customisation Process and Identifying Improvement Opportunities

Company P offers six different product types; each one of them focused on a different market segment with different customisation levels (Table 6). Most of the company's previous experience on customisation is related to A and B product types, which can be classified as tailored customisation. In those market segments, customers may hire their own architects to develop the interior design of their units. However, the focus of this investigation is on the D, E and F product types, in which customers can customise only a limited set of elements, mostly related to the finishings and fixtures of the residential unit. Product types D and E could be classified as a "segmented standardisation" level of customisation and F as a "point of delivery customisation".

Table 6. Company P product types and levels of customisation.

Product Types	F	C, D and E	A and B
Development stage of Customisation	Delivery	Construction	Fabrication
Level of customisation	Point of delivery customisation	Segmented standardisation	Tailored customisation
Available customisation units	Floor finishings, fixed furniture, air-conditioning, kitchen counter and bathroom sink stones	Drywall partitioning, floor finishings, double glazing, kitchen counter and bathroom sink stones, and the laundry tub	Internal layout, ceiling finishings, water and electricity services, air conditioning and internal finishings

The customisation department is in charge of defining the solution space for each project within the boundaries established for each product type by the NPD department. During the conceptual stage, representatives of both departments discuss which customisation units regarding layout and finishings will be offered to customers. At the end of that stage, two customer decision-making deadlines for the layout and finishings are established at the project launch meeting, which involves several departments of the company. These deadlines are included in a brief that is delivered to the project designers. After the project launch into the market, the CT defines different alternatives to be offered as finishings.

The customisation offered involves four main touchpoints with customers, in which different customisation units are available and portrayed by different visualisation tools (Figure 3). At each of these points, the customisation department is in charge of: (i) establishing a dialogue with customers; (ii) collecting and processing customer orders; (iii) making design changes; and (iv) delivering that information to the construction site. The CRM department promotes open days for visits to construction sites by the clients. In those open days, the CT is available at the housing unit prototype to offer customisation services. The CT guides customers through the solution space by using different visualisation tools, such as illustrated blueprints and finishing material catalogues, and informs prices of product alternatives by using simulations based on a simplified choice menu. The visualisation tools highlighted in yellow were, in Figure 3, improvements carried out during the empirical study.

The display of product prototypes in the construction site open days was identified as a key element for the customisation strategy of Company P. These enabled the CT to guide customers to make decisions within the solution space offered, and provided an opportunity for creating a relationship with clients. The CT may also arrange individual meetings in case open days cannot be undertaken or if customers show an interest in product customisation after those events. If the customer opts for a customised unit, an additional contract is signed. During construction, the CT carries out routine visits to the site to check whether customers' orders have been fulfilled in the construction site.

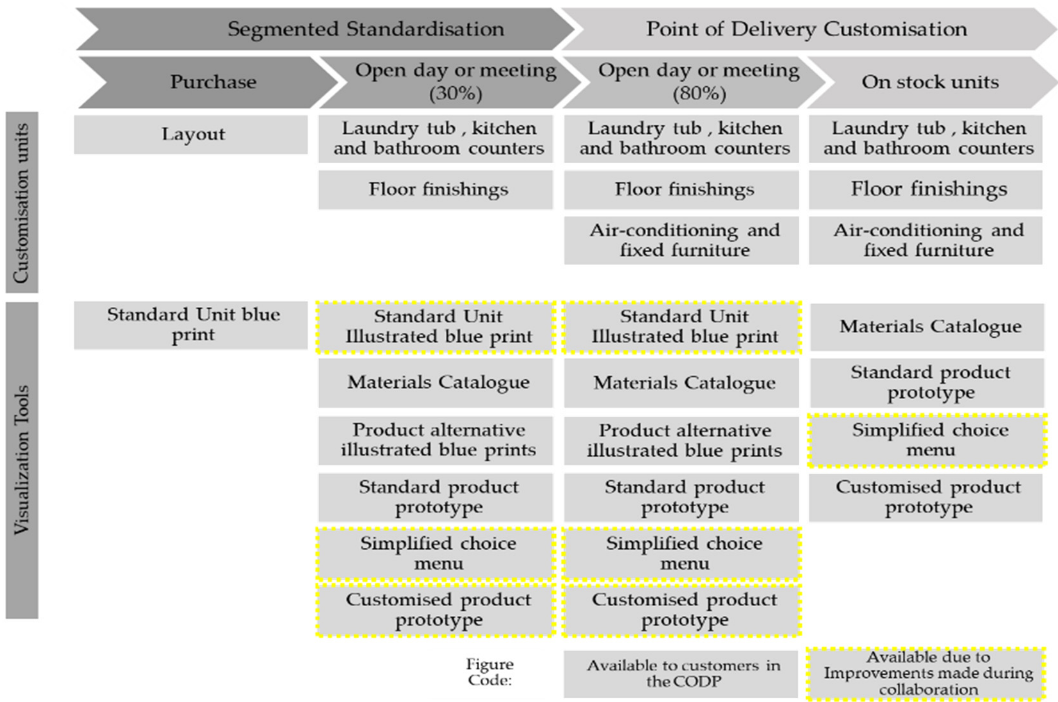

Figure 3. Touchpoints and customisation units.

In Company P, customers initiate their journey with the company when they purchase a housing unit, being registered at the CRM department. That department has three communication channels with customers: (i) an area in the company's web site, (ii) an APP, and (iii) a call-centre that connects customers to different departments. Besides being in charge of promoting construction site visits and events with customers, the CRM department is responsible for carrying out customer satisfaction surveys in different moments: (i) in construction site open days; (ii) post-occupancy evaluation undertaken one-year after project delivery; (iii) after the response of the company to complaints after project delivery; and (iv) when completing five years, considering the possibility of providing references of the company to friends or family.

Table 7 summarises the identified improvement opportunities as well as the improvements implemented by Company P during this research study. Those opportunities were classified according to decision categories and practices. For instance, regarding the "knowledge management", the company carries out a POE, yet, it is mostly concerned with the overall customer satisfaction with the product, but no questions are asked about customised items. Another example is facilitating, standardising and digitalising customer order collection, which was carried out by the CT, who used to handwrite customers' requests during open days, before processing these back at the office and e-mailing them to be confirmed by customers. This opportunity, for instance, inspired the development of a simplified choice menu, which enabled the use of a digital tool for registering customers' orders and simulating the product alternative costs in real-time.

A critical barrier for improvements, identified in interviews and participant observations, was the lack of communication between departments, which occasionally confused customers. For instance, the sales department offered the "point of delivery customisation" of residential units that have not been sold yet, while the customisation department offered other options at different touchpoints. Moreover, different customisation units are offered in each touchpoint, so by making the early announcement of the "point of delivery customisation", the sales department has confused customers regarding the available customisation units, the timing and to whom report their decision.

Table 7. Improvement opportunities identified during the understanding of customisation process.

Decision Category Related	Improvement Opportunities	Practices	Improvements Implemented
Customer interaction and relationship	Ability to better inform customers regarding the customisation offer and configuration process	31, 34, 40	
	Facilitate, standardise and digitalise customer order collection, reducing the processing time of the information and rework Tool for simulation of product alternatives costs to negotiate with customers during open days	29, 37, 38, 41	Development of a simplified choice menu
Solution Space	Solution space is defined based solely on CT expertise; there is an opportunity to enhance its definition by considering customers' preferences and other departments views	20, 21, 26, 28	
Knowledge management	Incentive communication and collaboration between departments	5, 7	Customised units database shared in the company intranet
	Develop graphs and presentation regarding the customisation department performance	15, 16	Starting to report to the manager
	Better understand the customisation process of residential projects and identify improvement opportunities	14	Customisation process map and service blue print in development
	Improve the market research to understand the demand for customisation of housing, providing insights to NPD and definition of a solution space	8	
	Improve POE assessment methods by including customised items and aiming to understand more deeply customers perception regarding product and service	10, 12	
	Process available information regarding customisation of projects and housing units to transform into knowledge	11, 13	

Lastly, the use of traditional construction methods and the outsourcing of product design created barriers for Company P in the adoption of modularity-related practices. As discussed by Fettermann et al. [25], the customisation of buildings that use traditional construction methods usually has little support from modularity, limiting the advantages of scale.

4.2.2. Assessing the Level of Implementation of Practices

The level of implementation of practices was assessed by the CT considering a five-point scale: not applicable (1), not applied with intended adoption (2), partially applied (3), partially applied with intended improvement (4), applied (5). This assessment is presented in Figure 4. It is noteworthy that the adoption of practices depends on the context of each organisation. Therefore, practices that are "not applicable" are the ones that were not considered to be useful to Company P, while the practices that are "not adopted with intended adoption" are the ones that the company recognises the need to implement shortly. Some practices were assessed as "partially applied with intended improvement", meaning the company has adopted it, but there is still room and motivation to improve.

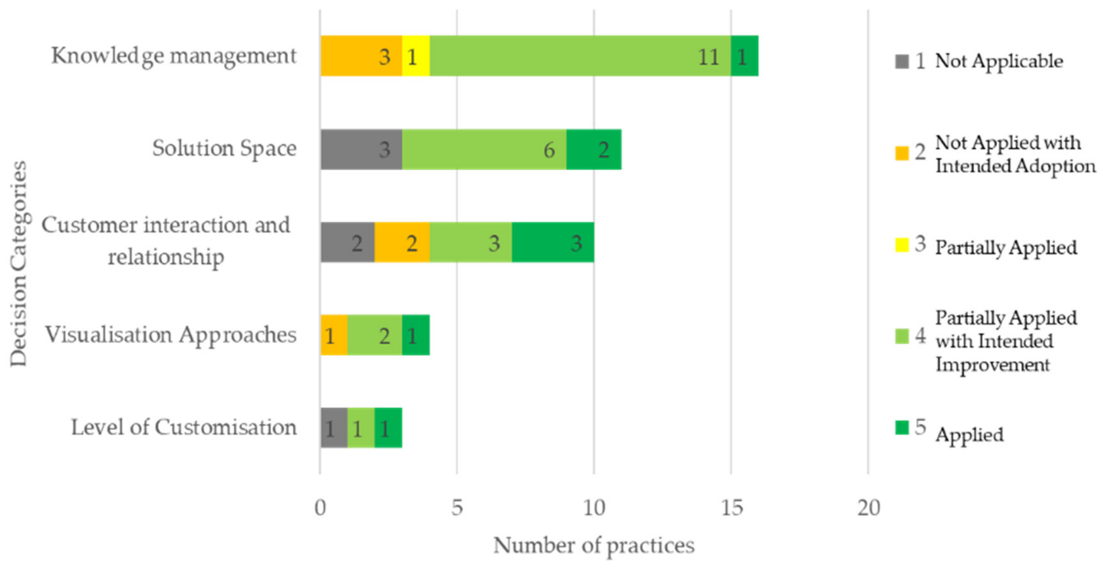

Figure 4. Practices by decision categories according to CT's assessment.

The number of fully applied practices is noticeably low. However, there was evidence that the company is motivated to continue improving, considering that many of the recommended practices changed to partially applied within the time frame of this research project. Further details on each decision category assessment are discussed in subsequent sections.

During the assessment of the level of implementation of MC practices, other improvement opportunities were identified (Table 8). Although many improvement opportunities remained from the previous research stage, the CT seemed motivated to improve. For example, the use of three-dimensional models to display product alternatives as a visualisation tool for meetings with customers was suggested during the discussions and shortly adopted two weeks later.

Table 8. Improvement opportunities identified during the assessment of the level of implementation of MC practices.

Decision Category Related	Improvement Opportunities	Practices	Improvements Implemented
Customer interaction and relationship	Continuous improvement of the customers decision support tools and techniques, facilitating the configuration process and increasing its transparency	29, 37, 38	Use of a simplified choice menu
Solution space	Improve the delimitation of the solution space and establish borders to the flexibility offered	22, 27, 28	Started processing data regarding some projects
Knowledge management	Create cost indexes, based on past projects percentages, to manage loss risk	15	
Visualisation approaches	Need for complementary visualisation tools to aid the solution space and standardised product explanation during meetings with customers	44	Three-dimensional model of the housing unit and customisation units
	Customers have presented some difficulties to envision and understand how the customised product will be delivered	42	New customised product prototype

The CT mentioned some barriers that they face in the adoption of MC practices such as financial and human resources, and tools to develop and implement new solutions. Moreover, a challenge for the customisation department is to be perceived as an innovation and customer-oriented sector as the development of new product ideas is often assigned to them. Thus, the CT must embrace activities that were not always related to their scope of expertise, such as customising non-residential projects. Moreover, the uncertainty of the new product types and attempts to improve the existing ones can be overwhelming, since their scope is continuously increasing.

4.2.3. Analysis of Decision Categories

Knowledge Management

Knowledge management was one of the decision categories which had the largest number of improvements during the empirical study and the highest number of "partially applied with intended improvement". One of the most significant improvements implemented was to share customisation information among departments, by using a customised units database. Initially, data regarding the customisation of housing units were held on by the CT and operations only. After that change, the CT compiles that information and shares it in the company intranet, making it available to sales and other departments. Additionally, any changes in customers' orders are also registered in that database. These improvements resulted in a high level of implementation of practices related to the "communication of customisation information" decision domain (see Table 4 practices one to seven), yet with room for improvement.

Even though the CT considered that many of the partially adopted practices of the "customer based knowledge" decision domain (see Table 4 practices eight to 13) had to be improved, there was much concern with how to operationalise the proposed practices, due to limited resources, and fear of exhausting customers with too many questions.

When discussing practice eight, "POE to understand customers' needs, capture new requirements and feedback the NDP", the CT stated that it would be beneficial to know customers' desires and preferences by including questions related to the scope of customisation on the existing POE. This improvement would avoid the initial concern to overload CT with an additional task and overwhelm customers with too many questionnaires.

Practices 14, 15 and 16 are related to the "organisational knowledge" decision domain, and for the last two of them, the company has plenty of data. However, the data have not been processed to create knowledge. For instance, practice 16, "share information regarding customisation performance ... ", is at its early adoption stage. Another example is practice 15, related to the creation of metrics: the CT argued that they have a large amount of data, but have not been able to establish any metrics yet. The reflections regarding strengths and shortcomings of the company strategy also inspired the proposition of a new practice, named "use methods and discussions to learn from practices adopted in other departments and levels of customisation", fostering the creation of a knowledge creation system and continuous improvement.

Level of Customisation

Practices 17 to 19 (see Table 4) are related to the definition of the level of customisation. The CT reported that they offer options for the attributes defined by the company, according to market segments and CODPs, yet the variation of the solution space offered in different projects is small. Nevertheless, the CT argued that they intend to offer more variety (e.g., painting services), as this would probably contribute to increasing customer satisfaction. However, the decision about the solution space should be carefully defined, as this would also affect operations. Furthermore, the decisions regarding the level of customisation are more strategic, once it might affect different departments, being out of the scope of the CT to be undertaken.

Solution Space

The solution space was identified as a critical area for improvement in the gap analysis. The CT's partially apply six practices that could still be improved. Regarding the assessment of practice 28, "define the customisation units based on the balance between the potential value-adding to customers and its feasibility and operations costs", the CT defines the solution space based on their previous experience with customers, considering general definitions made by the company for the segment and the return of investment. However, Company P has no systematic way to assess the value-adding potential of customisation units, neither discuss its feasibility and operations costs with all stakeholders. This criticism corroborates the findings of Fettermann et al. [25].

Practice 29, "IT tools and choice menu to enable customers to choose, configure and be integrated into the NPD", was assessed as partially applied with improvements to be done. Its application has evolved significantly during this research study, by the development of a simplified choice menu. However, some additional improvements opportunities were identified, regarding the visualisation of the product alternatives.

Some of the identified practices provided insights on how to overcome improvement opportunities. For instance, "Promote multidisciplinary discussions, among different departments and stakeholders" (practice 26), should be used to overcome the poor communication among stakeholders regarding customisation issues. The CT suggested some inter-department seminars to increase awareness about their work. As discussed by Kotha (1995), the information exchange between coworkers and cross-training can support the conversion of tacit into explicit knowledge and foster the adoption of practices and organisational learning. Another practice that was poorly adopted by Company P was "refine solution space according to previous experience in other projects" (practice27), meaning that lessons from previous projects were only learned informally.

Customer Interaction and Relationship

The practices related to customer interaction and relationship have significantly evolved over the empirical study. In fact, this decision category was concerned with an important role played by the customisation department, as the CT had the mission of establishing a good relationship with customers, as well as dealing with some reported problems related to customisation during NPD.

A strength of Company P's customer integration strategy was to "establish a dialogue between customers and the company's representatives for configuring the product . . . " (practice 37), which was mentioned by customers in the interviews and by the CT during the meetings. Customers mentioned that having a dialogue with the CT and engineers was an important source of information, which made it easier to choose customisation units and created trust. Additionally, several customers seemed to like the customisation service because of its convenience, reducing the time to move in and the need to deal with further construction works. At the end of the empirical study, this dialogue was aided by the combination of different visualisation approaches, such as the product prototype (practice 42), finishing material samples and the choice menu (practice 41).

The CT pointed out that practice 35, "have meetings with customers for product configuration", was implemented for product types D and E during the collaboration period. During those meetings, the architects explained the solution space and established a dialogue for configuring the unit, but without having the chance to show the prototype for customers.

Three improvement opportunities related to three practices that were considered as "not applied but intended": "advertise the possibility of customisation . . . " (practices 31), "use product catalogues for advertising and informing customers about the product and customisation process" (practice 40), and "clearly define interactions with customers and display them in a customer journey" (practice 33). In fact, the possibility of customisation was timidly mentioned in project information at the company website, and it was not always announced in the open day invitations. Interviews and observations in open days confirmed this fact, as several customers had only been informed of the possibility of customising their housing unit during that day, being surprised and confused.

Therefore, the company could improve communication regarding the possibility of customising residential units, to avoid confusion and increase transparency and trust in the relationship with customers. These shortcomings are also related to the lack of clarity about customers' involvement in the customisation process.

Visualisation Approaches

Several improvements have been made to embrace practices related to the visualisation approaches decision category. Currently, the CT offers more precise information regarding the customised units through the customised product prototype (practice 42), and the use of the simplified choice menu to simulate product alternative additional costs (practice 41). During the discussions, the CT architects revealed that they were trying to adapt the choice menu to product type B, in which the range of options is broader than in other product types, highlighting the opportunity of tailoring practices for different market segments.

An intended adoption by the CT can be seen in regard to practice 44 "Virtual prototyping, e.g., building information management (BIM) models, to show product alternatives to customers and ease choice". The initial step was developing three-dimensional models to illustrate product alternatives to be used in meetings with customers.

According to customers, some additional visualisation tools supported decision making during the open days such as standard housing unit prototype, finishing materials catalogue, and, in the third open day, the comparison between the standard and customised housing unit prototypes.

4.2.4. Analysis and Reflection

A low level of implementation of MC practices was identified in Company P, similarly to the results carried out by Fettermann et al. [25] on the MC practices of three Brazilian house building companies. The main improvement opportunities identified in this investigation were also similar to that study, being concerned with the solution space and visualisation decision categories, and customer-based knowledge decision domain. Jensen et al. [2] argue that by understanding customer's needs and preferences and making product recommendations based on the available solution space, companies can save much time in the configuration process, and also increase quality and reduce rework. Additionally, the implementation of MC practices enabled Company P to provide a better service for customers and to improve efficiency in some internal processes.

The CT has pointed out in the discussion meetings that some practices could be adapted for other product types that had a higher degree of customisation. However, this would require the analysis of a different context, in which the complexity of interactions with stakeholders would be much higher. These considerations reinforce the need for devising context-specific practices and implementation guidelines, as suggested by Suzic et al. [20].

The lack of communication, according to Andújar-Montoya [9], can be attributed to the fact that the NPD in housing is often divided into stages, which are not properly integrated. Beyond that, Schoenwitz et al. [60] suggest that this disconnection reflects different degrees of awareness regarding the customisation strategy, similar to what was observed in Company P. For example, the sales department was willing to extend the list of options with the aim of signing a contract, in opposition to the production management team. This often occurs due to different mindsets, concerns and nature of the job [60]. According to CT members', this reflects the lack of a common understanding in Company P of the role and impacts of customisation in house building projects. Thus, by encouraging better communication between departments, companies should be able to build up relationships based on trust, mutual commitment and understanding of others expectations, which might avoid extra costs and delays [9].

According to Gherardi [34], a shared understanding is needed to apply MC practices, i.e., a minimum agreement is necessary for the practice to be adopted and continue to be used.

Therefore, there must be opportunities for increasing the awareness of different stakeholders regarding MC, as well as for negotiation when deciding to adopt MC practices as a way to promote innovation.

4.3. Assessment of the Utility of the Solution

The utility of the proposed decision categories and the list of practices was tested in two different stages of the empirical study, both in terms of identifying improvement opportunities and assessing the evolution of the MC strategy. The decision categories were also used to increase the CT awareness and understanding regarding key concepts, enabling them to provide numerous examples and opinions during the discussions. In fact, the CT stated that through the discussions they were able to perceive underlying ideas that they overpass in daily routine, and that this can also be useful as arguments when discussing with other departments, which contributes to improve collaboration.

The discussions regarding practices and decision categories were also useful to understand the scope of the MC strategy of Company P, and, more specifically, to identify gaps and limits for implementation. For instance, some of the solution space practices were immediately rejected by the CT, due to limitations of MC scope that were defined by existing capabilities, and focus on specific market segments. Moreover, the customer and customisation manager highlighted that the practices identified in this investigation could be useful to support decision making, such as, for refining the solution space based on the choice of users from previously delivered residential projects. Furthermore, the participants pointed out the need to improve the identification of customers' needs and to provide feedback to NPD as two major gaps in the MC strategy of the company, highlighting the importance of the customer based knowledge decision domain.

Several improvement opportunities provided further evidences of the utility of the customer integration and core decision categories. After the first presentation of research findings, many improvements were undertaken, regarding the communications with other departments, customer interaction and relationship, and visualisation approaches. Furthermore, the refinement of the strategy was also influenced by lessons learned from other segments, projects and experiences. An example is the simplified choice menu that was adopted for some market segments, in which the team had more experience. That successful solution inspired the customisation department to adapt it to A and B product types. This example reinforces the need for creating a knowledge system that enables continuous improvement and organisational learning.

The discussions with the CT also brought to light many relevant customer integration aspects. The CT coordinator highlighted the utility of customer integration decision categories in terms of making explicit what the company offers, and how the customer is involved, which makes the decision-making process as straightforward as possible. In fact, some practices related to product visualisation approaches that were implemented by the company along the study, such as the choice menu, the customised product prototype, and 3D models had a positive impact in terms of explaining the solution space to customers.

5. Discussion

The aim of this research was to devise a framework to support the definition of MC strategies by house building companies regarding customer integration. The framework was initially based on a set of practices obtained from the literature review and on some existing MC conceptual frameworks (e.g., [24,28,30,36]). Furthermore, new MC decision categories and some adaptations on the existing ones have been proposed, for the context of house building projects. This research work has two main contributions in terms of new decision categories, namely "knowledge management" and "customer interaction and relationship". The first one sheds light on the relevance of creating knowledge and disseminating it within the company as a core element of an MC strategy. The second decision category expands the vision of previous research, concerned with defining an interface, to establish a long-lasting relationship with customers, by planning interactions and building trust. Tommaso [50] states that comprehensive knowledge about customers is essential to create relationships and manage customers experience, by anticipating behaviour and needs. This statement brings up the inherent connection between those two decision categories.

The resulting set of decision categories and practices, as well as their relationships, are the building blocks for the proposed framework on customer integration. Figure 5 provides an overview of the framework. It is noteworthy that the framework also includes a set of core decision categories at a higher abstraction level, as customer integration and core decision categories are connected by decision making refinement cycles.

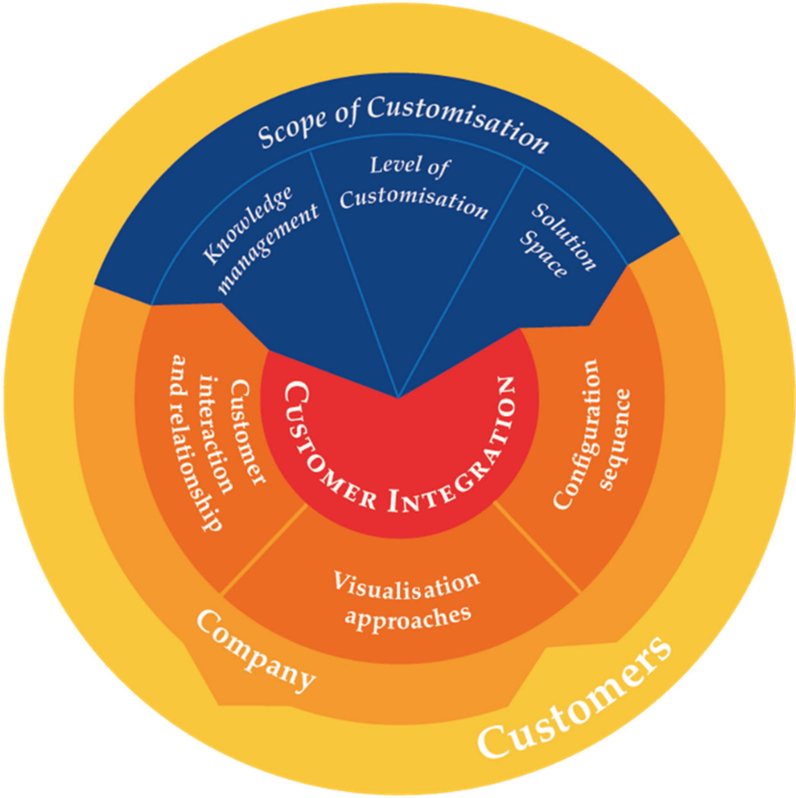

Figure 5. Customer integration framework for customised housing projects.

Firstly, decisions regarding customer based knowledge must be undertaken (Figure 5). Moreover, the definition of the level of customisation and of the solution space must be made, based on understanding the demand for customisation [21,28]. In this research, the level of customisation was assumed to be a strategic decision, being part of a broad definition of product types.

In the construction industry, there are often multiple CODPs, and the level of customisation and the customisation units must be defined for each of them. Therefore, the definition of the solution space follows the level of customisation by specifying the customisation units to be offered in each CODP. The solution space is outstandingly a core element of the MC strategy, as it influences the decisions regarding customer integration. Moreover, both visualisation approaches and configuration sequence decision categories are related to operationalising the solution space offer and supporting customers decision-making regarding the customisation units and product configuration. The customisation level and solution space definition provide directions on how should customer and company interact and establish a relationship.

The development of the framework can also be regarded as a contribution in terms of understanding of MC concepts, decision categories and domains, and their relationships in more detail, as shown in Table 9.

Table 9. Main research contributions—decision categories, source and relationship.

Group	Categories	Main Authors	Key Relationships with Other Decision Categories
Core categories	Solution space	[7,19,21,30,44]	The **solution space** decision category includes the **customisation units** and **classes of items decision domains**. A different set of **customisation units** are offered at each **CODP** defining precisely a **level or different levels of customisation**.
	Level of customisation	[7,21,28,30,35,38,40]	The **level of customisation** has a great influence on the level of **customer integration** and on **operations**. The level of customisation can vary by adopting different **CODPs**. Each **customisation level** defines boundaries for the **solution space** and defines **a CODP**.
	Knowledge management	[9,17,24–27,36,37,45–47]	The definition of a **customer integration** strategy relies on understanding customers demand for customisation, a concern of the **customer based knowledge** decision domain. Furthermore, the same domain influences the definition of the **customisation level and solution space**, by providing systematic information regarding customers needs, preferences and perception of the product in use. Additionally, discussions between departments regarding internal competences and performance of customisation can produce **organisational knowledge** related to the company's capabilities, in order to limit the **solution space**. The **communication of customisation information decision domain** depends on the amount of information produced by the MC strategy, which is closely related to the **level of customisation**. The higher the level of customisation, the higher is the need for sharing information and more intensive collaboration.
Customer Integration	Visualisation approaches	[6,30]	The **visualisation approaches** used to present the **solution space** for customers are defined accordingly to the **customisation level** and **customer interaction and relationship**.
	Configuration sequence	[30]	The **customisation units** can be organised and presented in different **configuration sequences** to facilitate customers' choice.
	Customer interaction and relationship	[14,19,21,22,24,49–51]	The **level of customisation** establishes limits and underpins the **customer interaction and relationship** decision category. **Visualisation approaches and tools** provide support for the implementation of this category.

Finally, as pointed out by some previous studies, customer integration needs to be aligned with operations and product design areas [22,28,30]. Although these areas are not represented in the framework, it is recognised that interactions between decision categories from different areas must be considered when defining strategies. This connection between areas becomes explicit when considering practices, such as, for example, the application of practices 28 and 36 requires information and actions from both customer integration and operations management teams. It means that communication and close collaboration between areas are essential for the successful implementation of practices.

6. Conclusions

The main outcome of this investigation is a framework of decision categories related to customer integration and the definition of the scope of customisation, considering the context of house building projects. These decision categories emerged from a list of MC practices that were identified in the literature and refined in an in-depth empirical study carried out in a Brazilian company that adopted some MC ideas as part of its business strategy. Some of the decision categories have been proposed in previous studies, and refined in this investigation, while two of them, knowledge management, and customer interaction and relationship, have been originally proposed in this research study.

The main theoretical contributions are concerned with exploring the underlying ideas of those practices, which have been used to explain the decision categories and their relationships. Additionally, the list of practices can be used to assess the degree of implementation of core and customer integration practices in house building companies in order to identify gaps in the existing strategy.

This exploration portrays the fruitful context of MC in construction. There are plenty of opportunities to improve value generation, not only for companies that use industrialised construction methods but also in the case of traditional ones. Customer integration seems to be a key area of improvement in house building companies, demanding efforts from different areas, which are not limited to the development of configurators or digital tools.

A major limitation of this investigation is that it was based on a single empirical study. More insights about customer integration could be obtained if other in-depth empirical studies were carried out in companies from other market segments or countries, providing opportunities for refining the framework and the assessment method.

Some opportunities for further research emerged from the discussions of the framework, such as the need to explore the interfaces between functional areas (customer integration, operations management and product design) and also between decision categories. Those interfaces need to be considered as it is expected that effective MC should have a holistic character. Other opportunities include the development of specific frameworks for product design and operations management for mass customised housing.

Another theme to be explored is how the customisation level contributes to different challenges and issues on the adoption of different sets of practices for customer integration. The higher the level of customisation and the degree of integration, the higher the complexity that needs to be dealt with due to the increasing number of stakeholders and product customisable items. Therefore, different types of MC strategies should be explored by considering the need for using different sets of practices or adapting some of them to specific contexts.

Finally, some other future research opportunities were identified regarding specific decision categories. For instance, not much has been explored regarding the configuration sequence decision category and the interdependences between customisation units that need to be considered in the design of choice menus. Another opportunity is the relationship between the solution space and the level of customisation, which has been superficially explored in the literature. Regarding the customer based knowledge decision domain, there are still many opportunities to explore approaches based on information-driven decision making and recommendation systems. Finally, the customer interaction and relationship decision category represents a fertile ground for the further exploration of experience design in mass customised housing.

Author Contributions: Conceptualisation, C.d.S.H.; methodology, C.d.S.H. and C.T.F.; analysis, C.d.S.H.; investigation, C.d.S.H.; writing—original draft preparation, C.d.S.H., C.T.F. and M.E.E.; writing—review and editing, C.d.S.H., C.T.F. and M.E.E.; supervision, C.T.F. and M.E.E. All authors have read and agreed to the published version of the manuscript.

Funding: This research was partially funded by CAPES (Coordination for the Improvement of Higher Education Personnel) an agency under the Brazilian Ministry of Education.

Acknowledgments: We would like to thank Company P for being a partner in this research project, and Luciana Gheller Amorim and Manoela Conte for the cooperation and support during the empirical study.

Conflicts of Interest: The authors declare no conflict of interest.

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4 Method for capturing demands for housing customisation: balancing value for customers and operations costs (Paper 2)

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Published in Journal of housing and the built environment Published online 04 April 2021.

Link: https://link.springer.com/article/10.1007/s10901-021-09838-9

Journal of Housing and the Built Environment
https://doi.org/10.1007/s10901-021-09838-9

ARTICLE

Method for capturing demands for housing customisation: balancing value for customers and operations costs

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Received: 20 January 2020 / Accepted: 19 March 2021

Abstract
Mass customisation is a business strategy for house building companies to improve value generation and obtain a competitive advantage by offering the product variety that meets customers' needs and, at the same time, maintaining costs and delivery time within market expectations. Companies aiming to define product variety should be able to assess the value of customisable attributes, as well as, estimate additional costs for both customer and themselves. This paper proposes a method for capturing customers' demands to support the definition of the solution space in mass customised housing projects, based on preference models and the willingness-to-pay approaches that regard customer´s value, and its trade-offs with operations costs. The method was applied in an exploratory study with potential customers of the main social housing program from Brazil for initially testing its utility. The method was useful for identifying the most relevant housing customisable attributes and for estimating customers' willingness-to-pay for different housing alternatives based on the preference model. The findings were summarised to support the definition of the solution space by indicating customers' propensity to buy according to operations costs and profitability for each product alternative.

Keywords Housing · Mass customisation · Stated choice · Preference modelling · Willingness-to-Pay

1 Introduction

Many housing programs in developing countries, such as Brazil (Kowaltowski & Granja, 2011), Chile (Greene & Ortúzar, 2002), Ecuador (Martinez et al., 2017), and Mexico (Noguchi & Hernández-Velasco, 2005), have adopted mass production ideas, such as

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Published online: 04 April 2021

repetition and large scale standardisation, aiming to simplify financial procedures and reduce production costs. The adoption of such ideas tends to reduce product variety substantially, neglecting the fact that there is an increasing diversity of requirements between dwellers (Formoso et al., 2011; Hentschke et al., 2014; Kowaltowski & Granja, 2011; Martinez et al., 2017; Noguchi & Hernández-Velasco, 2005). Furthermore, the large scale of those programs makes it difficult for customers to have a high level of involvement in the development of housing projects (Baldauf et al., 2020; Kowaltowski & Granja, 2011; Kowaltowski et al., 2018).

By contrast, society is rapidly changing, and there is a growing diversity of customer requirements in housebuilding, due to different household profiles and lifestyles (Jansen, 2014). Therefore, the perception of value of housing attributes is continuously changing due to evolving family profiles, lifestyle and the subjectivity involved in the assessment of housing products (De Medeiros et al., 2016; Greene & Ortúzar, 2002; Jansen, 2014). Moreover, customers are becoming more demanding: they make their housing purchase decisions according to expectations and preferences, based on the economic and social contexts (Greene & Ortúzar, 2002; Jansen, 2014; Jun et al., 2020; Olanrewaju & Wong, 2019). Therefore, the misfit between housing products and individual requirements of households lead to dissatisfaction and encourages them to make several changes in dwellings after project delivery (Hentschke et al., 2014; Olanrewaju & Wong, 2019). According to Baldauf et al. (2020), managing customers' requirements can play a key role in social housing programs, due to constraints in the purchasing power of dwellers, and to the limited resources available for funding, and often poor identification of households' needs. Therefore, both customer preferences and real-world constraints, such as price, regulations, market and availability, must be considered in the development of housing projects (Jansen, 2014; Jun et al., 2020).

Mass Customisation (MC) is a business strategy that has been used to increase the value of different types of products, by delivering products that fulfil specific customers' requirements through flexible processes with delivery times and costs similar to mass production (Pine II, 1994; Silveira et al., 2001). It has been adopted in different sectors to increase value generation, including house building (Hentschke et al., 2014; Noguchi & Hernández-Velasco, 2005). Some potential benefits of MC in housing are, from one hand, increasing satisfaction due to the proper consideration of households' requirements into new product development (NPD) (Frutos & Borenstein, 2004; Lee et al., 2018; Martinez et al., 2017), and lead to the " I designed it myself" effect (Lee et al., 2018). On the other hand, premium prices that can be charged by developers for products that meet specific customers' needs (Larsen et al., 2019) and establishing close relationships with customers to build trust (Kaur Sahi et al., 2017).

In MC, it is assumed that product variety must be limited, and should be determined from a deep understanding of customer demands (Fettermann et al., 2019; Fogliatto & da Silveira, 2008; Fogliatto et al., 2012; Frutos & Borenstein, 2004). In other words, it is essential to know which are the most relevant customisable attributes for costumers, to support the definition of the solution space (Barlow & Ozaki, 2003; Ferguson et al., 2014; Franke & Hader, 2014; Piller et al., 2004). The solution space defines a set of customisation units (i.e., customisable attributes and their options), which can be combined in specific ways, and the feasible alternatives may be offered to customers through choice menus (Salvador et al., 2009).

Over the last decades, research on MC has evolved, and new topics have been explored, such as customer integration and relationship (Ferguson et al., 2014; Fogliatto et al., 2012; Larsen et al., 2019). Nevertheless, some aspects have received little attention in the literature, such as: (i) understanding customers' demands (Fogliatto et al., 2012) and willingness-to-pay (WTP) (Hentschke et al., 2020a); (ii) design and implementation of choice menus (Franke & Hader, 2014); and (iii) the definition of solution space (Larsen et al., 2019; Salvador et al., 2009).

The focus of this investigation is on customers' preferences, with the aim of providing support decision-makers in the development and design of housing projects, such as architects, house building developers, and funding agencies (Jansen, 2014; Jun et al., 2020; Kam et al., 2018). Two different perspectives may be considered when studying those preferences: the actual choice and the original preference, termed, respectively, revealed preference (RP), and stated preference (SP) (Jansen, 2014; Jun et al., 2020; Vasanen, 2012), although the factors that affect those preferences may be the same (Jun et al., 2020). According to Jansen (2014), SP represents an unconstrained evaluation of attractiveness, e.g. when answering a survey, while RP represents actual and observed choices made by individuals (Ortúzar & Willumsen, 2011).

SP techniques, such as conjoint analysis (CA) and stated choice (SC), have been suggested to support the definition of the solution space by estimating consumers' preferences and choice regarding product alternatives (Ferguson et al., 2014; Fogliatto & da Silveira, 2008). In fact, they have been applied in several studies to estimate housing preferences providing contributions concerned with: (i) understanding preferences regarding value-adding attributes (Granja et al., 2009; Greene & Ortúzar, 2002); (ii) providing relevant information to support NPD by house building companies (Molin et al., 2001); (iii) housing recommendation systems (Jun et al., 2020); and (iv) definition of customisation level (Schoenwitz et al., 2017).

One of the main challenges regarding the definition of a solution space is finding a balance among the variety of options offered and operations costs. Both Fogliatto and da Silveira (2008) and Schoenwitz et al. (2017) pointed out the need for methods to define solution spaces, considering customers' demands and preferences, and trade-offs between variety and complexity. However, none of the previous SP applications has considered customers' WTP or explored trade-offs in the definition of the solution space regarding customers' value and operations costs. In fact, some previous applications of SP to estimate housing preferences have considered price as an independent factor or a product attribute with limited levels (e.g.Brandli & Heineck, 2005; Greene & Ortúzar, 2002; Jun et al., 2020; Molin, 2011). Nevertheless, a key factor that influences the choice of customers is their WTP for a specific product alternative, i.e. they seek the highest value when choosing a combination of attributes that configure an alternative, considering price elasticity (De Medeiros et al., 2016). Thus, within the context of MC, one of the most attractive benefits of applying this technique is to find out which are the customers' preferred alternatives and how much they are willing to pay for them. By indicating customers' WTP, preference models can be used to estimate the customers' buying propensity based on a price range.

The aim of this paper is to devise a method to capture customers' demands for customisation of housing projects, by combining a choice-based experiment, a WTP approach, and an estimation of operations costs. The proposed method seeks to provide an overview of the customers' preferences and their WTP for housing alternatives to support decision-making regarding the solution space. The proposed method relies on three core elements: (i) a choice-based experiment designed for understanding customers preferences regarding customised housing projects; (ii) an adaptation of a logistic regression model for estimating customers' WTP for housing alternatives; and (iii) a graphical tool for displaying trade-offs between value for customers and additional costs resulting from customised housing alternatives. An additional contribution regards the demonstration of the utility of the method in an exploratory study. This research work is part of a doctoral thesis, from which the initial findings were published in Hentschke et al. (2020a).

This paper is structured in eight sections, including the introduction. Section 2 presents the theoretical background, including MC related concepts, such as solution space, perceived value and choice menu, and preference modelling and WTP. In Sect. 3 and 4, the research approach and the research stages are described. The proposed method is described in Sect. 5, followed by an exploratory study carried out to test its utility, presented in Sect. 6. Then, in Sect. 7, the utility of the method and its limitations are discussed. Section 8 addresses the conclusions and opportunities for future research.

2 Theoretical background

2.1 Definition of the solution space

The adoption of MC strongly depends on the company's ability of translating customers demand into products and services (Ferguson et al., 2014; Silveira et al., 2001). It means that knowledge about customers' needs, desires and expectations should be captured and communicated during NPD (Zogaj & Bretschneider, 2012). Besides providing an understanding of their demand, knowledge acquired from customers can inspire new developments and product innovation, and also provide guidance to limit or expand product variety (Kotha, 1995; Piller et al., 2004).

Companies must define a solution space, based on the customers' demands and feedback regarding the product in use, and establish whether and how those will be meet (Fettermann et al., 2019; Salvador et al., 2009; Schoenwitz et al., 2017). Thus, companies should define their solution space by identifying what generates value for customers regarding customised products (Hart, 1995; Piller, 2004; Squire et al., 2004). According to Woodruff (1997), customers perceived value is an assessment carried out through a comparison between received benefits (e.g. utility, quality) and sacrifices made to obtain the product (e.g. time, price, effort). In other words, customers' perception of value increases when they can choose from a range of product attributes, foreseen as benefits, for which they are willing to pay for, according to their cognitive and economic limits (Ferguson et al., 2014) and reflecting the augmented utility of such products (Piller, 2004).

The solution space is often presented to customers by a choice menu, which can guide the decision-making process involved in the configuration of a product (Piller, 2004). Beyond that, choice menus can also be regarded as learning tools, as they provide feedback to the company by guiding customers through the configuration process to define a solution that better meets their needs and improves value generation (Franke & Hader, 2014). Indeed, companies can refine their solution space, by providing better options for the attributes often chosen by customers, and eliminating the ones that are rarely demanded (Salvador et al., 2009; Schoenwitz et al., 2012).

Choice navigation refers to supporting customers to identify or to configure products based on their preferences and needs, while minimising the burden of choice (Salvador et al., 2009). This means that, although customers seek product variety, it is recommended that companies limit their set of customisable attributes to achieve economies of scale in processes (Fettermann et al., 2019; Martinez et al., 2017) and to avoid overwhelming customers and confuse them with a large number of options (Salvador et al., 2009; Schoenwitz et al., 2017). These limits are particularly important in housing, due to a large number of customisable attributes that can make the decision-making process for customers highly complex (Frutos & Borenstein, 2004; Hentschke et al., 2014; Nahmens & Bindroo, 2011; Schoenwitz et al., 2012).

2.2 Stated preference and willingness-to-pay

SP techniques are concerned with the collection of data regarding customers buying intentions towards hypothetical product alternatives (Ortúzar & Willumsen, 2011). The most commonly used SP techniques are contingent valuation (CV), conjoint analysis (CA), and stated choice (SC) (Ortúzar & Willumsen, 2011). Those techniques measure consumers' preferences based on decision trade-offs: the respondent (i.e. customer) should state a choice facing a set of product alternatives, which vary across attributes assessed in a survey (Green et al., 2001). It means that customers' decision-making process depends on the mental assessment of trade-offs between product or service perceived benefits (e.g. utility of the product) and sacrifices (e.g. undesired attributes and costs) (Rietveld, 2018).

Differently from other multi-attribute techniques, in which the relevance of each attribute is independently evaluated, in SP product alternatives are assessed as aggregate solutions by equalising trade-offs between the perceived value of the attributes (Molin, 2011). It is also useful for market segmentation, enabling the investigation of the relevance of the attributes and consumption behaviour of different customers groups (Fogliatto & da Silveira, 2008; Kalantari & Johnson, 2017). However, the results of this technique should be carefully considered, as these are not absolute predictions of market shares, but reflect a probability of the choice of a good by a sample of respondents (Molin, 2011). Another limitation of those techniques is the dualism between assessing a large number of attributes and product alternatives possible in the survey and considering the limits of human cognitive capacity for assessing them at the same time (Kalantari & Johnson, 2017; Louviere et al., 2000; Rose & Bliemer, 2009). Furthermore, Ortuzar and Willumsen (2011) argue that traditional CA is limited by the use of rating or ranking scales, because "respondents in real life do not rate or rank alternatives and, even if they did, different people would approach such scales in psychologically different manners".

The differentiation between SP and CA in the literature is somewhat controversial. CA was devised in the area of statistics (e.g. Luce & Tukey, 1964) and expanded to be used in the field of marketing (e.g. Green et al., 2001; Green & Wind, 1975). It has evolved over the years to be applied in the area of transportation, being more commonly called SP (e.g. Ortúzar & Willumsen, 2011; Rose & Bliemer, 2009). In this investigation, the definition proposed by Ortúzar and Willumsen (2011) was adopted: SP is an umbrella of techniques to measure customers' preferences regarding hypothetical product alternatives. The main difference between SC and CA is the response scale: while in CA respondents should rank or rate the given alternatives, in SC, respondents must choose their preferred alternative from a choice set (i.e. a block of product alternatives) (Ortúzar & Willumsen, 2011). The same authors state that, in SC, few product alternatives are shown at the same time, and then changed, demanding from the respondents to repeat the choice task. Furthermore, Louviere et al. (2000) argues that the traditional CA should be carefully used in economic applications, as ranking or rating scales do not readily translate into choice or matching data (e.g. direct expression of WTP), the premises on which utility theory is based.

According to Orzechowski et al. (2005), SC is the technique most similar to real choice-making processes in MC, being a suitable alternative for this context. Franke and Hader

(2014) suggest the application of SP in that context, because of the similarity between the process of decomposing products into attributes and levels to define the solution space, and the preference measurement based on the effect of the attributes in product alternatives chosen by customers. Fogliatto and Da Silveira (2008) proposed a method to design choice menus, based on SP, which can support the development of market-responsive strategies. Thus, in this investigation, SC was chosen because of its potential to assess perceived value in mass customised housing, based on the trade-offs done between attributes, for choosing product alternatives.

Preference models are based upon the premise that customers' SP are estimates of the purchasing intentions, resulting from the combination of the relevance of product attributes (Jansen et al., 2011). According to Earnhart (2002) and Greene and Ortuzar (2002), SC can be used to estimate discrete choice models (DCMs), in which dwellers choose a house from a large set of product alternatives by finding the maximum utility, through a combination of attributes. Such models provide a decision protocol for selecting the best alternative available for an individual, who is assumed to behave as a rational consumer (Greene & Ortúzar, 2002).

WTP can be assessed by different RP and SP techniques, such as market data and experiments (Breidert et al., 2006); CV [e.g.(Lermen et al., 2020; Ortúzar & Willumsen, 2011)] and SC (e.g.Molin, 2011), respectively. After collecting data, according to Sillano and Ortúzar (2005), there are different methods that can be used to estimate the WTP of respondents from the discrete choice models, such as ratios of population means, log-normal distribution for WTP, and fixing the cost coefficient. Discrete choice analysis can be used to assess customers' WTP by estimating the latent structure of customers' preferences regarding product alternatives, which is commonly done by applying a logit model (Breidert et al., 2006; Kalantari & Johnson, 2017), or mixed logit models, which better considers profile and taste heterogeneity (Molin, 2011; Ortúzar & Willumsen, 2011; Sillano & Ortúzar, 2005).

3 Research method

3.1 Research approach

Design science research (DSR) was the methodological approach adopted in this investigation. It consists of devising an innovative solution concept (or artefact) to solve a class of real-world problems, and, at the same time, providing a prescriptive scientific contribution (Lukka, 2003). According to March and Smith (1995), there are different types of outcomes in DSR: models, constructs, methods and instantiations. In this research work, the artefact is a method to capture customers' demands regarding customised housing projects, to support the definition of solution spaces. This method is meant to be used by housebuilding companies in the design or refinement of the solution space, by aligning the offer of customisable attributes with customers' expectations, and considering the operations costs involved.

Similarly to the DSR process suggested by Lukka (2003), this investigation was divided into three main stages: (i) identification of a relevant practical problem and understanding the theoretical background; (ii) design and test of the solution (iii) assessment of the solution and discussion of the theoretical contribution.

4 Research stages

Stage 1 started by understanding the context of affordable housing in Brazil, based on a literature review on social housing, as well as on secondary data from a previous study that have assessed customer's preferences and changes made after occupancy in social housing projects (Hentschke et al., 2014). The main outcomes of this stage were an understanding of the diversity of customers' requirements in social housing, and knowledge about additional costs of customisation, based on the most frequent changes of product attributes demanded by customers.

In the second stage, the artefact was developed, by combining SC, preference modelling and a WTP approach, as detailed in Sect. 6. The method was based on a literature review on SP and WTP approaches, and on studies that have previously adopted those approaches in housing. The four phases of the proposed method were applied in the exploratory study with potential customers of housing projects. These were: (i) Context Understanding; (ii) Experiment Planning; (iii) Customer Preference modelling; and (iv) Balancing customers´ preferences and operations costs. In the context understanding phase, documents from the current main Brazilian housing program, My House My Life (MHML), as well as, some studies regarding customers demand in housing were reviewed, to define the purpose of the application, identify the target audience and define the sampling criteria.

During the experiment planning phase, the relevant attributes were identified and their levels were defined based on data gathered in previous studies (Hentschke, 2014; Hentschke et al., 2020b). The stated choice with two-stage stimulation method was chosen, due to its ability to reduce the number of product alternatives to be considered by respondents by blocking them into choice sets, and at the same time, confirm the respondents preference in a more extensive set at the second stimulation stage (Battesini & Caten, 2005). Furthermore, within a choice set, the product alternatives compete with each other as occurs in the real purchase situation. In the first stage, respondents make a preliminary choice for a product alternative and, at the second stage, respondents refine their choice by selecting one of the previously chosen product alternatives from the first stage (Battesini & Caten, 2005). Then, a full factorial design of the experiment (DOE) was carried out, and the resulting alternatives were blocked and randomised to distribute the probability of choice in each choice set and to enable the first stimulation stage. A full factorial DOE consists of all possible choice situations: it enables the estimation of the main effects of attributes and their interactions, being influenced only by the number of attributes and levels (Rose & Bliemer, 2009). This step was followed by the definition of nominal price (np), the development of the questionnaire, and survey planning.

The questionnaire devised for the survey was structured in three sections as follows: (i) introduction and filtering (six questions); (ii) product alternative preferences (five questions); (iii) profile of respondents (seven questions). The first section includes questions about the interest of the respondent in buying a new home, location, type of home and family income. These questions enable the selection of respondents by filtering them according to the sample criteria. In the second section, respondents express preferences for different product alternatives by choosing the favourite one in each choice set. Afterwards, respondents refine their choice by answering the fifth question (i.e. second stimulation stage), in which they state their preference regarding one of the previously chosen product alternatives. In the third section, questions related to the profile of respondents were asked, such as gender, age, level of education, number of family members, among others. The proposed questionnaire was tested face-to-face to refine its language and structure, taking from 20 to 30 min to be completed. Then the questionnaire was tested online by approximately ten respondents in Survey Monkey® before being effectively used for collecting data.

The survey was available online for a month, being disseminated by using university social media and e-mail focusing on MHML potential buyers. Altogether, 344 questionnaires were returned, from which only 80 respondents fulfilled the sampling criteria of: (i) income from U$642,57 up to U$2.141,12 (3–10 minimum wages); and (ii) willingness to buy a new home in the metropolitan area of Porto Alegre in the next 2 years. Due to the exploratory character of the study, this small sample was considered as sufficient for an initial assessment of the utility of the proposed method. However, due to the small sample size, the results cannot be generalised.

A descriptive analysis of the survey results was initially undertaken to obtain a general understanding of data, and a logistic regression was applied to estimate attributes relevance. The logistic regression technique was chosen due to its potential to model categorical variables and explain the occurrence of a specific event, by relating a categorical response variable to explanatory variables (Hosmer & Lemeshow, 2000). The response variable considered was the product alternative frequency of choice, and the model relates the attributes, which are categorical variables, with the choice of the product alternative that is represented by a dichotomy: 1 for the chosen one and 0 when not chosen. In other words, the response variable can be regarded as the probability of choice of the product alternative when a specific attribute is customised. Afterwards, customers' preference modelling was undertaken by applying the proposed regression model to estimate WTP, according to the propensity to buy. Finally, the information was summarised in a WTP profile graph, meant to support decision-making on the solution space.

Stage 3 involved an internal assessment of the method's utility, based on the following criteria: (i) support decision-making regarding the definition of the solution space; (ii) support the identification of improvements for standard housing products; and (iii) support decision-making regarding the balance between customer value and operations costs.

4.1 My house my life program

The target population of the exploratory study was the potential beneficiaries of MHML program. This housing program was launched in 2009 to reduce housing shortage in the country for households that earned from 0 to 10 minimum wages (Kowaltowski & Granja, 2011; Valença & Bonates, 2010). More than 4.1 million dwellings were delivered, and 10.5 million people have been beneficiated by the program between 2009 and 2019 (Moreira et al., 2017; BRASIL, 2019). Its main focus is to deliver affordable houses and apartments, usually including the necessary infrastructure for a housing estate (Kowaltowski & Granja, 2011). Differently than previous housing programs in Brasil, MHML involves private companies in the development of low-income housing projects (Kowaltowski & Granja, 2011).

The Ministry of Cities and National Savings Bank establish additional regulatory requirements for MHML program to guide the design of urban and housing developments, complementing other applicable regulations, such as city master plans and building codes (Baldauf et al., 2020; Kowaltowski & Granja, 2011). The set of minimal requirements for MHML projects includes the minimum floor area (39 m^2), internal and external finishings, windows and external doors, and guidance regarding furniture to be installed among others (Ministerio das Cidades, 2017). Figure 1 presents two examples of housing units, the two-bedroom apartment with 47 m^2 and the three-bedroom apartment with 61 m^2 approximately.

(a) (b)

Fig. 1 MHML FGTS Housing unit examples: **a** two-bedrooms apartment; **b** three-bedrooms apartment

5 Proposed method

Figure 2 provides an overview of the proposed method, which is divided into four phases, as mentioned in the previous section. The sequential relationships between activities are pointed out, as indicated by arrows.

5.1 Context understanding

The aim of the context understanding phase is to clarify the aims of the study and to define the objects of interest, as suggested by Ortuzar and Willumsen (2011). Different sources of evidence can be used, such as literature review, interviews with representatives of house building companies, results of surveys with potential customers, and observation of housing changes made after occupancy in similar projects. The primary outcomes of this phase are the definition of the purpose of the application (i.e. whether it is a new solution space or the refinement of an existing one), the identification of the target audience, and the definition of the sampling criteria.

According to Ortúzar and Willumsen (2011), after obtaining a deep understanding of the context, researchers need to identify and understand the population of interest. Therefore, the definition of the target audience and sampling criteria must carefully defined. Moreover, characteristics from this population that could influence decision-making, such as income, gender, and number of family members, should be identified and considered in the definition of the sample. Furthermore, this first phase of the method provides insights for the selection of relevant attributes, definition of the type of questionnaire and experimental design as suggested by Hentschke et al. (2020b) and Ortúzar and Willumsen (2011).

5.2 Experiment planning

The experiment planning phase consists of an adaptation of SP. Based on Green et al. (2001) and Molin (2011), SP was divided in five steps, as shown in Fig. 2. In step 4, a combination of attributes relevant for customers (i.e. factors) is identified as well as the levels in which they can vary are defined. Louviere et al. (2000) and Green et al. (2001). The

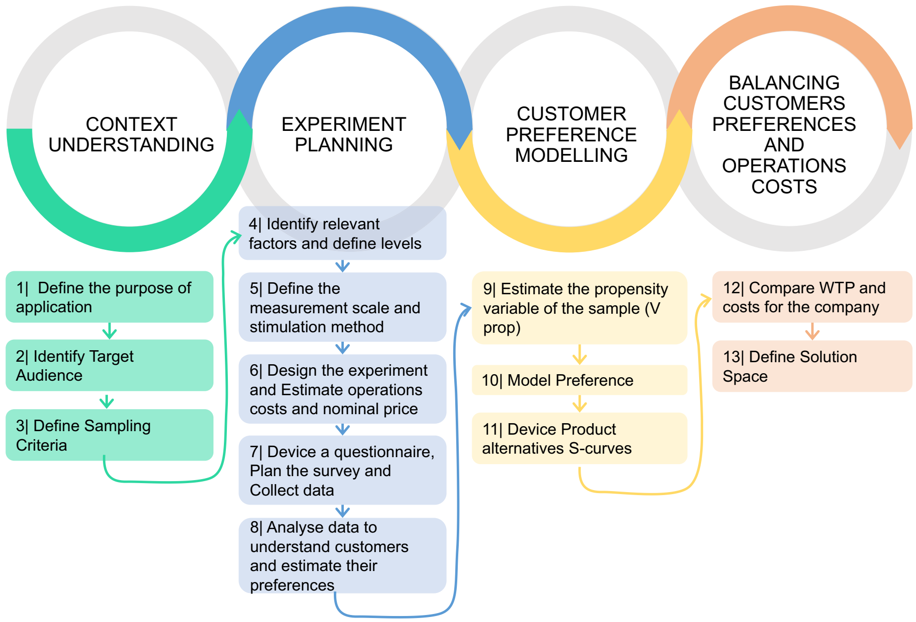

Fig. 2 Method for capturing demands for housing customisation

definitions of attributes, levels and product alternatives should be based on reliable sources of information, such as surveys with customers, business expertise and qualitative research on the topic (Green et al. 2001; Louviere et al., 2000; Ortúzar & Willumsen, 2011).

In step 5, the measurement scale to be used must be defined, usually from choice (e.g. SC or CBCA), rating or ranking (e.g. CA) (Greene & Ortúzar, 2002; Molin, 2011; Ortúzar & Willumsen, 2011) as well as the stimulation method. An important adaptation made in this phase was the definition of a choice scale and two-stage stimulation, in order to simulate a realistic residential acquisition process and reducing respondents' effort for choosing, without compromising the capacity of modelling consumers' preferences, respectively, based on the method proposed by Batesini and Ten Caten (2005).

In step 6, the experiment is designed by combining attributes and levels into product alternatives, establishing which set will be presented to customers (Ortúzar & Willumsen, 2011; Rose & Bliemer, 2009). The decision regarding the DOE depends on the number of factors and levels, to combine attributes in product alternatives. The application of DOE techniques assures to the researcher the estimation of attributes effect on customers' choice (Echeveste & Mossé, 2017). Several design techniques might be considered (Rose & Bliemer, 2009), such as full or fractional factorial DOE (Green et al., 2001; Louviere et al., 2000; Ortúzar & Willumsen, 2011). This process results in an experimental matrix to be translated by researchers into meaningful information for respondents so that each line represents a product alternative to be tested (Ortúzar & Willumsen, 2011; Rose & Bliemer, 2009).

At step 6, another adaptation proposed by this investigation was made related to the estimation of operations costs and nominal prices for product alternatives. Furthermore, the operations cost estimates must consider both direct costs (e.g. material, labour, equipment)

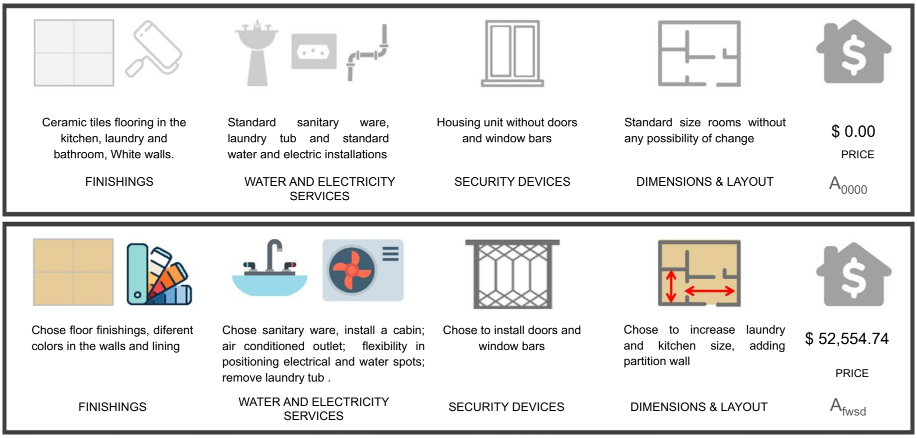

Fig. 3 Prop cards examples

and indirect costs (e.g. administrative costs, site costs, risks) and the nominal price of product alternatives embody the cost of the standard housing unit, additional costs of customisation units, and a profit margin. Therefore, this phase should be based on detailed cost estimates carried out by the company. The resulting product alternatives and nominal prices are used in the questionnaire design and preference model.

Then, in step 7, the questionnaire is devised, the survey is planned, and the data is collected from a sample of customers or potential customers considering the defined criteria. Each product alternative is illustrated in a prop card (see Fig. 3) which combines short paragraphs with graphic elements. The prop cards can reduce ambiguity, facilitate understanding and support choice-making (Green et al., 2001; Orzechowski et al., 2005).

In step 8, data is analysed by using statistical techniques and estimation methods. Firstly, a general understanding regarding customers' preferences regarding product alternatives must be obtained with the aim of defining the relevance of each attribute. Customers' preferences regarding product alternatives and attributes can be estimated by: (i) decomposing the overall utility through a utility function (Breidert et al., 2006; Green et al., 2001; Molin, 2011), (ii) applying statistical techniques such as LOGIT (Breidert et al., 2006), multinomial logit models (MNL) (Molin, 2011; Ortúzar & Willumsen, 2011) and mixed logit models (Ortúzar & Willumsen, 2011; Rose & Bliemer, 2009). Results from this phase, such as DOE, nominal prices of product alternatives and frequency of choice are used to model customer preferences.

5.3 Customers' preference modelling

The customers' preference modelling stage consists of the estimation of the WTP and propensity to buy mass customised housing by applying an adaptation of the logistic regression model. Firstly, the propensity to buy is estimated according to the choice frequency from the data collected converted in a proportion (%) of customers who have chosen a given product alternative. Then, for modelling customers' preferences, the presence or absence of customisable attributes are considered as independent variables (X), and the customers' stated preference through the observed propensity to buy (%) is the response variable (Y), as detailed in

Eq. (1). In this model, the expected value of Y is a Logit (π), as explained in Eq. (2). The unknown parameters are estimated by applying a logistic regression (Eq. 1).

$$Logit\pi = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 +, \ldots ..\beta_k X_k \tag{1}$$

$$Logit(\pi) = Log\left(\frac{\pi}{1-\pi}\right) = \alpha + \sum \beta_k X_k \tag{2}$$

It is noteworthy that $\left(\frac{\pi}{1-\pi}\right)$ represents the *odds ratio*, which is the probability of a product alternative, a combination of X's, being chosen. In this case, the logit function was used for modelling the best fit of purchasing decision, agreeing with initial results of the regression into an S-curve, in which the expected values are probabilities varying from 0 to 1. This model is expressed in Eq. 2, in which the beta coefficients (β_0, β_1, β_2, β_3… β_k) can be regarded as estimates of the part-worth utility and the response variable used is the observed propensity to buy.

The proposed model considers customers' preference and monetises this function by considering two constants seeking for the nominal price best fitting (K_1 and K_2), based on the maximum likelihood estimation method. This method seeks to obtain the parameters of the population that is most likely to have generated by the collected sample (Hosmer & Lemeshow, 2000). The economic perspective is reinforced by considering the nominal price of the product alternative as the response variable and a monetised form for considering customers' WTP in the model.

The constants K1 and K2 are calibrated according to the indicators of goodness-of-fit model and included in the model to achieve the best prediction error of regression estimates. K_1 is the constant that adjusts the propensity to buy according to the optimum price (i.e. that every customer would pay for the customisation) and represent the WTP. The second constant, named K_2 converts the values back on an estimated propensity to buy regarding the product alternative. It also indicates the steepness of the curve, which illustrates how fast the decision changes from Y=0 para Y=1. It means that the higher slope factor has the curve, the faster is the change in the decision of buying the property. The estimated propensity for choosing a product alternative is determined by the observed proportion of choice of each product alternative, adjusting the preference model to what is observed in the real sample. The constants and beta coefficients of the model should be obtained considering the objective function: (i) maximising the coefficient of determination r^2; and (ii) minimising the error between the observed propensity to buy and the estimated propensity to buy for the S-curve. This results in the S-curve function of customers´ WTP expressed by Eq. (3).

$$\pi = exp - [\max(0; f(s))]$$

$$f(s) = \left(\left[Y_{price} - K_1 * \left[\sum_{K=0}^{K1} \beta_k X_k\right]\right] * 1/K_2\right)^n \tag{3}$$

where: β_0 β_1 β_2 β_3 ….β_k: angular coefficients that represent the utility of each factor, K_1: elasticity coefficient, K_2: Steepness of the curve, n: asymmetry coefficient, X_k: presence or absence of the attribute k in the product alternative, 1 or 0, Price A_i: is the estimated nominal price of product alternative A_i.

This equation must be applied for each product alternative to estimate the corresponding customers' WTP. According to De Medeiros et al. (2016), customers' WTP can be illustrated by an S-curve, involving the price elasticity and percentage of customers that would buy the product. In this case, the S-curve is built upon the estimated propensity to buy and a price range, defined for each product alternative, establishing the limits X_{min} and X_{max}. Furthermore, X_{min} is the nominal price that every customer would probably pay for the property (≅ 100%), while X_{max} represents the value that no consumer would pay for, meaning that the probability is ≅ 0%.

5.4 Balancing customer preferences and operations costs

This phase aims to support the definition of the solution space for housing projects, considering the balance between customers' preferences and operations costs regarding product alternatives. It considers the operations cost and nominal prices defined in step 6, and customer preferences and propensity to buy that is compared in a WTP profile graph and a table. These devices are developed by combining the S-curves for product alternatives assessed by customers and operations costs limits and profit margins. An example is provided in the results section.

6 Results

The results of the exploratory study are presented, following the four stages and 13 steps presented in Fig. 2.

6.1 Context understanding

The target population of this exploratory study was potential beneficiaries of MHML from the Metropolitan Region of Porto Alegre, where the price limit for housing units is R$ 200,000.00 (Lis & Amaral, 2017) or US$ 48,661.80. The exploratory study was limited to bands 2 and 3 of MHML, which beneficiates people with monthly income between U$642,57 and U$2.141,12 (3–10 minimum wages) (CAIXA, 2018). The housing unit can be financed to the households up to 30 years, with an interest rate of five per cent, and the monthly payment cannot exceed 30% of the family income (CAIXA, 2018). In these bands of the program, there is less involvement of the local authorities and lower subside of the federal government that in the lowest income band (Klink & Denaldi, 2014). Thus, MHML provides loans for house building companies to buy land and develop housing projects, considering the 22% margin for covering indirect costs and profit (CAIXA, 2015). All the information regarding the program was used to define the attributes of standardised product alternatives and nominal prices.

A previous study on changes made by users of social housing projects after occupancy (Hentschke, 2014) was used as a source of evidence to understand the demand for customisation in this context, especially regarding the frequency of changes made and desired in affordable housing.

6.2 Experiment planning

The definition of factors (i.e. a set of attributes) was based on two previous studies, one that established a ranking of the most frequent changes made after occupancy in MHML projects (Hentschke, 2014), and another that identified preferred attributes regarding customised low-income housing (Hentschke et al., 2020b). The four factors considered were: (F) finishings; (W) water and electricity services; (S) security; and (D) dimensions and layout. The levels defined were the presence of customised attributes (+1), in which a set of product characteristics that could be customised; and the absence of customised attributes (−1), representing a standard option of the attribute delivered by house building companies, as presented in Table 1. In this investigation, the attribute security is concerned with the protection of people or buildings against robbery and violence (Cambridge Dictionary, 2020), by using physical elements, such as bars in doors and windows.

As mentioned before, SP with two-stage stimulation method was selected, and the defined measurement scale was 'choice'. The experiment was designed by applying a full factorial of 4 two-level factors, 2^4, resulting in 16 product alternatives to be assessed by respondents. Considering that choosing from 16 different product alternatives at the same time would overwhelm respondents, those alternatives were randomly blocked into four choice sets of four product alternatives, meant to be shown in the first stimulation stage. Then, after performing four choice tasks, in the second stimulation stage, the respondents selected one alternative among the four previously chosen. The product alternatives were named according to the customised attributes considered, through the combination of the respective factor letter and the absent attributes (−1) represented by a zero "0". For instance, A_{0000} represents a standardised apartment, and A_{fwsd} represents the fully customised one. Thus, each alternative resulting from the experimental design was then presented in a prop card (Fig. 3).

Besides the attributes, the prop cards included the nominal price (np) of the product alternatives. The np and operations costs of each product alternative were estimated, based on the housing program rules and local market practices. First, the cost of each attribute was calculated by considering both a minimum estimate of direct cost,[1] plus a margin of 60%, which embodies indirect costs and a profit margin. Afterwards, nominal prices were estimated, considering the presence or absence of each attribute in the product alternative, adding it to the price of the standardised unit, which was US$ 48,661.80. The price of the standardised unit embeds direct costs, 2% of indirect costs and a profit margin of 20%. Thus, operations costs of each product alternative result from its nominal price minus a 20% rate that would represent only the profit margin. These nominal prices and operations costs represent general estimates as they were based on hypothetical housing projects eligible for MHML program. The DOE and np are further detailed in Table 2.

Considering eighty completed questionnaires, half of the households had a monthly income from U$642,57 up to U$1.284,67 and half earned from U$1.284,81up to U$2.141,12. Sixty-six respondents would buy a two or one-person home, mostly couples (37) (Fig. 4d). Regarding household gender, 50 respondents (63%) were female (Fig. 4a). The age of respondents varied from 20 to 65 years old, and most of them were from 20 up to 29 years old (Fig. 4b). The level of education of the households was balanced between graduate and postgraduate (Fig. 4c). The respondents' age and the high level of education seem to have been influenced by the dissemination methods used in this exploratory study by promoting the survey via social media and contacts made mostly by postgraduate and undergraduate students.

[1] The minimum cost of construction work was established based unitary costs estimated by on SINAPI (a Building Cost Index System run by the Brazilian Government) and an average amount of construction work in housing units of MHML Program.

Table 1 Attributes, levels and description

Factors	Level	Description
Finishings (f)	− 1	Housing units with ceramic tiles only on wet areas and all rooms painted in white
	+ 1	Customised floor finishings, walls painting and lining
Water and electricity services (w)	− 1	Housing unit with standard options for sanitary ware, laundry tub and electricity services
	+ 1	Customised sanitary ware and adding a shower cabin; remove laundry tub to install washing machine; add an air conditioning power outlet; change the position or add power outlets
Security (s)	− 1	Housing unit without any security devices
	+ 1	Customised by adding doors and window bars
Dimensions and layout (D)	− 1	Standard room sizes
	+ 1	Customised laundry room, kitchen and living room partitioning

Table 2 Design of the experiment and absolute frequency of choice from the second stimulation stage

Choice set	Product alternative	Finishings (F)	Water and electricity services (W)	Security (S)	Dimensions and layout (D)	Nominal price in US$ (np)	Choice frequency (f)
1	A_{0ws0}	−1	+1	+1	−1	$50,501.95	1
	A_{f000}	+1	−1	−1	−1	$50,255.47	1
	A_{f00d}	+1	−1	−1	+1	$50,705.60	6
	A_{0wsd}	−1	+1	+1	+1	$50,961.07	4
2	A_{fw0d}	+1	+1	−1	+1	$51,946.47	15
	A_{00sd}	−1	−1	+1	+1	$49,720.19	3
	A_{fw00}	+1	+1	−1	−1	$51,496.35	6
	A_{00s0}	−1	−1	+1	−1	$49,270.07	1
3	A_{0w00}	−1	+1	−1	−1	$49,902.68	1
	A_{f0sd}	+1	−1	+1	+1	$51,313.87	5
	A_{0w0d}	−1	+1	−1	+1	$50,352.80	6
	A_{f0s0}	+1	−1	+1	−1	$50,863.75	0
4	A_{fws0}	+1	+1	+1	−1	$52,104.62	4
	A_{0000}	−1	−1	−1	−1	$48,661.80	3
	A_{fwsd}	+1	+1	+1	+1	$52,554.74	21
	A_{000d}	−1	−1	−1	+1	$49,111.92	3

Design of the experiment

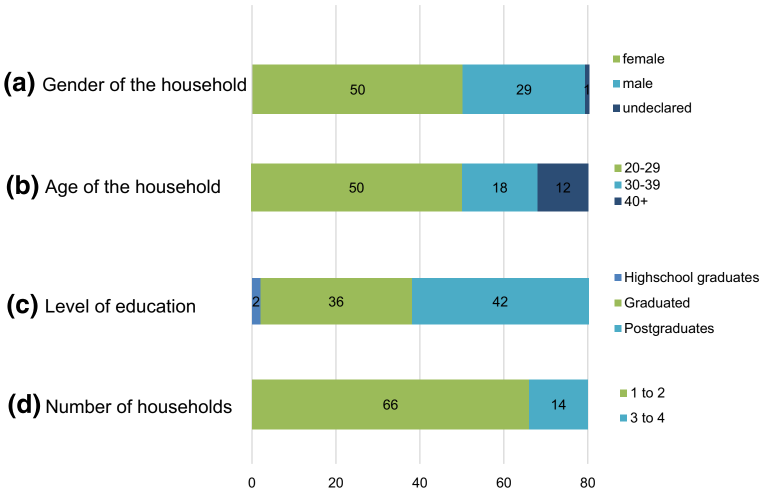

Fig. 4 Demographics of respondents absolute frequency of: **a** gender of the household; **b** age of the household; **c** level of education; **d** number of house users

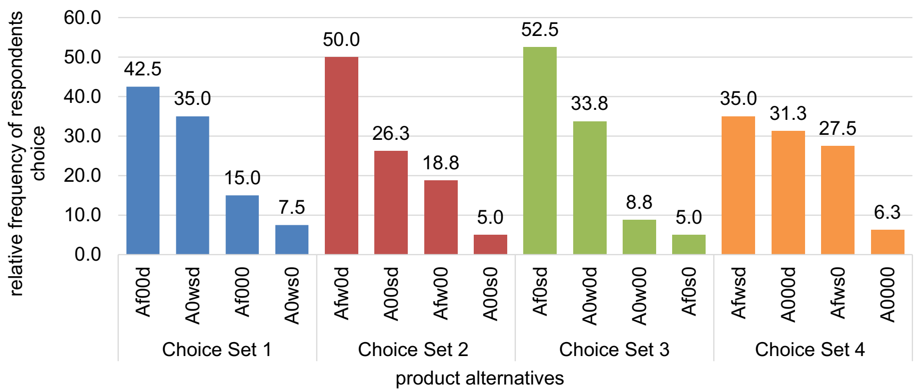

Fig. 5 Absolute frequency of the first choice by choice set

Figure. 5 presents the frequency of the choices made by respondents in each choice set. Alternative A_{fw0d} represents half of the choices in the second choice set. In the third choice set, the alternative A_{f0sd} was chosen by more than 50% of the respondents. Finally, the alternative A_{0000}, representing a standard apartment, was chosen only by five respondents (6.3%), which reinforces that offering a choice menu is relevant for most of the potential customers. Furthermore, the frequency of choice for different housing alternatives and the low rate of choice for the standardised unit corroborates the need for offering flexibility in affordable housing, as suggested by Greene and Ortuzar (2002).

The choice frequency (f) results of the second stimulation stage are presented in Table 2. A_{fw0d} (15) and A_{fwsd} (21) were the most frequently chosen among all 16 product alternatives, shedding light to the relevance of offering customisable attributes. A_{fw00}, A_{f00d} and A_{0w0d} shared third place, being chosen by six respondents. It is noticeable that the least frequently chosen alternatives (e.g. A_{0ws0}, A_{00s0}, A_{0w00}, and A_{0000}) do not offer customised finishings or dimensions and layout, highlighting the importance of those attributes for potential customers, pointed out previous studies (i.e. Hentschke, 2014, Schoenwitz et al., 2017 and Olanrewaju & Wong, 2019). Table 2 also indicates that potential customers are willing to pay a premium price to customise their housing units, as the frequency of choice is distributed in different product alternatives despite their additional cost, and only three respondents chose the cheapest one. It means that, although the price is considered in decision-making, customers seek for the best utility, making trade-offs between benefits and sacrifices when choosing a product alternative.

The top five product alternatives chosen by respondents were associated with their socio-economic profile in Table 3. The potential customers that have chosen the most popular product alternative A_{fwsd} (the fully customised product alternative) were mostly young females, highly educated and who live alone or with their partners. From the respondents who chose A_{fw0d} (product alternative with finishings, water and electricity services, and dimensions and layout customised), the second most chosen alternative, 63% earns from U$642,57 up to U$1.284,67 monthly, most of them live alone or in couples, are young, females and graduated. Most of the households that chosen A_{f00d} (product alternative with finishings and dimensions and layout customised) have a higher family income, live alone or in couples, are females, have a postgraduate level of education and are up to 40 years old. A_{fw00} (product alternative with finishings and water and electricity services

Table 3 five most chosen product alternatives and socio-economic characteristics of the respondents

Socio-economic profile characteristics		Relative frequency of choice (%) of product alternatives				
		A_{fwsd}	A_{fw0d}	A_{f00d}	A_{fw00}	A_{0w0d}
Family income	U$642,57 up to U$1.284,67	56	63	40	60	50
	up to U$2.141,12	44	38	60	40	50
Number of households	1–2	83	81	60	100	83
	3–4	17	19	40	0	17
Household Gender	Female	72	63	60	100	33
	Male	28	31	40	0	67
Household Age	20–29	50	69	40	80	50
	30–39	28	19	40	20	50
	40+	22	13	20	0	0
Household education level	Highschool	0	6	0	0	0
	Graduate	44	56	0	40	33
	Postgraduate	56	38	100	60	67

customised) has been chosen only by female households, mostly young and postgraduates, with a lower income, and that live alone or with their partners. Meanwhile, male households are a majority in those who chosen A_{0w0d} (product alternative with water and electricity services and dimensions and layout customised), most of them are live alone or with their partners, and are postgraduates.

6.3 Customers' preferences modelling

As described in Sect. 5, the Beta coefficients from the sample were obtained by applying a logistic regression model to estimate the relevance of each attribute, in which the response variable was the frequency of choice for each alternative and the independent variables were the presence or absence of attributes. Based on that regression, the most relevant attributes were: dimensions and layout (D), finishings (F), and water, and electricity services (W), respectively. Some respondents argue that they feel already safe by living in a residential condominium, justifying the irrelevance regarding security devices in this study. This fact corroborates the findings from Olanrewaju and Wong (2019) regarding customers' preference for gated residential developments because they feel safe.

Table 4 presents the results obtained when the values obtained in the study were replaced in the function expressed in Eq. (3) to model the S-curve for each product alternative, estimating customers' WTP. The beta coefficients were $\beta_0=0.0000$, $\beta_1=0.12394$, $\beta_2=0.12986$, $\beta_3=0.02029$, $\beta_4=0.11807$. Given constants were $K_1=19{,}870.38$; $K_2=34{,}170.59$ and $n=15.3745$. Finally, the Y_{price} used was the nominal price of each product alternative.

An individual S-curve for each product alternative was produced to illustrate customers´ WTP. The horizontal axis of the graph presents the price range for the corresponding housing alternative. In the vertical axis, the buying propensity scale corresponds to the estimated proportion of customers that are willing to buy the product. Figure 6 illustrates

Table 4 Consumer preference modelling

Choice set	Product alternative	Nominal Price (np)	Constant (c)	Choice frequency (f)	Observed propensity to buy (p) (%)	Estimated propensity to buy ($\tilde{p}$) (%)	Error (0.003) (E) (%)
1	A_{0ws0}	$50,501.95	1	1	1.4	1.3	0.0
1	A_{f000}	$50,255.47	1	1	1.0	1.3	0.4
1	A_{f00d}	$50,705.60	1	6	7.0	7.5	0.2
1	A_{0wsd}	$50,961.07	1	4	5.3	5.0	4.6
2	A_{fw0d}	$51,946.47	1	15	18.3	18.8	0.9
2	A_{00sd}	$49,720.19	1	3	3.7	3.8	1.2
2	A_{fw00}	$51,496.35	1	6	7.6	7.5	2.9
2	A_{00s0}	$49,270.07	1	1	1.0	1.3	1.1
3	A_{0w00}	$49,902.68	1	1	1.0	1.3	0.4
3	A_{f0sd}	$51,313.87	1	5	6.5	6.3	0.2
3	A_{0w0d}	$50,352.80	1	6	8.0	7.5	3.7
3	A_{f0s0}	$50,863.75	1	0	0.0	0.0	0.6
4	A_{fws0}	$52,104.62	1	4	5.3	5.0	1.3
4	A_{0000}	$48,661.80	1	3	3.1	3.8	3.6
4	A_{fwsd}	$52,554.74	1	21	26.5	26.3	8.8
4	A_{000d}	$49,111.92	1	3	4.3	3.8	0.5

the example of A_{fw0d} S-curve, in which approximately 20% of the customers are willing to pay the nominal price for the product alternative.

6.4 Balancing customers' preferences and operations costs

Figure 7 presents the final outcome of the method, represented by a set of S-curves for product alternatives, making explicit the relationship between the nominal price and operations costs of each housing alternative, and the estimated propensity to buy of MHML potential customers. Two critical limits were established in this profile graph, to support the definition of the solution space: the mean of operations costs (red line), and the maximum price for the standardised unit (yellow line). The red, yellow and green areas identify the zones in the graph where offering mass customised solutions are, respectively: (i) unfeasible, (ii) a transition between operations cost and price of the standardised unit, and (iii) profitable. Within the transition area, the company might consider offering some level of customisation embedded in the maximum price of the housing unit, working inside their profit margin by considering the trade-offs to attract customers and at the same time maintaining affordability.

In Table 5, detailed price information is provided to support solution space definition. All product alternatives that need to be offered by a price lower than $ 43,800.00 to be attractive to customers, for example, most of the alternatives to be appealing for 90% of the customers, represent values lower than the standard housing unit's price and operations costs, making them unfeasible. The product alternatives with prices between 43,800.00 and 49,000.00 must be further analysed regarding costs and trade-offs, such as A_{f00d} to become a probable choice for 50% of the customers. Moreover, if a product alternative does not represent a high impact in cost for the company and increases the attractiveness

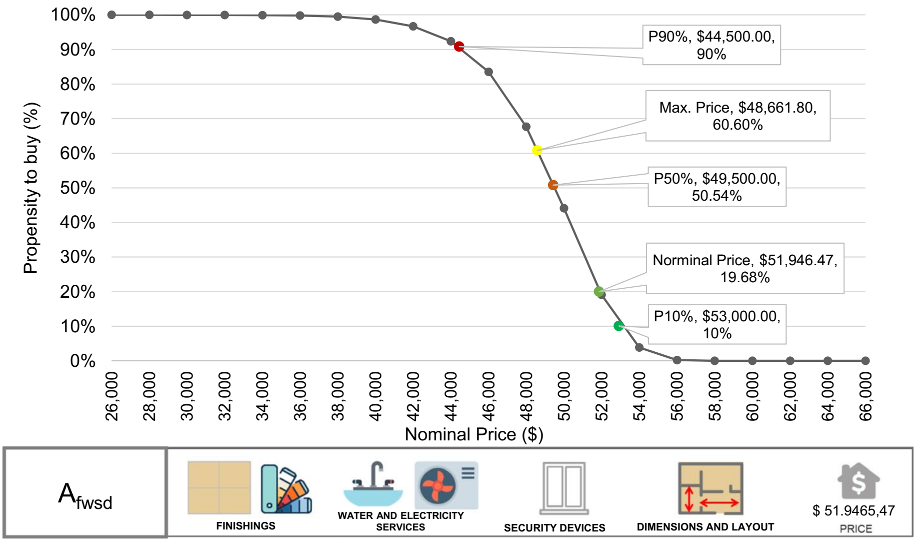

Fig. 6 Individual product alternative S-curve

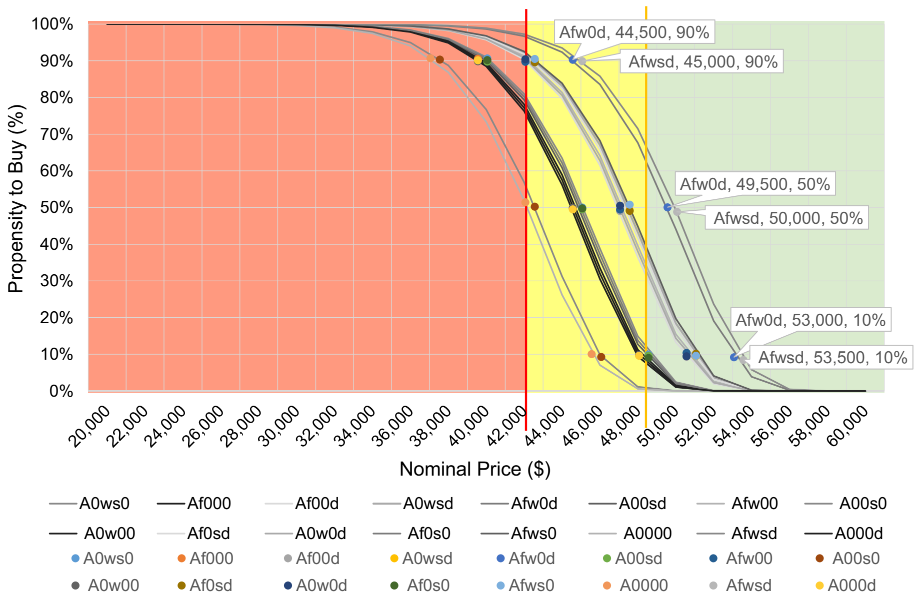

Fig. 7 Willingness-To-Pay profile graphic

of the product for customers, it should be further analysed before included in the solution space, to check whether an acceptable level of profitability is achieved. Finally, the product alternatives that could be offered by more than $49,000.00 and still would be of customers interest represent the most profitable ones, for which customers are willing to pay a premium price for customisation in comparison to the standardised housing unit.

Table 5 Balance between operations costs and willingness-to-pay

Product alternative	Nominal price	Percentile 10%	Percentile 50%	Percentile 90%	Operations cost	Profit
A_{0ws0}	\$50,501.95	\$48,500.00	\$45,100.00	\$40,000.00	\$42,092.00	\$8,418.95
A_{f000}	\$50,255.47	\$48,000.00	\$44,600.00	\$39,500.00	\$41,880.00	\$8,375.47
A_{f00d}	\$50,705.60	\$50,400.00	\$47,000.00	\$42,000.00	\$42,255.00	\$8,450.60
A_{0wsd}	\$50,961.07	\$50,900.00	\$47,500.00	\$42,500.00	\$42,468.00	\$8,493.07
A_{fw0d}	\$51,946.47	\$53,000.00	\$49,500.00	\$44,500.00	\$43,289.00	\$8,657.47
A_{00sd}	\$49,720.19	\$48,500.00	\$45,000.00	\$40,000.00	\$41,433.00	\$8,287.19
A_{fw00}	\$51,496.35	\$50,000.00	\$47,200.00	\$42,300.00	\$42,914.00	\$8,582.35
A_{00s0}	\$49,270.07	\$46,000.00	\$42,500.00	\$37,500.00	\$41,058.00	\$8,212.07
A_{0w00}	\$49,902.68	\$48,100.00	\$44,700.00	\$39,800.00	\$41,586.00	\$8,316.68
A_{f0sd}	\$51,313.87	\$50,700.00	\$47,500.00	\$42,500.00	\$42,762.00	\$8,551.87
A_{0w0d}	\$50,352.80	\$50,500.00	\$47,000.00	\$42,000.00	\$41,961.00	\$8,391.80
A_{f0s0}	\$50,863.75	\$48,500.00	\$45,000.00	\$40,000.00	\$42,386.00	\$8,477.75
A_{fws0}	\$52,104.62	\$51,000.00	\$47,500.00	\$42,500.00	\$43,421.00	\$8,683.62
A_{0000}	\$48,661.80	\$45,500.00	\$42,000.00	\$37,000.00	\$40,552.00	\$8,109.80
A_{fwsd}	\$52,554.74	\$53,500.00	\$50,000.00	\$45,000.00	\$43,796.00	\$8,758.74
A_{000d}	\$49,111.92	\$47,900.00	\$44,500.00	\$39,500.00	\$40,927.00	\$8,184.92

The three most profitable product alternatives to be offered are respectively A_{fw0d}, A_{fwsd} and A_{0w0d}, for which approximately 10% of the potential customers are willing to pay over the nominal price. It is also noteworthy that both alternatives A_{fw0d} and A_{fwsd} would attract 50% of the respondents if offered by 49.500,00 and 50.000,00, resulting in highly recommended alternatives to be included in the solution space.

Other product alternatives (A_{f00d}, A_{fws0}, A_{f0sd}, A_{fw00}) are profitable, as indicated in Table 5. However, they do not reach their nominal price, so the company can further analyse the trade-off of offering them so that 10% of the customers are satisfied in exchange for losing some profitability. Moreover, several product alternatives customers would only consider buying if they were offered by prices between 43,000.00 and 49,000.00, which means embedding the customisation in standardised unit price. The inclusion of those in the solution space could increase customers' perceived value of the product and represent a competitive advantage for the company in the affordable housing market, yet require further analysis.

7 Discussion

A method for capturing the demand for customisation of housing projects was proposed combining a choice based experiment for understanding customers' preferences, and a logistic regression model for the estimation of customers' WTP. The proposed method was tested in an exploratory study, in which the four phases were systematically applied, indicating that the results provide support to the definition of solution spaces. This method compared to traditional applications of SP, this method has a context understanding phase before its application, as well as uses the two-stage stimulation method, and considers the definition of the price of the product alternatives in the experiment planning.

In the exploratory study, several different product alternatives were chosen regardless of their price, corroborating the results of other studies that customers are often willing to pay premium prices for customised goods (e.g. Hankammer et al., 2016; Kalantari & Johnson, 2017). However, the preference modelling results indicated that a limited number of consumers are willing to pay premium prices for customised alternatives, and this should be considered in decision making. This fact reflects some concerns from potential customers related to the money invested in the acquisition of a new home, and reinforce the need to maintain a variety of affordable product alternatives in this market segment to attract different customers. Moreover, as discussed by Lermen et al. (2020), the limited number of customers willing to pay for products might result from the lack of reference regarding the fair price of the attributes offered, highlighting the need for providing more information and increasing their awareness of the products. By contrast, the diversity of product alternatives should be carefully considered as this increases the complexity of operations and the need for information exchange during the NPD, as discussed in other studies (Da Rocha, 2011; Schoenwitz et al., 2017).

Regarding the identification of improvement opportunities, the results corroborate results of previous studies (Greene & Ortúzar, 2002; Jansen, 2014; Jun et al., 2020; Molin et al., 2001; Olanrewaju & Wong, 2019) which pointed out the potential of SP to provide information for the planning and design of housing alternatives. Accordingly, the findings of the exploratory study reinforce the relevance of offering customisable attributes in housing to increase consumers' value perception, indicating which attributes should be prioritised, e.g. finishings, and dimensions and layout. This type of information can be used to define the customisation units to be considered within the solution space and also indicate which ones should be offered in a wider variety for customers. Additionally, the lack of preference for specific attributes, such as security devices in the exploratory study, indicates that some customisation units can be eliminated, while others should be incorporated as an improvement in the standard product. Consequently, the method can potentially provide insights for defining both customised and standardised parts of the product. According to Jun et al. (2020), this type of quantitative data provides a basis for design decision-making, instead of solely professionals' knowledge and previous experience as traditionally done, can potentially influence the quality of buildings and definition of the market price.

According to Jansen (2014), understanding and considering lifestyles and underlying values of residential preference and choice solve only a part of the puzzle, as many other factors might affect preferences, such as budget constraints, availability of housing and concerns from other members of the household. In order to support decision-making related to the balance between customer value and operations costs, the WTP data displays in the form of a graph (Fig. 5) or a table (Table 5) were devised, bringing to light the trade-offs of different product alternatives and enabling the selection of a set of customisation units to be offered to customers. They provide an overview of how many customers are willing to pay for a set of product alternative and how profitable are these for the company. Based on that, the limits for customising housing alternatives can be established, as well as the best combination of customisable attributes to be offered to customers.

For example, a company might decide that at least 10% of customers willing-to-pay are necessary for a product alternative to be offered in the choice menu, similarly to what was suggested by Schoenwitz et al. (2012). Establishing such a limit would depend on the goal of the company, either to reach more customers or to increase profitability. Moreover, this information also allows companies to identify product alternatives which should be further analysed regarding its feasibility, i.e. the ones that add much value for customers but have a tight profit margin. Additionally, this overview enables companies to devise more than one solution space, as suggested by Da Rocha (2011), considering different types of customers which may lead to a product family.

One key limitation of this exploratory study is that the socio-demographic variables were not considered within the preference model and WTP analysis, due to the focus of the study on exploring a balance between operations costs and WTP for customisation. Train (2016) argues that the problem of not considering socio-demographic variables in logit functions is that the utility coefficient varies over people. Moreover, the use of mixed logit models to overcome this limitation by considering two logit function at the same time: (i) one for specifying a person's probability to choose a product alternative, which depends on parameters considered in the person's utility function; and (ii) other for specifying distribution over people (i.e. mixing distribution), by the selection parameter for the decision making (Train, 2016).

Although many authors discuss the estimation of WTP, there is no consensus on the literature regarding how its distribution occurs among the population. According to Train and Weeks (2005), utility parameters in mixed logits can represent a person's WTP, rather than coefficients from the person's utility. According to Sillano and Ortuzar (2005), linear models have a limited capability of portraying WTP and its distribution in the population, they suggest an alternative method based on a Bayesian estimation. Such an approach considers the parameters as stochastic variables so, by applying Baye's rule of condition probability (i.e. defined by previously known parameters regarding the population) (Sillano & Ortúzar, 2005). The same authors argue that the proposed approach has some advantages over the classical ones, such as: (i) the approach easily handles more attributes and full covariance matrix; (ii) it reduces effects and confusion on the model caused by insufficient sample points; and (iii) it better fits population parameters at the individual-level in small samples.

8 Conclusions

The main outcome of this investigation is a method for capturing customers' demands and supporting the definition of the solution space for affordable housing. This method was built on three contributions to this field of knowledge: (i) the combination of choice-based preference models, and a WTP approach, which considers cost estimates of customisation units; (ii) the development of a logistic regression model for estimating customers' WTP for mass customised housing; and (iii) the development of a visual device to support decision making regarding the balance between customer value and operations costs, in which trade-offs for several customisation units can be simultaneously analysed.

An important limitation of the exploratory study is the fact that a small sample of respondents was used to assess the utility of the artefact, which means that the results of the survey cannot be generalised. Moreover, the survey was based on a hypothetical projects, rather than a real choice, due to limitations of time and resources. This may have affected the propensity-to-buy of respondents. In this respect, future testing and applicatiossn of the method to other contexts it should be carried out using information provided by house building companies, so that the context of specific projects could be considered, which would be useful also for testing the applicability of the proposed artefact. The method can also be refined to consider socio-demographic variables into the preference model and WTP approach by the use of more flexible techniques (e.g. mixed logit models and Bayesian estimation approaches) as suggested in the literature (Ortúzar & Willumsen, 2011; Rose & Bliemer, 2009; Sillano & Ortúzar, 2005; Train, 2016).

Customers' WTP for housing customisation has been initially explored in this study for the affordable housing market segment in Brazil. An opportunity for future research is the application of the method in different market segments and distinct countries, in which there might be differences related to the diversity of requirements, or propensity to buy. It would also be insightful to test in in projects that use different types of technologies or supply chain configurations, in which the trade-offs between the variety of products and operations costs are different.

Furthermore, customers WTP for housing customisation could be further explored by understanding how value is generated and perceived by combining the proposed method and other value modelling techniques such as laddering (e.g. Hentschke et al., 2014) and Schwartz Value Survey (e.g. Jansen, 2014; Nijënstein et al., 2015).

Finally, the proposed method can be regarded as a starting point to integrate customers' and house builders' perspective for making MC strategies feasible in housing. The initial definition of a solution space might be used as a trigger to a set of other decisions towards customer integration in NPD. Therefore, future studies should explore processes related to the definition of choice menus and decoupling points, and their impacts on customer integration and operations management.s

Acknowledgements The authors would like to thank CAPES for partially funding this research. The authors would also like to thank João Soliman Junior, Luciana Gheller, Cristiane Schvarstzhaupt, Angélica Segala, Angela Silva and Mariana Nolde, for their collaboration in the initial steps of this research.

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Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

5 Menu-Based Choice models as a strategy to support value generation in housing customisation (Paper 3)

Submited to the Journal of Housing and the Built Environment in 06 October 2021.

Abstract

House building companies are currently challenged to meet the increasingly diverse needs and expectations from customers. Mass customisation has been suggested in the literature as a business strategy that can be implemented in this sector to increase value generation by offering product variety while maintaining costs and delivery time similar to mass production. The product variety offer depends on the definition of which customisable attributes add value for customers, as well as the costs of customisation for the company and customers. **This paper aims to propose a method for capturing customers' preferences to support the definition of a solution space based on menu-based choice technique.** Menu-based choice has been used to measure customers preferences based on their selection of features individually priced from a menu**.** The proposed method was assessed in an empirical study carried out in close collaboration with a residential building company from Southern Brazil. The main outcome of that method is the identification of value-adding product attributes and a statement by customers of their willingness to pay for different housing alternatives. The main contribution of this paper is the adaptation of the menu-based choice technique to the housing customisation context and devising a hierarchical structure of housing attributes to support experiment planning and modelling of customer preference and willingness to pay. A critical analysis of the method was made considering the utility and applicability of the solution.

Keywords: Housing. Menu-Based Choice. Willingness to pay. Mass Customization.

5.1 INTRODUCTION

Society has been rapidly changing over the years, and there is a growing diversity of customers' needs and expectations for housing products (Jansen, 2014). Different trends and factors have led to changes in housing preferences: (i) demographic transitions of households (e.g. smaller and older families); (ii) technological and communication changes (Jansen, 2020); and (iii) evolvement of the family over the life course (BOOI; BOTERMAN, 2019). Furthermore, customers make their housing purchase decisions based on trade-offs between their preferences, economic and social contexts (Booi and Boterman, 2019; Jansen, 2014; Jun et al., 2020; Olanrewaju and Wong, 2019). Rahadi et al. (2012) pointed out that those trade-offs occur in the customers' minds until they find a housing solution at a reasonable price that addresses their essential requirements.

Housing new product development (NPD) must be based on customers preferences and market constraints, such as regulations and prices (Jansen, 2014; Jun et al., 2020). Moreover, house building companies need to understand the underlying motivations for such preferences to keep their product updated to changes in demand (Jansen, 2020).

Mass customisation (MC) seems to be a suitable strategy to consider customers' heterogeneous needs and preferences (Khalili-Araghi and Kolarevic, 2016) and improve value generation in the housing context (Hentschke et al., 2020a). MC can be regarded as a business strategy through which companies deliver products that fulfil customers' requirements, adopting flexible processes, and at the same time maintain cost and time within market expectations (Pine II, 1994; Silveira et al., 2001). Value-adding customisation attributes are foreseen as benefits (Ferguson et al., 2014), and customers are often willing to pay premium prices for customised products that fulfil their needs (Colombo et al., 2020; Larsen et al., 2019).

Although the MC strategy has been recently associated with promising approaches such as open product platforms to deliver customer value, one remaining challenge is how to deliver products that balance market expectations and manufacturing constraints (Dou et al., 2020; Tan et al., 2020). Companies can reach such a balance by defining a solution space, which is a set of customisation units (i.e. customisable attributes and their options) and rules to combine them into product alternatives, usually offered to customers in a choice menu (Salvador et al., 2009). The solution space must be limited, as offering too many options can make operations inefficient, reduce profitability, and cause customer frustration and confusion (Colombo et al., 2020; Salvador et al., 2009). The definition of the solution space must be based on customers' preferences, perceived value and feasibility analysis (Fogliatto and da Silveira, 2008; Salvador et al., 2009). In housing, this is a difficult task due to a large number of configurable attributes, which increases the complexity of the choice-making process (Schoenwitz et al., 2012).

Therefore, there are several research opportunities in housing regarding solution space definition, customer decision-making during product configuration, and capture of customers' requirements (Fettermann et al., 2019; Hentschke et al., 2020b; Larsen et al., 2019). New methods are needed: (i) to reduce the trade-offs between value for customers and customisation process complexity (Khalili-Araghi and Kolarevic, 2016) and (ii) to explore different product alternatives' profitability at early NPD stages (Tan et al., 2020).

This investigation is focused on the definition of a solution space based on the identification of customers' preferences and motivations. Customer preferences can be considered from two different perspectives: (i) revealed preferences (RP), i.e. the real and observable choice made by people (Ortúzar and Willumsen, 2011); and (ii) stated preference (SP) that refers to an unconstrained evaluation of attractiveness (Jansen, 2014). Moreover, SP encompasses a set of techniques, such as conjoint analysis (CA), stated choice (SC) and menu-based choice (MBC), which are used to measure customers preferences regarding hypothetical products through surveys (Ortúzar and Willumsen, 2011), based on their decision trade-offs when choosing from a set of alternatives (Green et al., 2001).

Previous investigations have proposed methods based on SP techniques that can support the definition of key elements in the MC strategy, such as the solution space (Fogliatto and da Silveira, 2008; Hentschke et al., 2021, 2020a), level of customisation (Schoenwitz et al., 2017), modules and platforms (Colombo et al., 2020; Tan et al., 2020). However, those studies were mostly focused on preferences regarding a limited set of product alternatives, rather than estimating customers willingness-to-pay (WTP) for customised products, and have not explored the analysis of trade-offs between customers value and the operations costs[5] when defining product variety.

Some studies have applied SC to the context of mass customised products (Hentschke et al., 2020b; Orzechowski et al., 2005), others (Agarwal et al., 2015; Liechty et al., 2001) have suggested the use of MBC for those cases. Given the growing adoption of MC, including the dissemination of web-based configuration of products, the opportunity to assess customers preferences through MBC emerges (Agarwal et al., 2015; Neuerburg et al., 2020; Orme, 2010). A major advantage of MBC in comparison to other techniques is that respondents have the freedom to configure their own set of product attributes instead of choosing from a predefined set, as in SC, enabling the assessment of several product alternatives (Liechty et al., 2001b; Magalhães et al., 2019; Orme, 2010). Agarwal et al. (2015) add that MBC provides an opportunity for understanding the complexity of offering customisation. The consideration of preference information can support: (i) profitability maximisation, (ii) the design of MC strategies (Liechty et al., 2001a), (iii) portfolio optimisation (Neuerburg et al., 2020). Although MBC has gained attention in recent years, its application to MC is still scarce (Magalhães et al., 2019; Neuerburg et al., 2020).

Therefore, **the aim of this research study is to propose a method for capturing customers' preferences for housing customisation based on MBC.** An empirical study was carried out in a residential building company, focusing on the identification of customers' preferences and WTP for housing alternatives and customisable attributes. This method has some advantages in relation to others proposed in the literature: (i) provides a systematic way to identify attributes and levels, (ii) devises a hierarchical model of housing attributes in order to consider the housing solution as a whole, (iii) associates preferences with motivations, and (iv) estimates customers WTP for customisable housing attributes.

[5] Operations costs include production and supply chain costs of construction.

5.2 LITERATURE REVIEW

5.2.1 Choice Menu and related concepts

Choice menu is a tool to guide customers during the configuration process based on the solution space (Piller, 2004). It is widely used nowadays in e-commerce websites (Colombo et al., 2020) and can play a key role in MC (Neuerburg et al., 2020). According to Liechty et al. (2001), choice menus enable companies to interact with customers, exploring their preferences through MBC experimentation, and new ways to create value for customers. Thus, they have been used as a knowledge-gathering tool by providing feedback regarding the customisation process chosen (Franke and Hader, 2014), being useful for testing new products with genuine buyers (Colombo et al., 2020), and generating reliable preference and price sensitivity forecasts (Neuerburg et al., 2020). Furthermore, such information can be used for developing recommendation systems that suggest product alternatives for new customers.

According to Jun et al. (2020), recommendation systems that consider customers' information and present suggestions have received growing attention in recent years, as these help users to deal with the increasing volume and variety of product information. In housing, recommendation systems based on customers' preferences can be especially helpful for inexperienced customers who have limited knowledge of searching for and choosing a housing alternative. Preference measurement is critical for the design of recommendation systems because it can be compared with product attributes or other customers' preferences to suggest alternatives (Scholz, 2008). According to Scholz (2008), SP techniques are more suitable to provide data for recommendation systems due to their predictive validity.

5.2.2 Stated Preferences and Willingness to Pay

SP techniques have been applied in different sectors, such as manufacturing, transportation (Ben-Akiva et al., 2019; Ortúzar and Willumsen, 2011) and housing (Molin, 2011). Those techniques are used for: (i) evaluating market acceptance, customers WTP for innovative product alternatives, and price sensitivity (Magalhães et al., 2019; Neuerburg et al., 2020), and (ii) for enabling market segmentation (Fogliatto and da Silveira, 2008; Kalantari and Johnson, 2017). A critical challenge of using SP techniques is finding a balance between evaluating numerous product attributes and the limited cognitive capacity of respondents of considering all of them simultaneously (Kalantari and Johnson, 2017; Louviere and Timmermans, 1990; Rose and Bliemer, 2009).

In MBC, respondents are asked to pick several attributes individually priced from a menu (Agarwal et al., 2015; Liechty et al., 2001a). Usually, the total sum of the picked attributes is shown and updated according to choices (Magalhães et al., 2019; Neuerburg et al., 2020). Showing the attributes' and total prices makes the trade-offs more explicit for respondents when deciding on a product alternative.

Lietchy et al. (2001) state that MBC models are designed to explain which combination of attributes is chosen and at which price. According to Magalhães et al. (2019), data analysis and utility estimation from MBC experiments are carried out through multinomial or multivariate probit models. Neuerburg et al. (2020) suggest that logit-based approaches are frequently used to estimate MBC. According to Orme (2010), Multinomial Logit (MNL) can be used in the analysis, including aggregate logit and hierarchical Bayes (HB).

SP techniques are commonly used for measuring customers WTP (Agarwal et al., 2015; Breidert et al., 2006; Ortúzar and Willumsen, 2011). The WTP assessment becomes more relevant when there is the possibility of upgrading attributes and increasing the utility perceived by customers (Agarwal et al., 2015). Discrete choice analysis can be used to assess customers' WTP by estimating the latent structure of customers' preferences regarding product alternatives, which is commonly done by applying a logit model (Kalantari and Johnson 2017; Breidert et al. 2006), or mixed logit models, which better considers profile and lifestyle heterogeneity (Molin, 2011; Ortúzar and Willumsen, 2011; Sillano and Ortúzar, 2005).

5.3 RESEARCH METHOD

5.3.1 Research approach

The methodological approach adopted in this investigation was Design Science Research (DSR), which is used to develop innovative solution concepts (named artefacts) to solve classes of problems while making a prescriptive scientific contribution (Lukka, 2003). Different types of outcomes may result from the adoption of DSR, such as models, constructs, methods and instantiations (March and Smith, 1995). The main outcome of this investigation is a method for capturing customers' housing customisation preferences to support solution space definition based on MBC. The solution was devised and refined in an empirical study carried out in close collaboration with Company W. The instantiation of the method provided an opportunity for adapting it to a real context and assessing its utility and applicability. This paper is part of a PhD thesis.

Company W was chosen because of its orientation for innovation and collaboration in developing new residential products. It is a small company that started its business activities in 2014. Three business partners created Company W intending to improve the city and customers' lives through high-quality products and an enhanced purchasing experience. The company focuses on developing unique residential products at a fair price for medium and high-income customers in the central area of Porto Alegre. Company W's portfolio is diverse between and within the housing developments, delivering from studios (40m^2) up to three-bedroom apartments and houses (approximately 200 m^2).

According to one of the company Directors, a key challenge in real estate market is the long lead time of the projects and how to keep up with customers' requirements and market changes during that time. The idea of adopting MC in the company has been raised as a possible solution to cope with those challenges and was reinforced by the frequent customers' requests for product changes. Besides, MC has been considered as one potential source of competitive advantage in Company W's five-year plan. Nevertheless, some of the company's representatives were unsure if the company could deliver mass customised products, due to additional product and managerial costs. Therefore, the practical contribution of this investigation for the company was to identify customers' preferences for housing customisation and assess their WTP for such products.

The development of this investigation was guided by the phases proposed by Lukka (2003) for DSR, as shown in Figure 2. A literature review provided support to the whole investigation. The main outcome of phase 1 was to find a relevant practical problem with the potential for a theoretical contribution and obtain a deep understanding of that problem and theoretical background. Therefore, data from the company was collected to find a practical problem. In phase 2, the solution was devised based on the literature regarding MBC, preference modelling and WTP approaches, and discussions with company W's representatives. Thus, the solution was devised to address the following questions: (i) how to identify relevant attributes and to consider different housing product aspects systematically? (ii) how to simulate the configuration and purchasing process to capture customers' requirements? (iii) how to identify what motivates housing choice?. In phase 3, the solution was tested and refined during the implementation in the empirical study. In phase 4, the method was partially evaluated regarding its utility and applicability based on different sources of evidence. Besides, the theoretical contributions were analysed, considering the contributions from the literature.

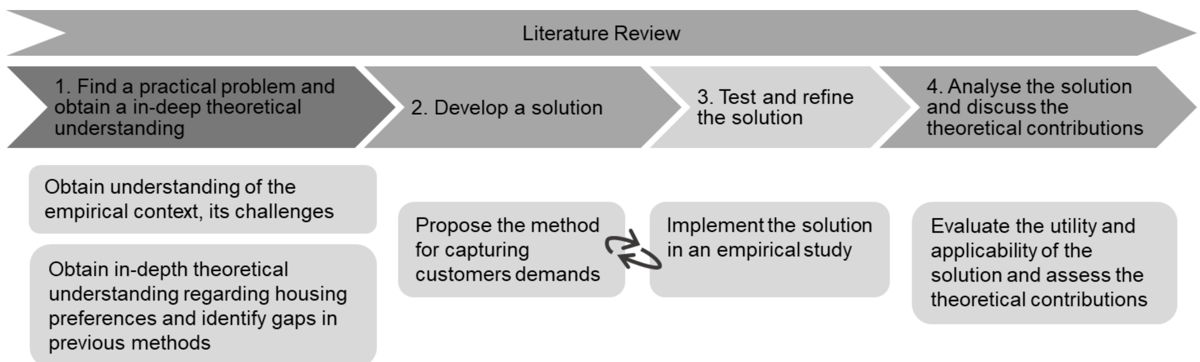


Figure 2 Research Design

5.3.2 Research phases

In phase 1, data collection for finding a practical problem involved two online meetings with one of Company W's directors and twelve semi-structured interviews: two company directors, the marketing consultant, the commercial manager, the new business manager, the customisation architect and five architects from a design supplier firm. The semi-structured interviews took between 40 and 60 min, being divided into three sections: (i) brief history of Company W, their business model and customers, (ii) NPD process, and (iii) products and attributes. The interviews with the architects from the design supplier firm were slightly different; they took between 45 and 60 min, being divided into three sections: (i) partnership between the two companies, (ii) collaboration during NPD, and (iii) project definition process.

In phase 2, the method was devised, considering the study by Hentschke et al. (2021) as a point of departure and making some adaptations for applying MBC in housing. The proposed method encompasses five stages that were implemented in the empirical study in phase 3: **(i) context understanding, (ii) experiment planning, (iii) survey planning: design the questionnaire and collect data, (iv) customers preference modelling, and (v) balancing purchase propensity and prices**. In **the context understanding stage**, the semi-structured interviews carried out in phase 1, the company's website and some documents provided by the company were used as a source of evidence to identify customers, products and attributes. The attributes were organised in a hierarchical structure, and represented on a Miro[6] whiteboard. Then, seven online meetings involving the research team, a company director and a marketing consultant (duration: 7h30min) were held to discuss the hierarchical structure in order to prioritise and preselect attributes.

In the experiment planning stage, the relevant attributes and levels were defined based on two workshops. In the first one, the attributes were discussed with the support of the hierarchical structure to identify the most relevant product and service attributes (duration: 3h10min). The participants, including the research team, two directors, a marketing consultant and a new business manager, were organised in pairs to discuss a set of attributes related to the apartments, the project and the service in the Miro whiteboard. Then, each pair presented and discussed the outcomes with the rest of the group, highlighting which attributes should be added or excluded in their set. In the second workshop, Company W's representatives were asked to prioritise attributes according to the Kano based scale, relying on their previous experience dealing with customers (duration: 3h45min).

The design of the experiment was divided into three hierarchical levels, regarding (i) the project, (ii) the standard apartment, and (iii) the customisable apartment. They were randomly designed in Lighthouse Studio Sawtooth Software®; the scale used was choice, and each respondent should configure their solution once per menu. Subsequently, the prices and cost estimates were provided by Company W, and discussed with the researcher, including: (i) operational costs for the standard

[6] Miro is an online whiteboard platform built to create, collaborate and centralise communications for team work (Miro, 2021).

apartment, parking spaces, private outside areas; (ii) percentage for solar orientation, location in the building and architectural style; (iii) additional costs for customisable attributes.

In **the survey planning**, the **questionnaire was designed** in the Lighthouse Studio® Software, including four sections: (i) introduction and filter; (ii) stated preference; (iii) motivation; (iv) socio-demographic profile. The introduction and filter question enabled the selection of the respondents according to the sampling criteria, including: (i) the interest in buying a dwelling in the next five years, (ii) located in Porto Alegre, and (iii) apartment type. For section ii, choice menus were developed by an information technology specialist using web technologies (e.g. CSS, JavaScript) and Sawtooth scripts in the Lighthouse Studio®, so that respondents could state their preferences. In section iii, respondents stated their motivation for project, apartment and customisation choice by selecting options in lists, and, in section iv, answered questions regarding their socio-demographic characteristics.

The content and structure of the questionnaire were refined in discussions carried out in two online meetings with the Company W representatives: two company directors, their marketing consultant and the research team (duration: 2h30min). The questionnaire was pre-tested by the research team, three outsiders, five built environment specialists, and three Company W's representatives, and refined. A key issue mentioned by respondents during pre-test was that the prices presented were too high. Therefore, the company Directors discussed it with the commercial department and revised the prices for the final questionnaire version. The research team and Company W promoted the survey through social media and e-mail. The survey was available online for a month. Respondents took approximately 10 minutes to complete the survey.

In **the customer preference modelling stage**, a descriptive statistical analysis was carried out to obtain a general understanding of the survey data, such as measuring the choice frequency of product alternatives. The analysis of the most frequently chosen product attributes enabled selecting variables to be initially considered on the preference models.

A preliminary analysis of the attributes choice probability and the main effects across variables was run in MBC Sawtooth software® to select variables for building preference models. Some iterations were needed to define such variables, including defining a minimum choice frequency (e.g. 15%) and recategorising some variables through a combinatorial coding approach. The combinatorial coding approach is recommended for limiting the analysis to the probable combinations of the menu by recoding attributes into one dependent variable (Orme, 2016). The independent variables were kept as the attribute prices to maintain the models' price sensitivity, as recommended by Orme (2016). Furthermore, the models were built upon the premise that the choice of an attribute, the dependent variable, is explained by its price and prices of other available attributes, the independent variables. Only the significant values resulting from the analysis of the effects of independent variables were considered to specify the logit models of each dependent variable.

For **balancing customers preferences and costs**, a price sensitivity analysis was carried out based on the utilities estimated. Finally, customers WTP for customisable attributes were summarised into interaction plots, showing purchase propensity (i.e. the likelihood of a potential customer to purchase a product) and price, aiming to support the discussions with company W regarding the solution space to be offered.

In phase 4, the evaluation of the method in terms of utility and applicability was based on two main sources of evidence, including open interviews with company W representatives and the leading researcher perspective from the implementation of the method. The evaluation of utility considered the following criteria: (i) provide support for the definition of solution space and offering of mass customised products; (ii) provide support for defining standardised parts of housing products; (iii) consider the need to balance between customer value and operations costs on decision-making; (iv) provide support for recommendation systems. The evaluation of applicability included: (i) ease of use of the method and (ii) reuse of the hierarchical model of housing attributes and questionnaire.

5.4 PROPOSED METHOD

An overview of the proposed method is presented in Figure 3. **The context understanding stage** starts by defining the purpose of application of the method, e.g. whether it consists of the proposition of a new solution space or the refinement of a previous one. In this phase, a target audience (e.g. potential customers) and sampling criteria are defined to filter respondents and estimate customer preferences more precisely. Therefore, context understanding is necessary to support experiment planning, and some steps can be carried out simultaneously and feedback each other. For instance, while understanding the context, some relevant attributes and product characteristics can be identified. Furthermore, the definition of the sampling criteria can be refined due to decisions related to the scale of choice and experiment design.

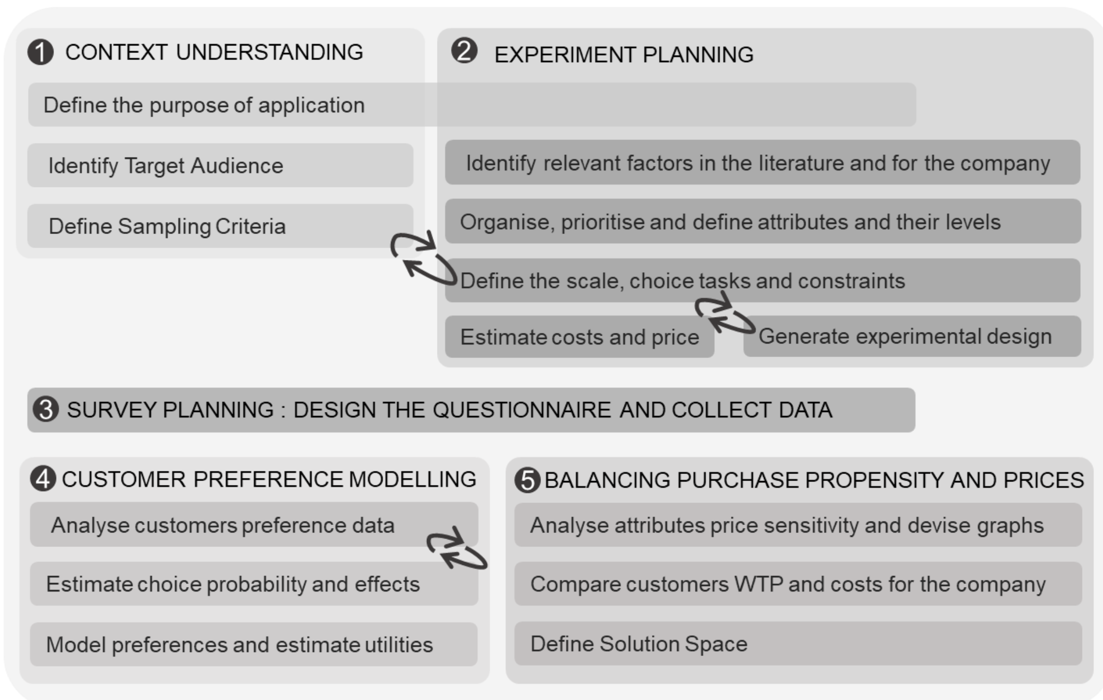


Figure 3 proposed method for capturing customers demands based on MBC

The experiment planning starts by identifying relevant factors or sets of attributes. One of the main adaptations proposed in relation to existing methods was the process of systematically identifying, organising, prioritising relevant attributes and defining their levels, devised for handling the wide range of configurable attributes available for housing. Furthermore, a hierarchical structure was proposed to organise housing attributes according to different aspects of the product, which are relevant for customer choice when buying a new home. It was based on the product architecture matrix proposed by Schoenwitz et al. (2017) for prefabricated housing, which encompasses five hierarchical levels: (i) the surrounding area, concerning the surroundings of the project and location attributes; (ii) the residential environment, regarding project attributes; (iii) housing unit parts (adapted from Schoenwitz et al. (2017)); (iv) components or customisation units (adapted from Schoenwitz et al. (2017)); and (v) items or levels, which consist of attributes options or levels of choice. The hierarchical levels are concerned with product attributes that can be branched into levels to be combined to design experiments. Furthermore, housing choices are a combination of decisions that occur across hierarchical levels involving trade-offs between them, to be considered in the experiment design and preference modelling.

A scale for prioritising attributes was proposed, based on the types of requirements defined in Kano's Model. The Kano Model is a useful tool for exploring, classifying and prioritising customers needs (Dou et al., 2020). According to Dou et al. (2020), the first priority for companies must be the basic requirements, as these are considered as mandatory by customers; then progress to expected or performance requirements, which may bring a competitive advantage when compared to other products; and finally, charm factors must be addressed, as these can enhance loyalty. Therefore, the proposed scale should be used to classify the attributes in the hierarchy as unnecessary, basic, performance and exciting attributes by a group of stakeholders.

The proposed method suggests the segmentation of experiments by the hierarchical levels to be assessed, reflecting the number of menus shown to respondents. Thus, the response scale and number of choice tasks are defined after selecting attributes and their levels. Then, the MBC experimental design is generated. This process of defining attributes, levels, prices and choice tasks may have some iterations, until generating the final experiment.

In stage 3, **the survey is planned including the questionnaire design and data collection**. The proposed questionnaire was divided into four sections explained in section 5.3.2. It was based on the one proposed by Hentschke et al. (2021) regarding some customisable attributes and profile questions and considering some questions and housing attributes from other SP studies (Jansen, 2020; Jun et al., 2020; Nijënstein et al., 2015). Furthermore, the questionnaire was designed to assess customers' residential preferences in all hierarchical levels by the survey.

A new section to identify the motivations for customers choice regarding housing and its customisation was included. According to Jansen (2014), customers usually choose a particular housing alternative by pursuing values and goals relevant for them. Previous studies have explored how underlying values and motivations influence housing preferences and choice (Jansen, 2020, 2014; Nijënstein et al., 2015) by combining SP surveys with adaptations of Schwartz Value Survey or predefined lists of motivations. Based on those previous studies, a list of motivations was proposed (see tables 2 and 3, section 5.5).

The customer preference modelling phase begins by analysing data through descriptive statistics, such as choice frequency, to obtain a general understanding of customers and their preferences. To analyse the motivations and understand customers value orientation, these should be categorised into value types and domains (Jansen, 2014; Nijënstein et al., 2015).

A stepwise regression backward elimination approach has been adopted for modelling customers preferences. A database is built upon the variables considered relevant in the descriptive analysis to run a preliminary analysis, estimating choice probability and effects between variables. Then, the selection of variables to specify the model should be based on the significant effects of independent variables in the dependent variables (following stepwise regression backward elimination). Lastly, the utilities are estimated by using logit-based models (Neuerburg et al., 2020), such as aggregate logit models (Orme, 2019).

This method proposes two customer preference models, one for each hierarchical level of the housing product and another one integrating all levels. By isolating the levels of the housing product, it is possible to understand the relevance and preference for attributes, also its interaction with other components of the housing product part. Furthermore, this method proposes an integrated hierarchical analysis regarding the preference at all levels to understand the impacts of the sequence of choices and trade-offs made between different housing elements.

Finally, a price sensitivity analysis should be carried out based on the logit models and graphs that show the purchase propensity according to the price of the attribute level to **balance purchase propensity with prices**. Then, customers WTP for attributes and costs are compared to underpin discussions regarding the solution space definition.

5.5 RESULTS

5.5.1 Context Understanding

Representatives of the company stated that many of their customers are young adults who value innovation, sustainability, and new design trends. These customers are those who identify themselves most with the company's brand. However, the company delivers a mix of housing products for diverse customer profiles (e.g. single, couples, couples with children).

Interviewees have mentioned around 27 customer appealing attributes of the product, such as location and terraces. Other sixteen attributes were identified in the analysis of documents provided by company W.

5.5.2 Experiment Planning

The attributes identified in the context understanding phase had different abstraction levels. Therefore, they were categorised and refined during initial discussions with the company's representatives, resulting in a hierarchical structure with 68 attributes organised into 13 categories to be discussed in the first workshop. In the second workshop, 57 attributes classified into 14 categories were assessed by Company W representatives, resulting in a ranking of attributes. The categories with most attributes ranked as basic and performance, representing a purchase appeal for customers, were considered the starting point for developing the experiment and questionnaire design. Therefore, two exclusion criteria were used: (i) categories with most answers between unnecessary and exciting (e.g. permeability and connectivity); (ii) categories without customer appeal from the Company W's perspective (e.g. safety).

Figure 3 summarised key information about the implementation in the hierarchical structure, including: (i) housing attributes, (ii) hierarchical levels, and (iii) three MBC experiments outlined. The experiments were randomly designed, generating several versions of menus to be randomly distributed for respondents. Both standard apartment and customisable apartment experiments presented randomised pricing for their attribute levels, considered a nested factor. Moreover, each attribute level had defined two price levels considering a 10% difference from each other.

The standard apartment experiment was custom designed for four different segments of gross floor area to be selected by respondents (see Figure 4). In the menu of the segment, respondents would compare the available options with a control scenario (see Table 3). The control scenarios described the standard attributes of a baseline apartment defined for each segment. Moreover, the attributes included in the control scenario were priced as "zero", and the optional levels represent additional costs or discounts to be added to the average apartment price (see figure 4). The segmentation enabled potential customers to choose from a set of attributes and prices that they find more appealing within a specific menu, as suggested by Liechty et al. (2001).

Table 3 Control Scenarios description

Range	internal floor area average (m^2)	Average apartment price	Number of bedrooms	Number of bathrooms
Up to $40m^2$	35	R$ 358,750.00	Studio	1
$40m^2$ and $80m^2$	60	R$ 615,000.00	2	2
$80m^2$ and $120\ m^2$	100	R$ 1,025,000.00	2	3
$120m^2$ and $160\ m^2$	140	R$ 1,435,000.00	3	3

A proposal for a customisation menu was presented to the company's representatives in order to take suggestions, considering what they had in mind to offer for customers. The proposal included layout changes, floor finishings, wall painting, countertops, barbecue place and fireplace, bathtub, acoustic isolation and sanitary ware. Company W's representatives argued that although some customers have requested fireplaces and bathtubs, it would significantly increase project complexity because of ducting and water services, so they prefer not to offer those items. The wall painting was excluded due to common problems and rework in finishings, according to Director 2. Moreover, Director 2 felt apprehensive to offer many options for an additional price and that customers might think that the finishings delivered in the standard apartment were cheap or of low quality because they were included in the initial price. The final customisable attributes and levels are listed in figure 4.

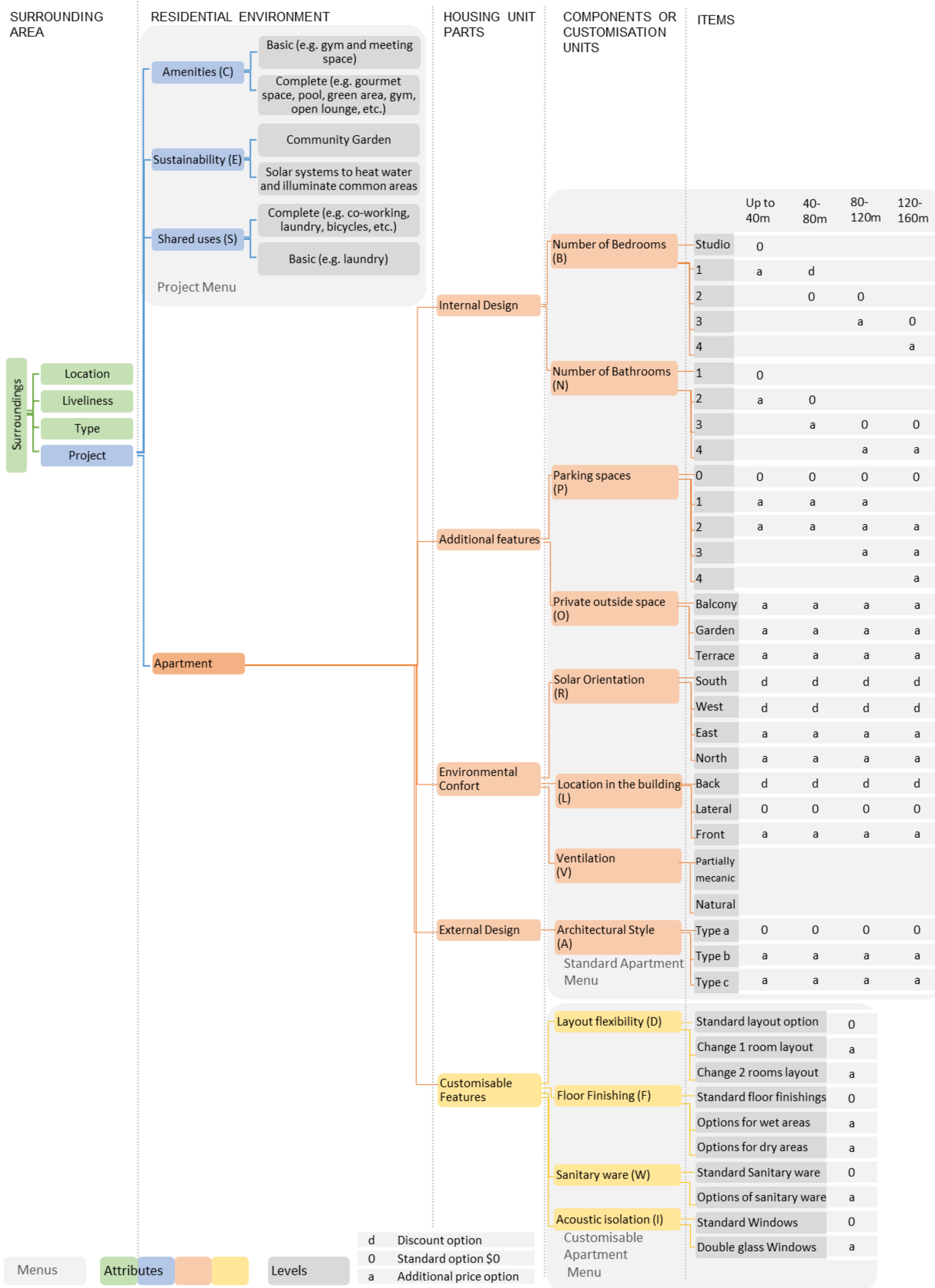


Figure 4 Housing choice hierarchical structure

5.5.3 Survey planning

The questionnaire was tailored to Company W's products information and discussions with representatives, especially the stated preference section. Figure 5 provides an example of the customisation menu used on the survey.


Select on the choice menu the customisations you would like to make on your apartment, bearing in mind that they have an additional to the price in your apartment:

Layout Flexibility
Standard layout option
R$ 0,00
Change one room layout (e.g. augmenting livingroom)
+ R$ 11.000,00
Change two room layout (e.g. augmenting living room and open concept)
+ R$ 20.000,00

Floor Finisishings
Standard floor finishings in the kitchen, laundry and bathrooms
R$ 0,00
Customised floor finishings in the kitchen, laundry and bathrooms
+ R$ 11.000,00
Customised floor finishings in living room and bedrooms
+ R$ 10.000,00

Acoustic Isolation
Standard acoustic isolation
R$ 0,00
Improve external acoustic isolation (e.g. add double glass windows)
+ R$ 12.500,00

Sanitary Ware
Standard sanitary ware and laundry tub
R$ 0,00
Customised option of sanitary ware and laundry tub
+ R$ 5.500,00

Property Total = standard apartment price + additional price for customisation (37.500,00)

Figure 5 customisable apartment choice menu

A total of 434 questionnaires were returned, 95 incompletes and 28 did not consent to use their preference data in the analysis. Of 311 who completed the survey, 129 had the intention to buy a new apartment in Porto Alegre, fitting into the survey sampling criteria. It is worth pointing out that the survey was carried out during COVID-19 pandemic, which might have reduced the number of potential customers, because of the economic uncertainty and crisis, also reflecting on increasing the preference for living in houses (52 respondents), and aspirations for living in the countryside.

5.5.4 Customers Preference Modelling

During the descriptive analysis, was identified that most of the respondents (81.4%) would like to live in an apartment in the Company W's area of operations. Moreover, most respondents (67.4%) already live in the region, and 89% prefer the mixed-use of residential and local commerce neighbourhoods, a dominant characteristic of the area.

Only 29% of the respondents stated that they have a monthly family income up to R$ 10.000,00, approximately 60% earn more than that, and 74% intend to have financial support to buy the property. As expected, the higher the household's income, the larger the apartments selected. Most respondents are female (66%), 55% had degrees at the postgraduate level, and half were between 30 to 39 years old. Most respondents families have up to three members (89%), and are distributed between couples (47%), single households (20%), and couples with kids (29%).

Most respondents who have chosen apartments up to 40m² and from 80-120 m² would like the plus option regarding the bedrooms (see Figure 6). Most respondents prefer east solar orientations and having a balcony, even though they represent additional costs in the apartments price. The frequency of choice for gardens and terraces seems to increase with the preference for bigger apartments, possibly reflecting the households' higher income.

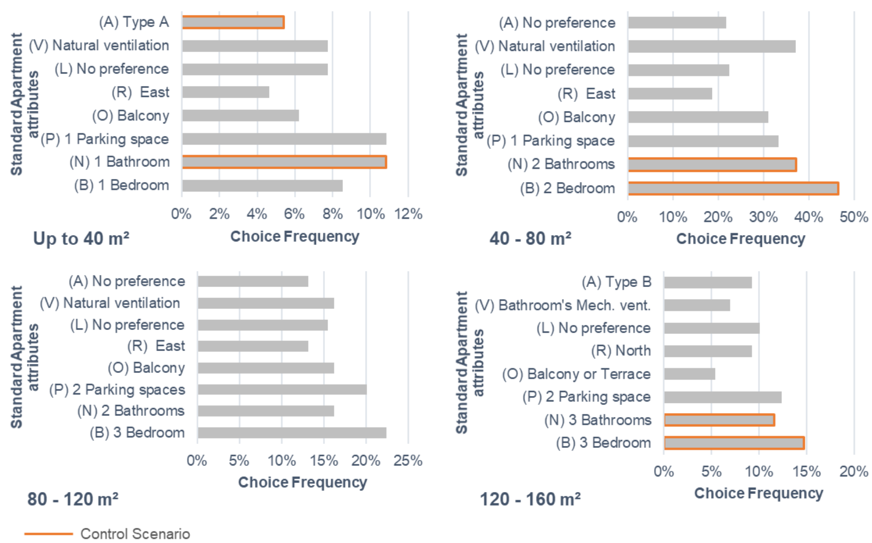


Figure 6 Relative frequency of most frequently chosen attributes the standard apartment menu

The respondents were also questioned about their primary motivations for choosing a project and apartment (see Table 4). Most respondents value having easy access to schools, hospitals, supermarkets, etc. (73%) living in a comfortable and pleasant environment (54%); and feeling safe at home (53%). Sixty-two per cent of the respondents were associated with self-direction values because they selected two to three motivations from the domain, and 32% were associated with security values as classified by Jansen (2014).

Table 4 Motivations for choosing the project and apartment

Motivations for choice	Relative choice frequency	Value type
Easy access to schools, hospitals, supermarkets, etc	73%	Stimulation
Living in a comfortable and pleasant environment	54%	Hedonism
Felling safe/secure	53%	Security
Performing different leisure and entertainment activities in the condominium or surroundings	33%	Stimulation
Contact with green and nature	25%	Universalism
View and feeling connected with the city	24%	Universalism
The feeling of peace and quiet	14%	Universalism
Good environment for children	12%	Conformity
Unique and exclusive design	8%	Achievement

Although the majority of respondents have chosen the standard option, the overall frequency of choice for customisable attributes is higher than 40% of the respondents (Figure 7), except for sanitary ware (36.4%). This provides evidence that some potential customers would value the offer of customised residential products. In fact, some of them have mentioned that they would like to customise other housing attributes (19.4%), including: (i) hot water services, (ii) home automation features, (iii) countertops, (iv) paint colours.

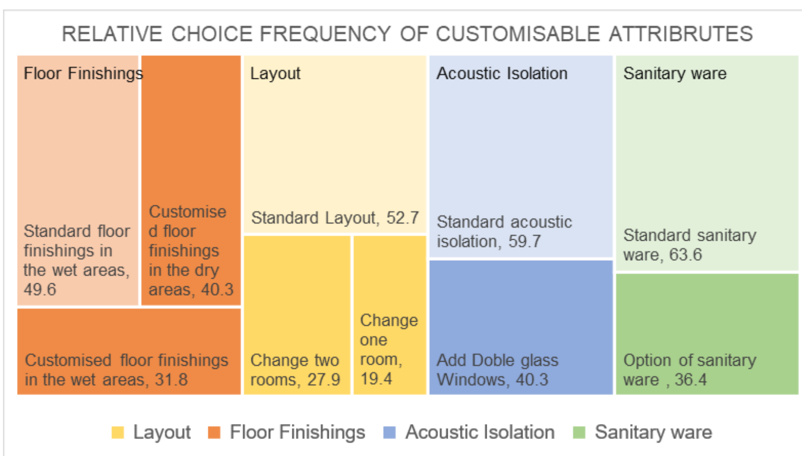


Figure 7 Relative frequency of customisable attributes choice

The service characteristics that respondents value the most were financial transparency (50%) and the possibility of customising their apartments according to personal taste and needs (40%).

Furthermore, respondents prefer apartments customised by the residential building company so that the same company is responsible for whole product quality (56%). These results indicate that Company W should consider offering customised residential products.

The survey also pointed out the motivation for customising the apartments (see Table 3) that is related to creating a comfortable and pleasant environment (62%), functionality (47%), and identity (43%), strengths of Company's W products propositions. The reasons for wanting customised apartments stated by respondents were mainly related to openness to change (28%), as classified by Nijestein et al. (2015).

Table 5 Motivativations for customising the apartment

Motivations for choice	Relative choice frequency	Value type
Comfortable and pleasant environment	62%	Hedonism
Functionality and flexibility of use	47%	Stimulation
Identify yourself with your property	43%	Achievement
Feeling of privacy	24%	Power or self-direction
Aesthetics	11%	Power
Self-achievement	10%	Achievement

A preliminary analysis of the variables regarding their choice probability (see Figure 8) and effects between variables was carried out to select the ones to be included in the hierarchical model (see appendix A Table A.2 and A.3). For instance, regarding the project, respondents prefer at least the basic amenities (50%), most of them would not like to share any uses with their neighbours (71%), and value environmentally friendly project attributes (80%). The application of the survey during the COVID-19 pandemic may have influenced the low interest in shared facilities.

Only the variables with significant relationships (p-value<0.2) were considered to build the logit models, as suggested by Orme (2016). The significant results of the hierarchical logit model are summarised in Figure 9 (see appendix B.2 for complete model results). The estimated utilities and p-value statistics indicate that the most important factors for the choice of additional acoustic isolation (utility=15.612; p-value<0.01) and sanitary ware (utility=14.14; p-value<0.01) are the prices of the items themselves, implying that customers are willing to pay for such items. Changing the layout of two rooms is affected mainly by the internal area of the apartment and acoustic isolation prices. The balcony price can stimulate the choice of floor finishings: for instance, the choice of the whole apartment floor finishings is regarded as a strong substitute for the balcony. Such results show that the choice of customisable attributes is significantly related to other housing choices and might represent trade-offs between levels.

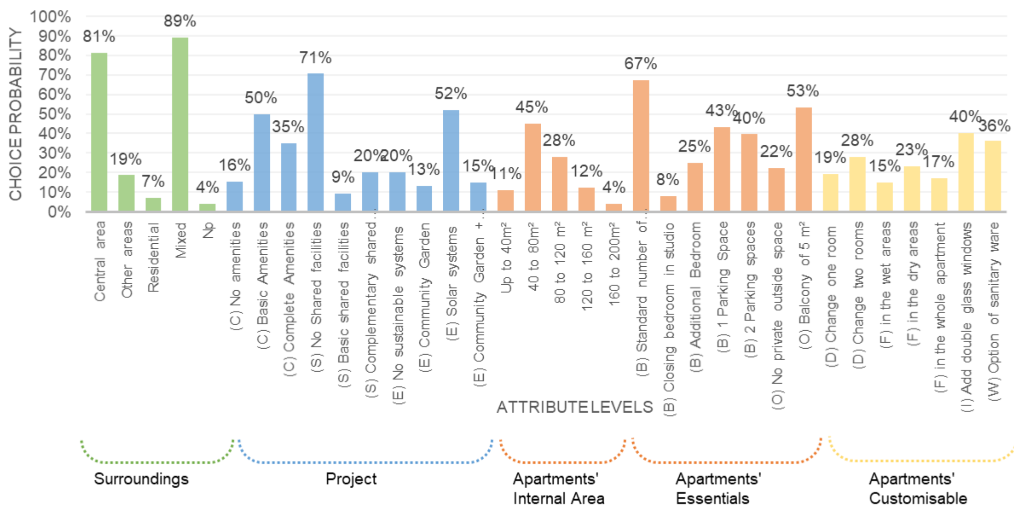
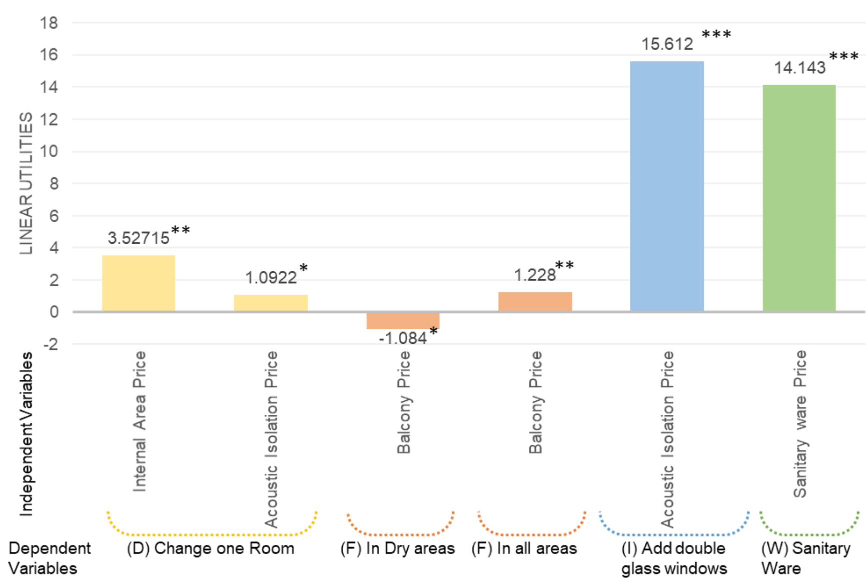


Figure 8 choice probability



*(p-value<0.1); **(p-value<0.05); ***(p-value<0.01).

Figure 9 Linear utilities of apartments customisable attributes

5.5.5 Balancing purchase propensity and prices

Based on the product configuration made by each respondent the total cost of the apartment was calculated at the end of the menu, stating how much he or she was willing to pay. Although the choice for customised apartment items seemed sparse and respondents willing to pay for it are limited, only 34 respondents have chosen a fully standardised product alternative, reinforcing the demand for customisation. Several respondents have chosen to customise two attributes according to the average stated WTP for customised items (see Table 6), considering that most attribute levels prices are approximately R$10,000.

Table 6 Average stated willingness-to-pay

	up to 40m	40-80	80-120	120-160
Average Stated WTP for customisation	R$ 13,589	R$ 17,845	R$ 27,559	R$ 35,125
Average Stated WTP for the standard apartment	R$ 464,447	R$ 730,617	R$ 1,299,255	R$ 1,831,934

Figure 9 shows the interaction plots of price sensitivity, indicating the purchase propensity according to the price of the customisable attributes offered. Some attributes do not have their purchase propensity related to the internal area segments, such as the probability of selecting an option of sanitary ware (W) of 39% considering a price of R$ 5,500 (see Figure 10e). The possibility of changing the layout of two rooms increases according to the internal area segments (see Figure 10a), from a 10% purchase propensity in the apartments up to $40m^2$ until 55% in the ones between $120m^2$-$160m^2$, independently of price. Furthermore, there is a positive effect of acoustic insulation price on the choice of changing two rooms, meaning that the higher the price of acoustic insulation, the higher the probability of potential customers choosing to change the two rooms (Figure 10b). The purchase propensity of changing one room layout and floor finishings in the wet areas decreases as their prices increase (Figure 10 c, g).

The interaction plots support the definition of different solution spaces according to customers purchase propensity for each segment. For instance, if the solution space was to be defined considering a minimum purchase propensity of 20% for offering customisable attributes: (i) changing the layout of two rooms would be only available for apartments with an internal area bigger than 80m²; (ii) adding double glass windows would be only available for apartments with an internal area of more than 40m²; (iii) the price of changing the layout of one room, and floor finishing should be kept at the lowest level, to be a part of all menus; and (iv) customised options of sanitary ware could also be offered to all potential customers.

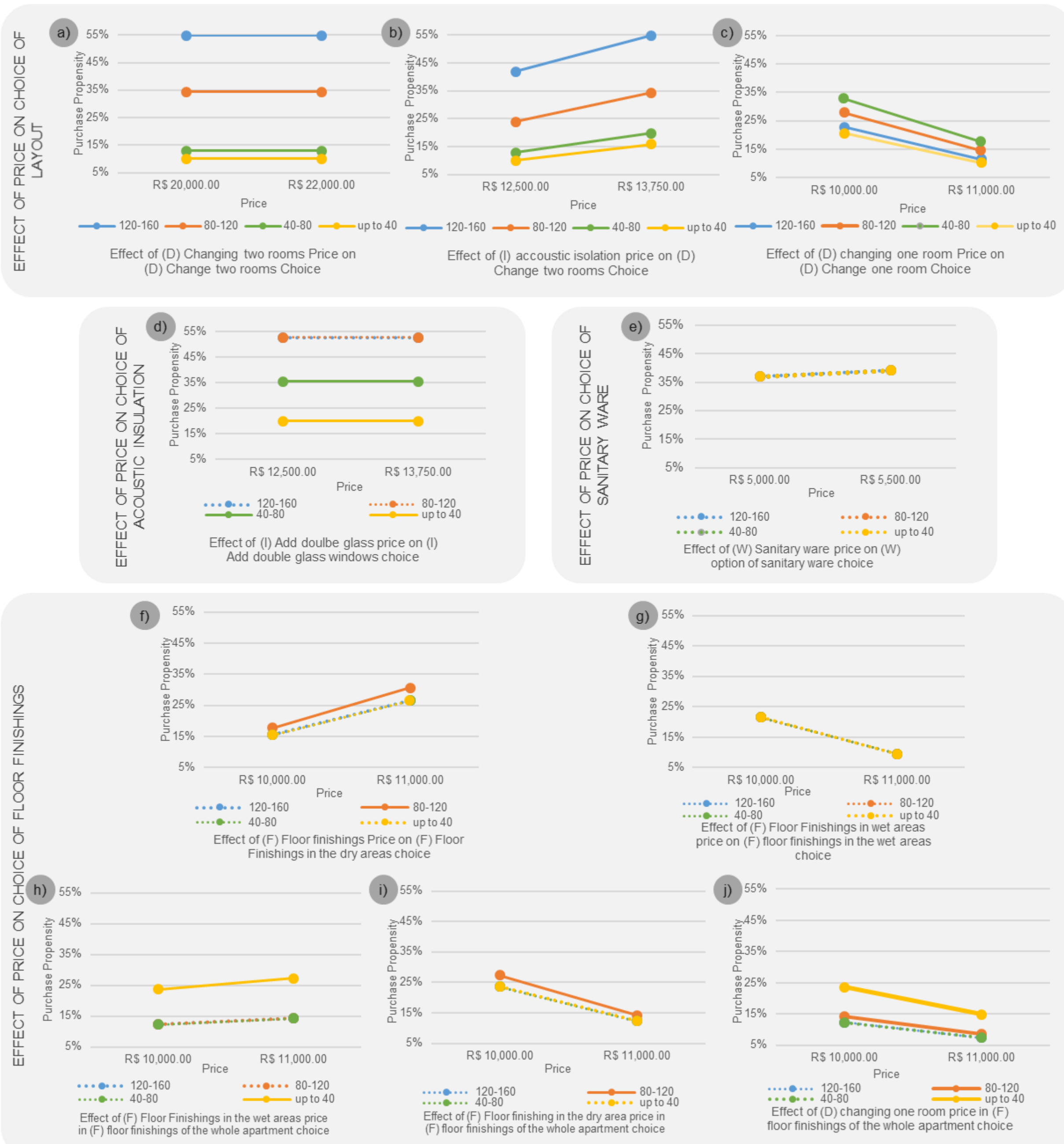


Figure 10 Interaction plots of the price sensitivity analysis

5.6 DISCUSSION

5.6.1 Evaluation of the utility

The **support for defining a solution space** started while selecting product attributes to be considered in the survey. Furthermore, hypothetical solution space and attributes prices were discussed and defined to structure the menu to be tested by respondents, enabling the consideration of both customer value and operations costs. Additionally, by focusing on the attributes, the method provides the possibility of estimating their relevance and proposing different levels of customisation for each housing component, as suggested by Schoenwitz et al. (2017).

The menu definition was an insightful process as the pricing strategies in real estate are usually based on an overall perspective rather than breaking housing into modules or attributes. However, the sum of attributes in product configuration may result in high prices pointed out by some respondents.

The survey results indicated the preferences for different product configurations and that some customers were willing to pay for customised residential solutions. Nevertheless, a limited number of customers are willing to pay for customised products. Two facts could explain this limitation: (i) respondents found the prices of product alternatives too high, and (ii) the lack of reference of what is a fair price of the attributes offered, as discussed by Lermen et al. (2020). The second reason reinforces the perception of Company W's that real estate customers are not very experienced with residential products, so they have a hard time choosing the right product for themselves. Lermen et al. (2020) argue that there is a need for more information regarding those products to increase customers' awareness and support decision-making.

The main outcomes of the method are the interaction plots, which make explicit the trade-offs between customer value and prices. Based on that information, decision-makers are able to decide upon the solution space to be offered by defining limits of profitability and or purchase propensity to be achieved. The overview of purchase propensity and prices by segment allows the definition of multiple solution spaces suggested by Rocha (2011) and supports the design of choice menus for different market segments, as recommended by Fogliatto and Da Silveira (2008).

The method can also **support the standard product definition** of building companies, which was assessed by the project and standard apartment menus. In the standard apartment menu, many respondents have chosen the attributes included in the control scenario, indicating an alignment between the standard solution offered by the company and the requirements of potential customers. Thus, by understanding what most customers prefer, there is an opportunity for defining product platforms (i.e. standardised parts), as discussed by Fogliatto and Da Silveira (2008).

According to Company W's representatives, the discussions regarding product attributes and customers priorities **support briefing and architectural programming** by enabling them to provide more objective and precise requirements to design partners. It was also pointed out that the method improves the design assessment process by better-establishing design criteria. This perception is corroborated by contributions made by Jun et al. (2020), Jansen (2020) and Olanrewaju & Wong (2019) regarding the support to design decision-making provided by SP studies. Additionally, one company Director stated that the information gathered by the method could be used for comparing their products and others available in the market, providing insights to NPD and sale arguments.

Although sets of attributes and product alternatives chosen by respondents presented a low probability of choice, having a **reduced recommendation potential**, some significant results have been pointed out. For instance, adding double glass windows and changing the layout of two rooms probability of choice increase with the internal area of the apartment and could be recommended for potential customers accordingly.

5.6.2 Evaluation of applicability

Regarding the **easiness of use**, an important requirement for applying the method is the need for a professional with previous experience with applying SP techniques.

The most time-consuming steps of the method are identifying, prioritising and organising attributes and levels, as they required close collaboration with the company's representatives, summing up approximately 15 hours of direct interactions and more than 30 hours for internal processing and planning. The availability and high level of engagement of company's representatives during those steps were critical for implementing the method, especially regarding experiment planning and questionnaire design. The remaining activities were carried out with a low level of involvement of Company W representatives, demanding only specific interactions for refining the questionnaire and prices (duration: 3,5 hours). Commercial software solutions can be used to support experiment design, apply questionnaires and customer modelling, such as sawtooth softwares®.

Another criterion regarding the solution's applicability is the **possibility of reusing the hierarchical model of housing attributes and questionnaires**. Both of them can be adapted for assessing other housing products. For example, the hierarchical model of housing attributes can be reused for structuring new assessments of customer preferences by selecting the categories and levels of interest to be investigated or adding new ones.

5.6.3 Assessment theoretical contributions

The main contribution of this investigation to the advancement of knowledge is the adaptation of MBC for assessing potential customers' preferences aiming to define the solution space for mass customised housing. It includes using a set of concepts and tools, such as prioritising attributes based on Kano's model, adopting a hierarchical logit model for estimating customers preferences and WTP, and considering motivations for preference.

The devised method presents benefits concerning previous ones, such as more realistic simulation of the housing configuration process and testing a wider range of possible product alternatives by enabling the selection of preferred attributes. It also exceeds other solutions described in the literature (e.g. Fogliatto and da Silveira, (2008), Tan et al. (2020) and Colombo et al. (2020)) by considering customers WTP for customisable attributes to define product variety. Although many authors mention that customers are willing to pay premium prices for mass customised products, few studies provide empirical evidence to support that statement and effectively explore customers' WTP. This investigation points out housing attributes' purchase propensities according to their prices and the effects of other attribute's prices, as illustrated in the interaction plots.

Another theoretical contribution of this investigation is the hierarchical conceptual model for housing attributes. It was built upon some levels related to the dwelling itself defined by Schoenwitz et al. (2017), combined with new levels of attributes concerned with the surroundings, the dwelling environment and items. The relationship between attributes of the residential environment and the dwelling itself, and how they influence the overall housing preferences, has been little explored in the literature (Jansen, 2020), even less concerning effects in the choice of housing customisation. In addition, the customisation unit concept proposed by Rocha (2011) is operationalised by the hierarchical model of attributes related to the components of the housing product.

The main objective of the hierarchical structure was to classify attributes, supporting the experiment design and preference modelling. The adoption of classes of attributes enables segmenting the experiment design into a manageable number of attribute levels to be shown to respondents, to avoid overwhelming them with too many possibilities and different topics at the same time. Such a segmentation has a similar effect to blocking the alternatives into choice sets, used in previous studies (Fogliatto and da Silveira, 2008; Hentschke et al., 2021; Molin, 2011). Furthermore, adopting a hierarchical structure allows building models for each housing solution level or a hierarchical logit model of all variables when modelling customers' preferences.

Coolen and Ozaki (2004) discussed that deconstructing housing in attributes simplifies understanding preference motivations, overall meaning and value. According to Jansen (2020), insights related to preferences and motivations can also support planning decisions regarding housing developments and contribute to households' well-being. Therefore, the motivations for the choice were also assessed in this investigation. Most respondents justify their project, apartment, and customisation choices through motivations related to the openness to change domain (i.e. hedonism and stimulation) described by Nijestein et al. (2015). According to them, openness to change values implies having a varied and stimulating life and enjoying life in a comfortable environment. Such values are related to creativity, freedom and independence, and needs that can be met by innovative architectural design, as stated by Jansen (2014). The values discussed corroborate Hentschke et al. (2014) results regarding the strong relationship between apartment customisation for creating a comfortable environment, aesthetics, enjoying life and well-being.

5.7 CONCLUSION

A method for capturing customers' demands and supporting the solution space's definition is the primary outcome of this investigation. This method has merged four contributions to this field of knowledge: (i) adaptation of MBC to the housing context, (ii) usage of a hierarchical model of housing attributes, (iii) association between preferences with motivations, (iv) adoption of a WTP approach.

The solution was tested and refined during its implementation in an empirical study for identifying potential customer's preferences for customised residential buildings. This implementation was focused on a single company context, and the survey was applied to a restricted number of potential customers. Due to time limitations, the method was not thoroughly tested as a decision-making supporting tool for the definition of solution spaces. Therefore, an opportunity for future studies is to fully implement the solution, monitor further actions and effects on MC strategies and comprehensively evaluate its utility and applicability.

Customers can state their preferences and willingness to pay for a product configuration by using a set of relatively simple menus. Some customers have indicated their WTP for obtaining an apartment with a customised layout, floor finishings, sanitary ware and or additional acoustic isolation. The limited number of customers who are willing to pay for these customisations and the perception of high prices might have affected utilities' estimation and the high importance of the item's price themselves. Moreover, a larger sample is required to improve the understanding of the interrelationship between items, confirm customers' preferences, and enhance the potential of recommendation of the results.

The use of MBC reinforces the critical role of choice menus in the adoption of MC strategies as an essential interface and source of information from customers. Furthermore, this type of investigation supports the initial steps for defining solution spaces and designing the choice menu, revealing a yet fruitful research environment and new research opportunities as follows:

(i) Understand the effects of product customisation on customers and how to explore the positive ones (e.g. enjoyment and "build your own") and mitigate the negative ones (e.g. information overload), focusing on value generation;

(ii) Further explore the use of customers' preference information to support platform design and recommendation systems;

(iii) Develop product architecture and price optimisation strategies, as discussed by Colombo et al. (2020), considering customisation price as an important factor for customers.

5.8 ACKNOWLEDGEMENTS

We would like to thank Company W for collaborating, being available to discuss and promote the research. Thanks CAPES, for partially funding this investigation. We would also like to thank Sawtooth Software® for providing academic licences and support. Thanks to Manoela Conte, for supporting as a researcher the initial steps of this investigation, and Cristiano Reis dos Santos, for developing the scripts for the choice menu questions.

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6 CONCLUSION

The divergence between the increasing diversity of customer's requirements and the adoption of traditional housing provision strategies is the practical problem addressed in this investigation. MC strategies and customer integration were chosen as the theoretical background to tackle such problems. This investigation has focused on providing decision making support to enable customer integration in MC rather than on the development of configurators or digital tools. Therefore, the objectives of this doctoral thesis encompass: (i) to propose a framework of decision categories for customer integration and for devising the scope of customisation to support the definition of housing MC strategies, (ii) to devise a method for capturing customers demands to support the solution space definition by combining a stated choice, a WTP approach, and cost estimation (iii) Propose a method for capturing customers' demands for housing customisation based on MBC and a WTP approach.

One of the outcomes of this investigation was a framework of decision categories related to customer integration and defining the scope of MC strategy (Chapter 3). Such a framework was built upon an overview of essential decisions and practices for integrating customers and defining the scope of MC for housing. Some of the decision categories were proposed by previous studies and refined in this investigation (e.g. solution space, level of customisation, visualisation approaches), and some were original contributions (e.g. knowledge management and customer interaction and relationship). In addition, a list of practices was compiled, which can support the assessment of MC strategies and customer integration and serve as guidance for refining or defining new strategies. This research stage provided background knowledge considered in the development of the artifact.

The main outcomes of this investigation are two methods for capturing customers demands for housing customisation; their similarities and differences are explained in Table 7 comparison between Method 1 and Method 2. The first method was developed based on stated choice, preference models and a willingness-to-pay approach and proposed a way for balancing customer value and operations costs (Chapter 4). It was tested in an exploratory study with a sample of potential customers from MHML program. Its limitations included assessing a small number of attributes focussing exclusively on the customisable ones, a limited number of product alternatives, a small sample size, and the implementation in a hypothetical context. However, a key advantage of the first method is the WTP profile graphic, which enables decision-makers to see all product alternatives, their buying propensity, prices, cost, and profitability to support solution space definition.

Table 7 comparison between Method 1 and Method 2

	First Method	**Second Method**
Stated preference technique	Stated Choice	Menu-Based Choice
Focus	Product alternatives	Attributes
Context understanding	Based on the literature and secondary data	Based on Semi-structured interviews, document analysis, meetings
Identification of Relevant attributes	Based on the literature and secondary data	Identification based on semi-structured interviews, document analysis, and in the literature; Organisation and prioritisation of attributes in a hierarchical way and rated on a scale based on Kano's model.
Experiment planning	Full factorial, Blocked Choice Two stimulation stages	Three experiments Choice One choice task per menu
Data collection	Online survey Survey monkey	Online Survey Sawtooth Software
Customer preference modelling	Logit model	Aggregate Logit model Hierarchical Logit Model
WTP Estimation	Logit-based model applied by product alternative	Price sensitivity analysis
WTP Representation	S-Curve Profile graph of all product alternatives	Interaction Plots of the price sensitivity analysis by attribute

The second artifact was based on MBC, preference models and another WTP approach (Chapter 5). The adoption of MBC is still recent and sparse, so it was adapted and applied in housing for the first time in this investigation. It was tested and refined in an empirical study with potential customers from a residential building company from south Brazil. Focussing on the attributes has a twofold effect on the contributions of the second method: it enables the assessment of each attribute's value and effects; however, it limits the perception of the housing product as an integral solution. Another limitation of the method included the decompositional approach adopted for cost and price estimates, which might need more robust cost models to be adequate for housing products peculiarities.

Another contribution that emerged from the implementation of the second method was the hierarchical structure of attributes. New categories of attributes regarding the surrounding areas and the residential environment were combined with some categories regarding the housing parts existing in the literature, assisting the organisation and grouping of attributes according to the scale of the product part and decision sequence for a new home. The hierarchical structure supported the experiment planning, enabled the hierarchical modelling of customers preferences, and can be used to assess different housing solutions from other companies and contexts.

The two approaches for modelling customers willingness-to-pay from both methods, resulting in profile graphs (see figure 7, Chapter 4) and price sensitivity interaction plots (see figure 10, Chapter 5), configure other contributions to the field of knowledge of this investigation.

For evaluating the utility of the solution, some criteria were defined for each research outcome. The decision categories and practices were accessed during discussions with company P according to some predefined criteria regarding its potential for (i) underpinning the assessment of decision categories, (ii) supporting the understanding of MC related concepts and fundamental ideas and (iii) defining MC strategies, in terms of customer integration. Both decision categories and practices enabled the assessment of the strategy in two different moments during the empirical study, resulting in the identification of improvement opportunities and incentive to refine the strategy. Discussions with the company representatives reflected on improving their understanding of MC underlying ideas, facilitating their daily routine and collaboration between sectors. Furthermore, the discussions regarding decision categories brought to light many relevant aspects of customer integration, including (i) making explicit the customisation offers for customers and their role in the customisation process, and (ii) how professional guidance during configuration can help to increase satisfaction and to building a trustworthy relationship between customer and company.

The utility of the methods was evaluated based on the following criteria: (i) support decision-making regarding the definition of the solution space; (ii) support for identifying improvements and defining standard housing products or parts; and (iii) support decision-making regarding the balance between customer value and operations costs. The first method was evaluated internally, and the second one based on discussions with company W, perceptions from the leading researcher, and existing literature. Furthermore, the second method was also evaluated regarding its utility to support the development of recommendation systems, and applicability. The applicability evaluation concerned the ease of use and reuse of the questionnaire and hierarchical model for housing attributes.

Both methods successfully identified the preferred customisable attributes, and for each of them customers were willing to pay, considering their respective samples. Such information compared with operations costs and prices supported the suggestion of items to compose case-specific solution spaces. In terms of the support for defining stardardised parts of the housing product, the second method has a major potential by considering the housing solution from a holistic perspective and identifying preferences regarding different levels of the housing solution. According to company W representatives, the identified attributes and preferences can support the process of defining new residential developments in early phases such as briefing and architectural programming. A limitation of both versions' instantiation was their small sample sizes, and consequently, the results have limited potential for creating recommendations. Nevertheless, the utilities and relationships found can be confirmed by applying the method in larger samples of customers or extrapolated by simulating data or using machine learning tools, as Tan et al. (2020) suggested.

The theoretical contributions of this investigation have been discussed regarding the existing literature in chapters 3, 4 and 5. Most of the contributions emerged during the empirical studies, inspired by the literature aiming to solve practical problems identified. For instance, the knowledge management decision category was strongly related to practical problems identified in the empirical study in company P, such as the lack of communication between sectors and with customers. Another example regards the adaptation of MBC for housing and the proposition of the hierarchical structure of housing attributes, which emerged during the implementation in company W. By contrast, the first version of the method for identifying customer demands for mass customised housing was more heavily grounded in the existing literature. Especially regarding the proposition of a combination of choice-based preference models and a WTP approach and the development of the logistic regression model.

Some suggestions for future research that emerged from this investigation:

i. To implement the method for capturing customers' demands for customised housing to support the solution space definition in other contexts, companies and markets.

ii. To further investigate customers' perception of value for customisation, including expanding the understanding of their willingness to pay and the underlying values and motivations for choice. Also, to explore the effects of enjoyment and "authorship" of configuring your own product on the perception of value.

iii. To develop further guidance for implementing the framework of decision categories for customer integration and definition of MC scope.

iv. To further explore the interfaces between customer integration, design, and operations to obtain a holistic perspective of the MC strategies. This investigation proposed a specific framework for customer integration; therefore, there are still opportunities for developing product design and operations specific frameworks.

v. To further explore and assess existing relationships between decision categories, such as the solution space and level of customisation categories. Another opportunity would be to investigate more deeply newly proposed decision categories and or ones that have been little explored in the literature, such as knowledge management and configuration sequence.

vi. To devise and refine recommendation systems for housing based on customers' preferences that can be embedded in choice menus, configurators, or based on surveys.

vii. To explore new concepts and tools that can provide support for customer integration and facilitate the adoption of MC strategies in construction, such as big data, information-driven decision making, and industry 4.0.

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APÊNDIX A – PAPER 3 ADDITIONAL RESULTS - EFFECTS BETWEEN VARIABLES

Table A.1: Effects between variables customisable attributes

	(D)		(F)			(I)	(W)	Internal area				
	change one room	change two rooms	In wet areas	In dry areas	In whole apartment	Add double glass windows	Option of sanitary ware	Up to 40m²	40 to 80m²	80 to 120 m²	120 to 160 m²	160 to 200 m²
Independent Variable	Relationship p-value	Relationship p-value	Relationship p-value	Relationship p-value	Relationship p-value	Relationship p-value	Relationship p-value	Relationship p-value	Relationship p-value	Relationship p-value	Relationship p-value	Relationship p-value
1 room price	0.11	0.57	1.00	0.33	0.21	0.37	0.61	0.15	0.74	0.83	0.15	0.79’
2 rooms price	1.00	0.87	0.83	0.38	0.83	0.35	0.28	0.07*	0.61	0.87	0.82	0.71’
Wet areas price	0.24	0.46	0.07*	0.43	0.78	0.27	0.32	0.75	0.54	0.94	0.12	0.68’
Dry areas price	0.83	0.75	0.73	0.17	0.08*	0.20	0.63	0.24	0.47	0.76	0.42	0.29’
Add Double Glass price	0.79	0.19	0.30	0.97	0.84	0.96	0.84	0.27	0.24	0.22	0.43	0.36’
Sanitary Ware price	0.83	0.75	0.73	0.74	0.45	0.46	0.84	0.71	0.12	0.01***	0.14	0.65’
Internal Area Price	0.69’	0.06’*	0.83’	0.88’	0.39’	0.34’	0.04’**	0.00’***	0.00’***	0.00’***	0.00’***	0.00’***
	Non-linearity p-value	Non-linearity p-value	Non-linearity p-value	Non-linearity p-value	Non-linearity p-value	Non-linearity p-value	Non-linearity p-value	Non-linearity p-value	Non-linearity p-value	Non-linearity p-value	Non-linearity p-value	Non-linearity p-value
Internal area Price	0.03’**	0.01***	0.99’	0.68	0.28’	0.01***	0.01’***	0.00’***	0.00’***	0.00’***	0.00’***	0.00’***

‘(Chi-Square test with expected frequency is less than 5); *(p-value<0.1); **(p-value< 0.05); ***(p--value<0.01).

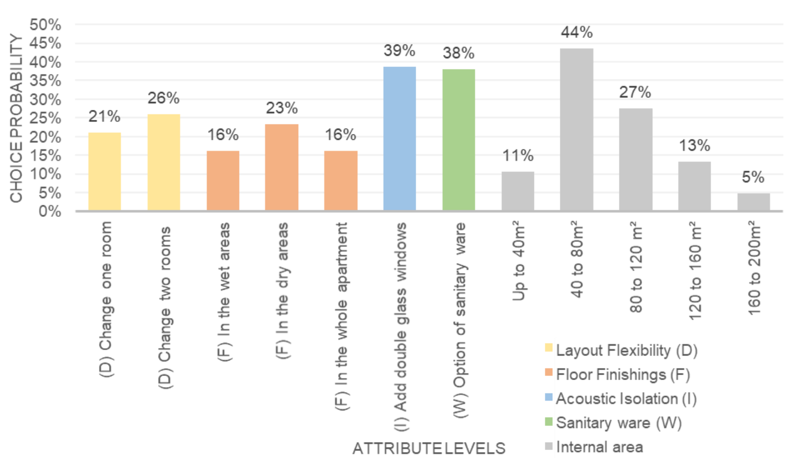
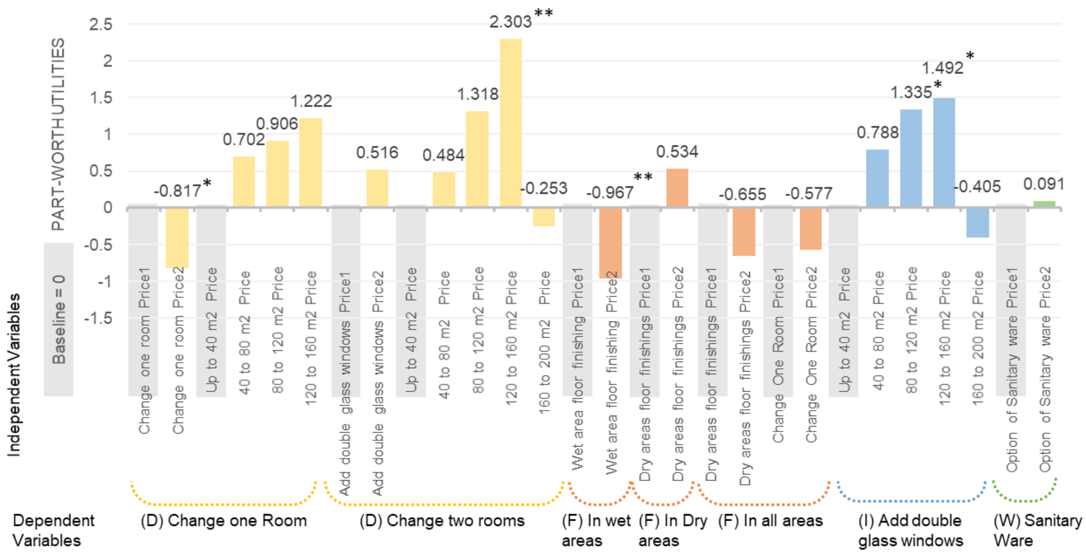


Figure A.1 choice probability of apartment’s customisable attributes



*(p-value<0.1) **(p-value<0.05) and ***(p-value<0.01)

Figure A.2 Part-worth utilities of apartment’s customisable attributes

Table A.2: Effects between variables customisable attributes for the hierarchical model

	Neighbourhood					Condominium									
	City Zone		Type			Condominium Amenities			Shared uses			Environmental Sustainability			
	Central	others	Residential	Mix	no preference	No amenities	Basic Amenities	Complete amenities	No Shared Facilities	Basic shared facilities	Complementary shared uses	No sustainable equipment	Community Garden	Solar systems	Community Garden + Solar systems
	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value
Internal area _Price	0.74'	**0.07‘ ***	0.42'	0.99'	0.44'	0.29'	0.96'	0.70'	0.89'	0.47'	0.46'	0.86'	0.49'	0.98'	0.79'
Bedroom _Price	0.51	**0.05‘ *****	0.62'	0.86	**0.08‘***	**0.08‘***	0.69'	0.35'	0.88	0.78'	0.46'	0.97'	0.28'	0.82	0.83'
1Parking Space _Price	0.92	0.83	0.29'	0.77	0.98'	0.34	0.74	0.81	0.67	0.46'	0.77	**0.06***	0.26	**0.10***	0.81
2Parking space _Price	0.58	0.25	0.90'	0.92	0.77'	**0.14**	0.42	0.98	0.95	0.74	0.72	**0.12**	**0.06**	0.49	**0.19**
No private ouside _Price	0.98	0.95	**0.07‘ ***	0.48	0.34'	0.42	0.94	0.65	0.58	0.59'	0.50	**0.19**	0.99	0.53	0.71
Balcony _Price	0.91	0.81	0.88'	1.00	0.84'	0.60	0.63	0.36	0.59	**0.17'**	**0.05**	0.26	0.33	**0.13**	0.56
Layout _Price	0.93	0.74'	**0.19'**	0.96	0.41'	**0.03'**	0.66	**0.03**	0.97	0.45'	0.60	0.82	0.58'	0.45	0.38'
Floor Finishings _price	0.98	0.83'	**0.03‘ *****	0.90	0.79'	**0.02'**	**0.12**	**0.06***	0.98	0.94'	0.68'	0.90'	0.62'	0.98	0.25'
Acoustic isolation_ Price	0.59	0.27	0.27'	0.62	0.35'	0.35	0.57	0.97	0.95	0.20'	0.32	**0.16**	**0.16**	**0.14**	0.87
Sanitary ware _Price	0.58	0.24	0.23'	0.71	0.87'	**0.13**	0.73	**0.15**	0.97	0.71'	0.85	**0.16**	0.68	0.88	0.32

‘= Chi-Square test may be unreliable. An expected frequency is less than 5. *= P-value<0.1 ; **=P-value< 0.05 ***=P-value<0.01

Continues

	Internal area					Apartment's essentials					Customisable apartment								
						Number of Bedrooms (B)			Parking Spaces (P)		Private Outside space (O)		Layout Flexibility (D)		Floor Finishings (F)			Acoustic Isolation (I)	Sanitaty Ware (W)
	Until 40m	Between 40 and 80m	Between 80 and 120m	Between 120 and 160	Between 160 and 200m	Standard number of bedrooms	Closing the bedroom in studios	Additional Bedroom	1	2	No private outside space	Balcony of 5 m²	Option to change one room layout	Option to change two rooms layout	Customised floor finishings in the wet areas	Customised floor finishings in the dry areas	Custom floor Finishings of all the apartment	Add double glass windows	Custom Sanitary Ware
	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value	Relationship P-Value
Internal area _Price	0.00' ***	0.00' ***	0.00' ***	0.00' ***	0.00' ***	0.00' ***	0.00' ***	0.00'***	0.00' ***	0.00' ***	0.52'	0.38'	0.49'	0.03' **	0.69'	0.91'	0.23'	0.36'	0.07' *
Bedroom _Price	0.00' ***	0.00' ***	0.00' ***	0.38'	0.64'	0.00***	0.00' ***	0.00'***	0.02' **	0.00' ***	0.87'	0.51	1.00'	0.32'	0.83'	0.68'	0.12'	0.57'	0.10' *
1Parking Space _Price	0.77	0.29	0.10*	0.50	0.35'	0.34	0.98'	0.12	0.16	0.81	0.84	0.57	0.96	0.79	0.24	0.96	0.57	0.47	0.90
2Parking space _Price	0.43	0.43	0.36	0.22	0.55'	0.74	0.82'	0.50	0.60	0.44	0.58	0.98	0.58	0.45	0.94	0.26	0.74	0.18	0.23
No private ouside _Price	0.04**	0.27	0.54	0.83	0.39'	0.17	0.05'*	0.26	0.79	0.56	0.47	0.93	0.61	0.68	0.93	0.53	0.65	0.64	0.84
Balcony _Price	0.10' *	0.24	0.18	0.50	0.26'	0.66	0.30'	0.88	0.41	0.81	0.36	0.73	0.65	0.52	0.29	0.16	0.16	0.88	0.20
Layout _Price	0.36'	0.18	0.40	0.01' ***	0.41'	0.95	0.42'	0.46	0.21	0.11	0.24	0.66	0.00' ***	0.00***	0.74'	0.79	0.00'	0.23	0.00***
Floor Finishings _price	0.79'	0.28	0.43	0.45'	0.41'	0.85	0.47'	0.25'	0.51	0.09**	0.53'	0.99	0.84'	0.00***	0.00' ***	0.00' ***	0.00' ***	0.22	0.00***
Acoustic isolation_ Price	0.15	0.52	0.40	0.07*	0.35'	0.67	0.19'	0.97	0.70	0.87	0.52	0.84	0.40	0.06	0.21	0.74	0.03**	0.00***	0.02**
Sanitary ware _Price	0.02**	0.16	0.04**	0.26	0.27'	0.95	0.02' **	0.22	0.04**	0.00	0.17	0.59	0.43	0.00	0.14	0.05*	0.00***	0.02**	0.00

'= Chi-Square test may be unreliable. An expected frequency is less than 5. *= P-value<0.1 ; **=P-value< 0.05 ***=P-value<0.01

Table A.3: Effects between variables customisable attributes for the hierarchical model - Non-linearity P-value

	Neighbourhood					Condominium										Internal area				
	City Zone		Type			Condominium Amenities			Shared uses			Environmental Sustainability								
	Central	others	Residential	Mix	No preference	No amenities	Basic Amenities	Complete amenities	No Shared Facilities	Basic shared facilities	Complementary shared uses	No sustainable equipment	Community Garden	Solar systems	Community Garden + Solar systems	Until 40m	Between 40 and 80m	Between 80 and 120m	Between 120 and 160	Between 160 and 200m
	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value
Internal area _Price	0.86	0.71'	**0.09'** *	0.91	0.66'	0.56'	0.95	0.37	0.84	0.11'	0.65'	0.66'	0.16'	0.78	0.11'	**0.00'** ***	**0.00'** ***	**0.00'** ***	**0.00'** ***	**0.00'** ***
Bedroom _Price	**0.03****	**0.00*****	**0.07'** *	0.84	**0.08'** *	**0.00'** ***	0.50	**0.00*****	0.42	1.00'	0.10	0.94	**0.01*****	0.28	0.53'	**0.00'** ***	**0.00'**	**0.00'**	**0.01'** ***	(N/A)
Layout _Price	0.71	0.42	0.13'	0.81	0.78'	**0.00'** ***	0.77	**0.03****	0.91	0.29'	0.65	0.60	0.78'	0.97	0.31	0.19'	**0.06**	0.24	**0.00'** ***	0.78'
Floor Finishings _price	0.90	0.61	0.59'	0.99	0.64'	0.46'	**0.03**	0.12	0.87	0.73'	0.36	0.67	0.38'	0.91	**0.03'** **	0.63'	0.97	0.90	0.92'	0.15'

'= Chi-Square test may be unreliable. An expected frequency is less than 5. *= P-value<0.1 ; **=P-value< 0.05 ***=P-value<0.01

	Apartment's essentials							Customisable apartment						
	Number of Bedrooms (B)			Parking Spaces (P)		Private Outside space (O)		Layout Flexibility (D)		Floor Finishings (F)			Acoustic Isolation	Sanitary Ware (W)
	Standard number of bedrooms	Closing the bedroom in studios	Additional Bedroom	1	2	No private outside space	Balcony of 5 m²	Option to change one room layout	Option to change two rooms layout	Customised floor finishings in the wet areas	Customised floor finishings in the dry areas	Custom floor Finishings of all the apartment	Add double glass windows	Custom Sanitary Ware
	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value	Non-linearity P-Value
Internal area _Price	**0.00** ***	**0.00'** ***	**0.00'*****	**0.01'** ***	**0.00'** ***	0.53'	0.55	0.24'	**0.01'** ***	0.37'	0.87	0.33'	**0.02*****	**0.05'** **
Bedroom _Price	**0.00'** ***	**0.00'** ***	**0.00'** ***	**0.05** **	**0.00*****	0.38	0.38	0.92	**0.01*****	0.53'	0.54	**0.00'** ***	**0.04****	**0.00*****
Layout _Price	0.76	0.12'	0.22	**0.09***	**0.04****	**0.06***	0.39	0.40'	**0.00'** ***	0.95	0.52	**0.00'** ***	**0.10***	**0.00*****
Floor Finishings _price	0.81	0.50'	0.82	0.95	0.20	0.66'	0.91	0.66	0.91'	**0.00'** ***	**0.00'** ***	**0.00'** ***	0.32	**0.00'** ***

'= Chi-Square test may be unreliable. An expected frequency is less than 5. *= P-value<0.1 ; **=P-value< 0.05 ***=P-value<0.01

APÊNDIX B – PAPER 3 ADDITIONAL RESULTS - LOGIT MODELS AND UTILITIES

Table B.1 Customisable attributes logit models results

Dependent Variables	Independent Variables	Part-worth Utilities	Error	t-ratio	Model Validation Parameters
(D) Change One Room	ASC (change one room)	-1.208	0.81176	-1.48782	Difference LL–LLN = 23.26
	change one room Price 2	-0.817	0.44118	-1.85261*	Percent Certainty = 14.91323
	40 to 80 m2 Price	0.702	0.83853	0.83723	Consistent Akaike Info Criterion (CAIC) = 336.94566
	80 to 120 m2 Price	0.906	0.88481	1.02423	Chi-Square ($\chi2$) = 46.53015
	120 to 160 m2 Price	1.222	1.03754	1.17767	Relative $\chi2$ = 3.87751
	160 to 200 m2 Price	-13.126	*******	********	
(D) Change Two Rooms	ASC (change two rooms layout)	-1.927	0.79685	-2.41794**	
	Add double glass windows Price 2	0.516	0.41871	1.233	
	40 to 80 m2 Price	0.484	0.84608	0.572	
	80 to 120 m2 Price	1.318	0.86024	1.53247	
	120 to 160 m2 Price	2.303	0.94975	2.42485**	
	160 to 200 m2 Price	-0.253	1.33622	-0.18904	
(F) floor finishings in the wet areas	ASC (floor finishings in the wet areas)	-0.605	0.29751	-2.03237**	Difference LL–LLN = 19.02345
	Wet area custom floor finishing Price 2	-0.967	0.49067	-1.97128**	Percent Certainty = 9.66374
(F) floor finishings in the dry areas	ASC (floor finishings in the dry areas)	-0.936	0.32176	-2.90744**	CAIC = 397.35149
	Dry areas custom floor finishings Price 2	0.534	0.41795	1.27864	$\chi2$= 38.04690
(F) floor finishings in the whole apartment	ASC (floor finishings in the whole apartment)	-0.509	0.34164	-1.48915	Relative $\chi2$ = 5.43527
	Floor finishings Dry areas Price 2	-0.655	0.50743	-1.29117	
	Change One Room Price 2	-0.577	0.48252	-1.19595	
(I) Add double glass windows	ASC (Add double glass windows)	-1.386	0.64549	-2.14765**	Difference LL–LLN = 7.56244
	40 to 80 m2 Price	0.788	0.69794	1.1297	Percent Certainty = 7.68331
	80 to 120 m2 Price	1.335	0.72062	1.85258*	CAIC = 211.50805 $\chi2$ =
	120 to 160 m2 Price	1.492	0.79232	1.88264*	Relative $\chi2$= 3.02498
	160 to 200 m2 Price	-0.405	1.25812	-0.32228	
(W) option of sanitary ware	ASC (option of sanitary ware)	-0.533	0.24244	-2.1977**	Difference LL–LLN = 4.14483
	Option of Sanitary ware Price 2	0.091	0.34586	0.26303	CAIC = 200.47579 $\chi2$= 8.28966 Relative $\chi2$= 4.14483

LL= Log-Likelihood; LLN= Log-Likelyhood for Null; ASC= alternative-specific constants; *=t-ration > 1.645; **= t-ratio > 1.96

Table B.2 Customisable attributes Hierarchical Logit Model results

Dependent	Independent	Linear Utilities	Error	t-ratio	Model Validation Parameters
(D) Change one room	ASC (Change 1 room)	47.652	******	******	Difference LL–LLN = 107.11287
	ASC (Change 2 rooms)	48.521	******	******	Percent Certainty= 75.58010
	Layout Flexibility Price	163.604	******	******	CAIC = 110.23493
(D) Change two rooms	ASC (Change 1 room)	47.652	******	******	χ2= 214.22573
	ASC (Change 2 rooms)	48.521	******	******	Relative χ2= 30.60368
	Internal area Price	3.527	1.46788	2.40289**	
	Layout Flexibility Price	163.604	******	******	
	Floor Finishings Price	0.748	0.92276	0.81099	
	Acoustic isolation Price	1.092	0.63664	1.71558*	
	Sanitary ware Price	0.044	0.71801	0.06177	
(F) floor finishings in the wet areas	ASC (Floor Finishings wet areas)	13.846	******	******	
	Floor Finishings Price	60.309	******	******	
	Sanitary ware Price	0.671	******	******	Difference LL–LLN = 105.45717
(F) floor finishings in the dry areas	ASC (Floor Finishings dry areas)	14.136	******	******	Percent Certainty = 58.96998
	Floor Finisings Price	60.309	******	******	CAIC= 199.48791
	Sanitary ware Price	0.671	******	******	χ2= 210.91435
	Balcony Price	-1.084	0.63043	-1.71981*	Relative χ2= 23.43493
(F) floor finishings in the whole apartment	ASC (Floor Finishings whole apartment)	14.124	******	******	
	Floor Finisings Price	60.309	******	******	
	Sanitary ware Price	0.671	******	******	
	Number of Bedrooms Price	0.501	0.56472	0.88653	
	Layout flexibility Price	0.594	0.67245	0.88304	
	Balcony Price (2)	1.228	0.61426	1.99996**	
(I) Add double glass windows	ASC (Add double glass windows)	-0.051	3.39498	-0.01501	
	Internal area Price	0.056	7.10211	0.0079	
	Number of Bedrooms Price	-0.019	5.59069	-0.00336	Difference LL–LLN = 89.36512
	2Parking spaces Price	0.067	5.16931	0.01305	Percent Certainty= 99.94312
	Layout Flexibility Price	-0.032	5.98773	-0.00528	CAIC= 41.12041
	Acoustic Isolation Price	15.612	5.26658	2.96439**	χ2= 178.73025
	Sanitary ware Price	0.125	5.3748	0.02327	Relative χ2= 25.53289
(W) option of sanitary ware	ASC (option of sanitary ware)	0.003	2.44976	0.00113	
	Internal area Price	0.063	7.11084	0.00883	
	Number of Bedrooms Price	-0.01	4.45764	-0.00226	Difference LL–LLN = 89.31181

	Balcony Price	0.021	3.94723	0.00536	Percent Certainty = 99.88350
	Layout flexibility Price	0.033	4.90689	0.0067	CAIC= 47.08685
	Floor finishings Price	0.144	5.77666	0.0249	$\chi2$= 178.62363
	Acoustic isolation Price	0.04	3.96872	0.01013	Relative $\chi2$= 22.32795
	Sanitary ware Price	14.143	4.69372	3.01316**	

LL= Log-Likelihood; LLN= Log-Likelyhood for Null; ASC= alternative specific constants; *=t-ratio > 1.645; **= t-ratio > 1.96