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ALGORITMOS PARTICIPATIVOS: METODOLOGIA PARA A CUSTOMIZAÇÃO ARQUITETÔNICA PARTICIPATORY ALGORITHMS: A METHODOLOGY FOR ARCHITECTURAL CUSTOMIZATION

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Abstract

This article presents a research result that aims to develop an algorithmic methodology for the application of the concept of mass customization in the architectural design process. For that, another parallel research developed by one of the authors is taken, in which the subtractive digital fabrication has been studied from the construction in real scale of exploratory models. The work begins with the context of large-scale housing production, which has characterized housing programs in several countries since the last century. Then, the concept of mass customization is presented, including reflections on its application in building production. In its final part, after a brief description of the research in digital manufacturing carried out simultaneously, the algorithm its structure and results are described, contemplating three aspects: adaptation to an architectural/constructive solution, generation of variations, and dialogue interface with future residents. Thus, through digital tools, we perceive a way of a more collaborative relationship in the architectural definitions of large scale housing production.

Keyword: Mass housing, Mass customization, Algorithmic architecture, Parametric architecture, Generative architecture

1 Introduction: large-scale housing in the 21st century

Since the middle of the last century, international examples have shown a tendency towards the production of large and massified residential complexes with identical housing units. This tendency seems to attend, particularly in countries with an emerging economy, the huge demand for adequate housing, especially in cities where slums and other precarious housing modalities generate large-scale problems (Buckley, Kallergis, and Wainer, 2016). Large-scale housing programs were widely developed in the 20th century, mainly in post-war Europe. The Soviet Khrushchyovkas, the Plattebaus of East Germany, the Czech-Slovak Paneláks, the Swedish Million Program and the British Tower Blocks are examples of these initiatives, which focused on large quantities of housing units with the repetition of identical plants, ignoring specific demands from communities and families (Urban, 2012). However, the French model stood out for the huge number of units delivered: more than 9 million *Habitation à Loyer Modéré* (HLM) built until the 1980s in the so-called Grands Ensembles (Power, 1993).

However, a significant change distinguishes postwar programs from current cases: the role of the state. The Social Welfare State was the great promoter of these 20th-century programs, which became evident by the speech, in 1953, of the former French reconstruction minister, Eugène Claudius Petit, who stated that instead of rebuilding the country, which was to him a way of looking to the past and not to the future, they should produce new houses for the French people. Petit had promised 14 million new housing units in 20 years and, although the French government has failed to deliver what he said, France and many other European countries have erected huge amounts of housing for their citizens (POWER, 1993). In the current model, the State no longer acts as a promoter but as a facilitator of construction. This trend of transferring the state promotion to the hands of society dates back to the years of 1970 when the State started to stimulate demand and not direct provision (Noia, 2017). Thus, the State facilitates the housing production by private companies, through financing and other advantages to builders (Buckley; Kallergis, and Wainer, 2016).

These changes promoted, from the second half of the 20th century, a revision of the paradigm, allowing self-managed processes (Noia, 2017), which emerge as responses to the social problems that arose from the large housing estates. The demolition of Pruitt Igoe, for example, was interpreted as the end of Modernism and its model of housing promotion was considered widespread, productive, and indifferent to real demands. Many other notorious examples of large residential blocks had the same destination, such as Cité de la Muette, in France, or Killingworth Towers, in England (Fonseca de Campos, 2016; Reis and Lay, 2006). Consequently, a new paradigm of social housing arises, in which specific communities directly participate in the production of their own home, supported by the idea that "the informal production should not be seen as a social affront but as an opportunity for promoting the control and autonomy of the inhabitant" (Noia, 2017, p. 64).

The importance and advantages of the so-called participatory processes began to gain enthusiastic supporters, a literature of their own from the late 1960s, and a better-defined outline of their objectives. Several world experiences of the stimulation of self-management processes and other types of participatory actions have become popular both in rich countries and emerging economies. Experiences like those of Giancarlo de Carlo, in Vila Matteotti, Terni, Italy; Christopher Alexander, in Mexicali, Mexico; the Local Support Service (SAAL), in Portugal; Egyptian Hassan Fathy, in Egypt; Englishman John F. C. Turner, in Peru; the Uruguayan Housing Cooperatives; Byker Wall, by Ralph Erskine, in England; and MolenVilet in Papendrecht, in the Netherlands, are notorious cases of the application of participatory methodologies.

In Brazil, the achievements of the so-called Technical Assessment [*Assessorias Técnicas*], created by the former Mayor Luíza Erundina in the city of São Paulo (1989-1992) (Fonseca de Campos, 2016), are notable, as well as examples such as the experiences of the group USINA CTAH and the NGO Peabiru. However, although participatory initiatives and self-managed programs continue to be practiced, mass models continued to be favored by different governments at the beginning of the 21st century. Several programs were created to provide the facilitation of large-scale housing production by private builders and developers, who benefit from low-interest rates and cheap land far from urban centers. These practices are common in developing countries, as in the examples in the table below:

Country	Program
Argentina	Programa de Crédito Argentino del Bicentenario para la Vivienda Única Familiar (PRO.CRE.AR)
Brazil	Programa Minha Casa Minha Vida (PMCMV)
Colombia	Vivienda de Interés Social (VIS)
Ethiopia	Integrated Housing Development Program (IHDP)
India	Rajiv Awas Yojana (RAY)
Mexico	Esta es tu Casa
South Africa	Comprehensive Plan for the Development of Sustainable Human Settlements a.k.a Breaking New Ground (BNG)
Thailand	Baan Mankong (CODI)

Table 1: Recent large-scale social housing promotion programs. Source: Adapted from Buckley, Kallergis, and Wainer, 2016.

These achievements are characterized by the enormous financial resources delegated to the subsidized interest; the preference for new constructions instead of refurbishing the existing housing stock; and the massifying and homogenizing character of the repetition of identical units. These are, in fact, financing programs, not architectural and urbanistic proposals (Buckley, Kallergis, and Wainer, 2016). In Latin America, the Mexican and Brazilian cases are noteworthy for the huge number of units built. Between the years 2000 and 2015, large Mexican cities witnessed a significant growth of their peripheries. This phenomenon is the result of a shift in the national housing policy from the mid-1990s under the World Bank's rules, stimulating actions focused on the development of the free market. Subsequently, public agencies began to focus their efforts on managing social credit mortgages – in the Mexican case through the Instituto del Fondo Nacional de la Vivienda para los Trabajadores (Infonavit) – stimulating private production of social housing.

If, until then, public agencies produced and managed vertical residential units, conceived under the European model of the Grands Ensembles, from that moment on, a more horizontal pattern, based on houses lined up in rows, began to prevail. It generated high-density housing developments with a low supply of equipment and far from urban centers, where most of its residents still depend on jobs in central areas, making mobility a significant problem (JACQUIN, 2012).

Even so, in 2014, the Secretaría de Desarrollo Agrario, Territorial y Urbano (Sedatu) identified a deficit of almost three million homes because, despite the millions of units built, the merely quantitative concern of the developers and the state's facilitation stance ignored that housing is not just a house. The poor quality of the constructions, difficulties of locomotion to the central areas, and lack of necessary infrastructures impacted on the vacancy of millions of housing units built in the Mexican peripheries at the beginning of this century. This has created huge under-occupied housing complexes and contributed to the physical degradation and social of these urbanizations (Blas, 2015).

In the Brazilian case, the Minha Casa, Minha Vida Program (PMCMV) completed ten years in 2019 with an absolute quantitative record: more than four million units delivered (Brasil, 2019). Launched in 2009 by the federal government, it is the most ambitious social housing program in the history of Brazil. Conceived by the ministries of the Civil House and Finance, in agreement with the construction industry, the PMCMV has been facing difficulties identified by some authors as a very simplified interpretation of the Brazilian housing problem, overcoming the deficit according to a purely productivist view based predominantly on quantitative targets (Rizek, Santo Amore, and Camargo, 2014). The program perpetuates more vigorously the characteristics of previous programs, such as the experience of the National Housing Bank (BNH) (Noia, 2016), while dealing with the housing problem from a financial perspective, relegating architectural and urban problems to the background.

Among the frequent criticisms about the program, we can mention the low percentage of financing dedicated to the Range 1 (Rizek, Santo Amore, and Camargo, 2014), dedicated to families with a gross monthly income of up to R$ 1,800.00, which are the neediest group. The search for cheaper lands tends to move enterprises away from urban centers and the imposed urbanizations ignore the daily dynamics of families, two factors that difficult the life of the residents. However, the attention of the present study focuses on housing units and their inadequacy to families and their daily habits. The perpetuation of the minimum unit model, designed for a hypothetical family different from reality, proves that the program serves the interests of builders more than residents.

The second phase of the program, which started in 2011, began to meet the demands of specific communities, promoting the relocation of people in precarious situations and the urbanization of slums. A new modality also emerged, in which the enterprise is organized and managed directly by popular entities of future residents (PMCMV Entities) (Noia, 2017). However, the Entity modality configures as an exception of the PMCMV, with a very limited number of examples (NOIA, 2017). Besides, it is important to remember that the Entities modality and the entire Range 1 of the PMCMV were the categories that had the most significant budget cuts since 2018 (CAMBRICOLI, 2018).

Many post-occupation assessments of projects financed by the PMCMV show the inadequacy of housing units not only for different family compositions but also for the use of spaces. The tripartite conception (social, intimate, and services sectors) presumes an excessively rational use of spaces that does not occur in practice. Different activities are developed in a room designed for a very specific use. For example, besides sleeping and dressing activities, a dormitory can be used for working and receiving guests. A room can often be used for sleeping and taking care of clothes (ironing and folding). In other words, the conception of architecture is perpetuated for an ideal man, avoiding the confrontation with reality (Villa et al., 2015). Family compositions often deviate from the model considered traditional. The model father, mothe and two children is the reference for the PMCMV (Santo Amore, Shimbo, and Rufino, 2015) – and maybe for other similar programs around the world – but it does not consider the reality of the families that are going to live there. Families with different compositions (single-parent, extended, couples without children, single persons, etc.) are more frequent than traditional families (parents and children) (Villa et al., 2015). These diversified arrangements have grown mainly in groups with lower incomes (Leone, Maia, and Baltar, 2010).

The customization of spaces, even with a limited range of variations, can contribute to the mitigation of conflicts between architecture, family compositions, and real uses of spaces. It can adapt and incorporate the desires of the people who will realistically occupy those spaces, based on the individual demands of specific families, the people who know their domestic routine like no other.

2 Mass Customization

In 1987, Stan Davis coined the expression Mass Customization in his book Future Perfect, which is a manifesto that advocates for a permanent state of economic revolution. He stated that products and services must be available in the instant a customer develops a need; products and services should be sent to customers and not the opposite; manufacturers must separate the information of a product from the physical matter that shapes it; and production processes must generate an infinite variety of goods and services adapted exclusively to customers (DAVIS, 1990).

Mass Customization is not the provision of varied products but the consumer's participation in the definition or specification of the characteristics of these products. In other words, products are offered as well as the ability to transform or define them based on previously available possibilities. This means that the supplier must define which attributes or characteristics of the product can be customized, forcing him to take a customer-oriented approach and not focusing on the market and the product as it usually occurs (Machado and Moraes, 2010). The efficiency of series production is associated with the possibility of adaptation, which is often identified as Build to order, make to order, assemble to order, configure to order, and engineer to order, emphasizing the production from demand (Gardner apud Azuma, 2016).

The application of Mass Customization has been facilitated or even enabled by Information and Communication Technologies (ICTs), and the Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) processes (Pine, 1994), which allow a greater dialogue with consumers, facilitate modifications, produce new products quicker, and manufacture them with an agility never seen before (Pine, 1994). For a digitally manufactured machine, such as a Router Computer Numerical Control (CNC), it is as easy and economically viable to produce a thousand of different objects as it is to produce a thousand of identical objects (Kolarevic, 2005). According to Yolovich, the element that distinguishes Mass Customization from simple customization is the integration of computerized design and production systems, which allow a flexible production and provides exclusive products for each customer quickly and without additional costs (Yolovich apud Bardakci and Whitelock, 2003)

Modular coordination can facilitate product customization, allowing the combination of different components. The greater the number of components, the more varied their combinations (PINE, 1994). The modularity of the product allows the large scale manufacturing of these components, taking advantage of economies of scale and consequently obtaining cost reductions with the speed of production and delivery (Azuma, 2016).

Regarding its application in architectural production, Kolarevic and Duarte (2019) state that modular coordination should operate on levels of architectural and urban issues. At the more elementary level, we should consider the materials and components that form spaces, which in turn would compose buildings. These levels, finally, would compose urban spaces. The definition of a modular coordination system must consider not only its production and assembly but its impact on the formal and spatial definitions of buildings and cities.

Kieran and Timberlake (2004) claim that there must be a greater integration between the agents involved, seeking a better dialogue between Architecture, Engineering, and production. The same authors recognize the enormous importance of ICTs and CAD/CAM systems for the effectiveness of this integration. Silveira, Borenstein, and Fogliatto (2001) also argue that the CAD/CAM dialogue is essential since they enable the participation of the consumer/user. Kolarevic and Duarte (2019) state that, from a purely technological perspective, mass customization perfectly suits for the real estate sector. Instead of identical houses, they could offer unique, highly personalized products and provide their services to broader segments of society, not just to the wealthier. This is possible due to the current technologies, which allow the viability of economically deliver highly personalized houses, with parametric design, digital fabrication, interactive sites for their design, visualization, evaluation, and estimation with the automatic generation of production, and assembly data.

User participation aided by digital resources in architectural and urban definitions has been discussed since the middle of the 20th century. The influence of cybernetics and the search for objective criteria for the creation process, led to the production of fundamental works such as Gordon Pask's Architectural Relevance of Cybernetics (1969) or A Pattern Language: Towns, Buildings, Construction (1977) by Christopher Alexander. It was sought, then, to discretize the creative process in architecture to make it more objective, accessible, and adaptable to reality. Thus, the association with emerging digital resources was natural. Some works seeks to discuss this relationship such as Nicholas Negroponte's Soft Architecture Machines (1975), Yona Friedman's Towards a Scientific Architecture (1975), and Nigel Cross's Design Participation (1972). More recently, José Pinto Duarte's (2001) doctoral thesis also brought a fundamental contribution to this discussion. In these works, the computer is seen as an interlocutor that quickly provides the production of large amounts of different responses to being evaluated and chosen (Vardouli, 2011).

3 The constructive experiment

This paper presents an algorithm created in the search for a strategy of applying mass customization to the production of large-scale architecture. This work is the result of parallel research that is not the object of this article. However, its brief presentation, given the limitations of text extension, is necessary to understand the algorithm.

The research group Teoria e Projeto na Era Digital (TPED) of the Faculty of Architecture and Urbanism of the Mackenzie Presbyterian University (FAU-UPM), has been studying the application of subtractive digital fabrication in the architectural production since 2014. The research started with a public call of the Ministry of Science and Technology (MCT) and the Financier of Studies and Projects (FINEP) for the development of studies focused on the contribution of the use of new constructive technologies for the Minha Casa Program, Minha Vida (PMCMV) and the promotion of scientific and technological researches dedicated to the improvement of sanitation and housing conditions. (Nardelli and Backheuser, 2016)

Inspired by international examples such as Instant House, Wikihouse and Clip Hut, as well as national examples such as the Casa Revistas of the Rio de Janeiro Federal University and the WikiLab project of the ABC Federal University, TPED has been producing models in reduced and real scales (Figure 1), in the search for the improvement of construction techniques, adaptation to the national context, and automation of the production process of both project and execution. (Backheuser and Campolongo, 2017)

Fig. 1: The full-scale models developed by TPED. From left to right: Model 1 (2015), Model 2 (2016) and Model 3 (2019). Source: TPED Collection, 2019.

Among the results, we can mention the definition of a dimensioning for components and spaces, the definition of a modular coordination solution, revision of the joints, and structural solution, and reduction of the thickness of the main material chosen for the construction of both the structure and the walls, the Oriented Strand Board (OSB). The solution is based on parallel frames, as shown in Figure 2, built from components machined on a CNC milling machine, with OSB plates 9.5mm thick and spacing between frames of 1.10m. The commercial dimension of the panels is one of the conditions for the modular coordination solution (Campolongo, 2019).

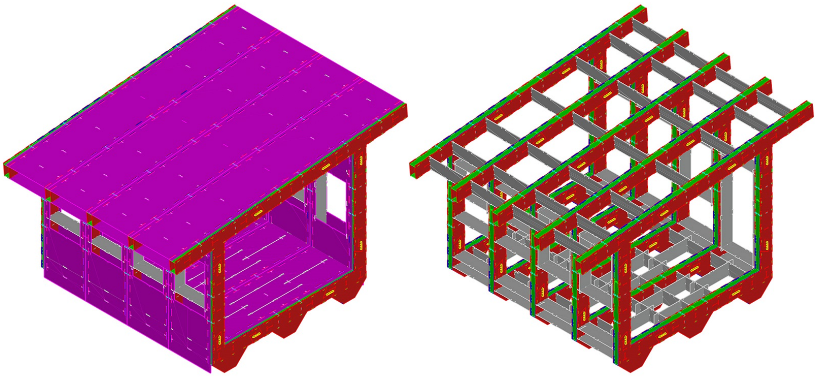


Fig. 2: Constructive volume of the proposal for the third model. Source: Campolongo, 2019.

The algorithm presented in this article is based on the experiments developed by TPED since 2014, especially the latest model built in 2019, whose dimensional and constructive characteristics were proven through its execution and a series of laboratory tests developed by one of the group researchers (Campolongo, 2019).

3.1 The algorithm

The algorithm comes from a constructive solution, considering its material characteristics, modular coordination and dimensioning of the components. The frames are the initial definer of the architectural proposal and the variations generated by the algorithm. Hence, the expansion or retraction of the construction occurs along a vector, with the addition or subtraction of these frames (Figure 3).

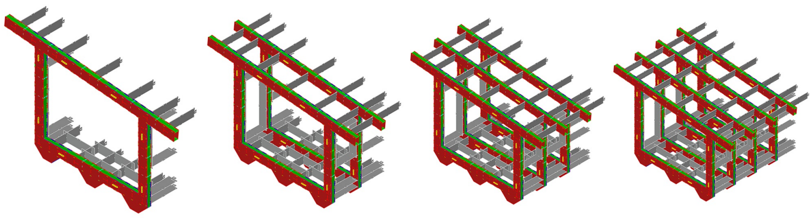


Fig. 3: Linear growth from the addition of frames. Source: TPED Collection, 2019.

All constructive definitions were obtained through constructive experiments, imposing very strict rules on the algorithm. However, to increase the possibilities of architectural variations, a double frame was created, which, although it was not built, consists of the same components, with few exceptions, and has the same span between pillars and coverage inclination (Figure 4). Then, it is possible to choose between two types of frames, single or double, promoting, in addition to linear growth, a lateral expansion, even if more limited.

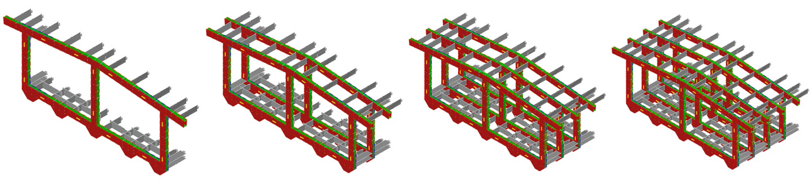


Fig. 4: Linear growth from the addition of double frames. Source: Authors, 2019

The components were already designed. Therefore, they are added automatically by the algorithm, which works by adding or subtracting them. This strategy allows the increasing or reduction of the dimension of the rooms with the repetition of identical pieces, taking advantage of the economy of scale but with the possibility of generating different results, enabling the architectural adaptation.

The constructive solution rationalized through the subtractive and modularly structured digital fabrication contemplates the authors who advocate for mass customization. The construction based on the CAD/CAM dialogue, enhanced by the interfaces developed by ICT, facilitates not only the offer of options for a future resident but also the immediate transmission of the information necessary for the production of the components (Bardakci and Whitelock, 2003; Kolarevic, 2005; Pine, 1994).

The entire process of creating the algorithm is based on architectural drawings. The rooms were designed based on the constructive solution, in other words, on the frames, which can be added, removed, and combined. For the digitization of the process and production of the algorithm, a series of computer programs were used: AutoCAD for the drawings of the floorplans, Sketchup for the design of three-dimensional models, and Rhinoceros with the Grasshopper plug-in for the creation of the algorithm, which also had part of its structure written in the Python programming language.

Since this is an exploratory approach, the work proposed from the beginning to offer a *Proof of Concept* and not an application to a real case, which would eventually involve families in vulnerable situations, imposing a responsibility that it was not convenient to still preliminary and exploratory research. Although it takes into account criticisms regarding family compositions and the real uses of spaces, this work does not intend to propose new ways of living, nor to problematize the tripartite model of housing (social, intimate, and service areas). We consider that the possibility of choosing the number rooms and their dimensioning, even within pre-established limits, brings the necessary flexibility to better adapt the architecture to the real demands of the families' daily lives.

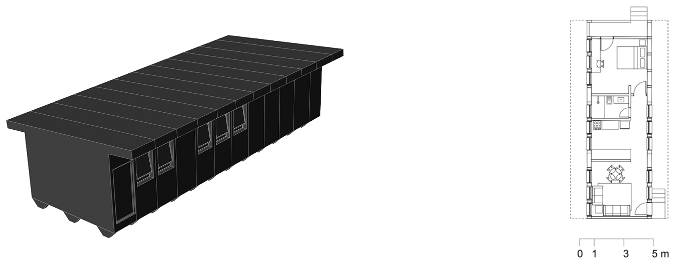


Fig 5: Minimum unit. Source: Authors, 2019.

A series of components were created, both in plan and three-dimensional model, for each room, which are added or removed according to the dialog with the software through the algorithm. It starts with a minimum unit (Figure 5) with a living room, kitchen, bathroom, and a bedroom, where each room, except the bathroom, accepts three growth sizes: small, medium, and large; with the addition or subtraction of these components. Besides, two more bedrooms can be added (Figure 6).

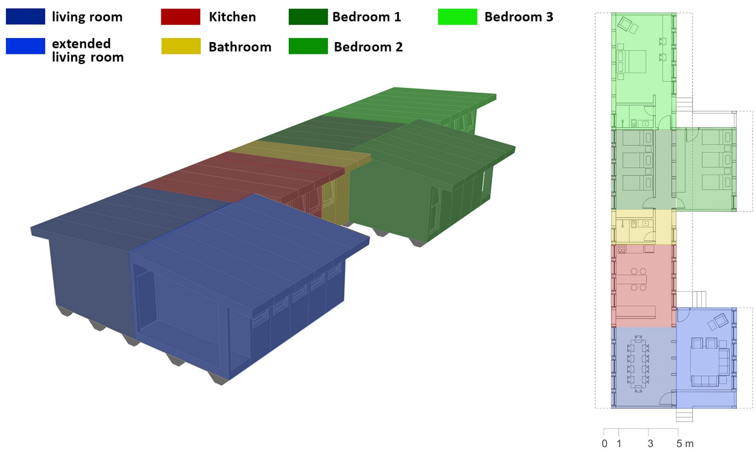


Fig. 6: All possible rooms. Source: Authors, 2019.

A series of conditional rules were established for the rooms (living room, kitchen, bedrooms, and bathroom):

+ Living room: Two room options: with single porch (simple - S) and with double porch (Extended - A); Three sizes (both simple and extended): small, medium and large;

+ Kitchen: Three options: integrated (I) to the living room, closed (F) and American type (A); Three sizes: small, medium and large;

+ Bathroom: Two bathroom options: small and large;

+ Bedrooms: a minimum of one of these rooms has been established, and a maximum of three. Each of them has three size options: small, medium and large.

There are six options for the living room, nine options for the kitchen, two options for the bathroom, three options for the first bedroom, and four options for the second and third bedrooms. In a combinatorial analysis, this is a case of the fundamental principle of counting, in which there are 6*9*2*3*4*4 = 5184. That is, this strategy allows five thousand one hundred and eighty-four different combinations of room arrangements.

Living room	Kitchen	Bathroom	Bedroom 1	Bedroom 2	Bedroom 3
(S) Small	(I) Small	Small	Small	Nonexistent	Nonexistent
(S) Medium	(I) Medium	Large	Medium	Small	Small
(S) Large	(I) Large	2 options	Large	Medium	Medium
(A) Small	(F) Small		3 options	Large	Large
(A) Medium	(F) Medium			4 options	4 options
(A) Large	(F) Large				
6 options	(A) Small				
	(A) Medium				
	(A) Large				
	9 options				
Total: 5.184 combinations					

Table 2: Combinations of room arrangements. Source: Authors, 2019.

The proposal for algorithmic adaptation is organized in a linear sequence of decisions that arise from the architecture itself, with the definition of the characteristics of each room, in addition to the constructive solution with the successive addition or subtraction of frames, which allows the increase along with a vector. We have:

+ The substitution of a room by its variation - for example, we have two room options (S and A), three kitchen options (I, F and A) and two-bathroom options;

+ Adding or removing a room - for example, we may or may not add a second and third bedroom;

+ Expansion of each room, except the bathroom, with three possible sizes (small, medium, and large).

The algorithm was organized in large blocks of commands, from:

+ Geometries: plans, layouts, and three-dimensional model;

+ Actions: parameterization of geometries, calculation of the built area, the numbering of the combination and quantification of the panels to be machined, and generation of a code for each possible combination.

The command structure follows the logic of the algorithm design, using essentially the Move, Stream Filter, and Linear Array commands. The Stream Filter command allows us to choose between the options offered (simple or expanded room, for example). The Linear Array command defines the sizes of the rooms (small, medium, or large). The Move command moves the next volumes according to the choices option and size of the previous geometries.

Regardless of the participatory methodology, we propose that the construction of the algorithm takes place after a step of collecting qualitative data from a community and defining the architectural characteristics that best serve this community.

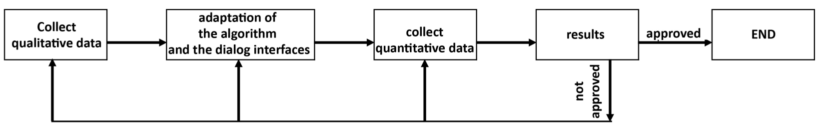


Diagram 1: Sequence of actions proposed for a computer-aided participatory process. Source: Authors, 2019.

As aforementioned, this is a proof of concept and not the application in a real situation. Therefore, the first stage of this work is represented by the constructive experiment. Regarding the dialogue with the alleged users for the collection of quantitative data, it takes place in two ways:

+ Interactive option: When the results of the choices arise immediately as they are made, essentially through Grasshopper's Slider and Boolean Toggle commands. That is, the result is constructed immediately as the input data is changed.

+ Iterative option: When the results of the choices arise only after the conclusion of a sequence of related questions, in which each one depends on the answer of the previous one. A total of eleven questions complete the cycle. The questions appear in a floating frame generated from the import script rhinoscriptsyntax in Python, which interacts with Rhinoceros.

The iterative option seems to be more flexible as the questions can adapt to the repertoire and vocabulary of the user/future resident. The interactive option, on the other hand, may require the participation of an agent or intermediary for the operation of the machine if the respondent is not familiar with this technology. However, both options seem valid and adaptable to different circumstances and methodologies for participation.

The generated products are the floorplan, three-dimensional model, and calculation of the built area. A spreadsheet is also generated with a specific numbering for each possible combination, in addition to the quantification of panels for machining, calculation of machining time and estimated cost of the main material used (OSB). This quantification is only possible since all the panels necessary for the execution of the frames and their closings have already been defined. These panels with the components properly distributed in OSB sheets (nesting) are numbered and organized in groups related to each part of the construction. For example, double frame, roof, floors, connections, etc., as shown in Figure 7.

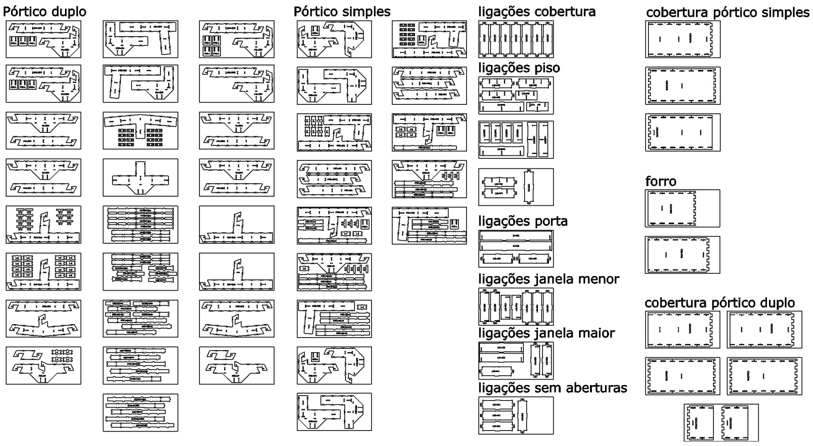


Fig. 7: Distribution of the parts to be machined in the OSB panels (nesting). Source: Authors, 2019.

The spreadsheet is automatically generated in Microsoft Excel software (*.xlsx), in which the characteristics of the machine that served as the basis for time and cost estimation are already registered. Data such as the model and manufacturer of the CNC milling machine, characteristics of the cutters used, drag speed, and rotation speed are reported. The value of each panel with a link to the chosen supplier's page is also recorded, as well as the date of the last consultation (Figure 8).

QUANTIFICADOR

DE PAINÉIS OSB PARA USINAGEM

número da combinação:

1 1 1 0 1 1 1 0 0

GRUPO	QUANTIDADE
GRUPO 0	0
GRUPO 1	15
GRUPO 2	14
GRUPO 3	14
GRUPO 4	1
GRUPO 5	3
GRUPO 6	16
GRUPO 7	2
GRUPO 8	14
GRUPO 9	14
GRUPO 10	0

Quantidades geradas pelo Script no Grasshopper

Material utlizado:
Oriented Strand Board (OSB)
Dimensões: 2.400x1.200x9,5mm
Modelo: Home PLus
Marca: LP Brasil
Fornecedor: Leo Madeiras
https://www.leomadeiras.com.br/product/prod-3-OSB_Home_Plus_2400x1200x95mm_LP_Brasil

Máquina de usinagem utilizada:
Fresadora Router CNC
Modelo: Linha S-Duty
Fornecedor: DS4
https://www.ds4.com.br/linha-s-duty

Fresas utilizadas:
6,0mm (4c) x 15mm área de corte x 50mm total x 6,0mm haste. (FTR520)
Fornecedor: Walter&Walter
https://www.fresascnc.com.br/

Velocidade de rotação: 13.000 RPM
Velocidade de arrasto: 2.400 mm/minuto

julho e agosto de 2019

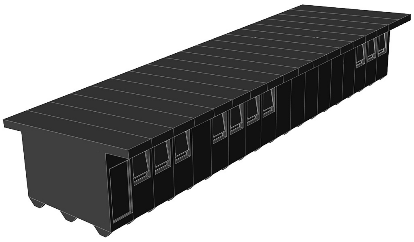
TOTAL	358	Painéis	
Custo estimado de painéis de OSB:			
358	x	R$ 66,28	(Leo Madeiras - 28/08/2019)
R$ 23.728,24			
Tempo estimado de usinagem dos painéis:			
358	x	20	Minutos
		7160	Minutos
ou (aproximadamente)			
		119	Horas
ou (aproximadamente)			
		15	Dias

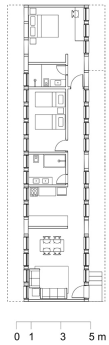
PAINEL	QUANTIDADE
01	0
02	0
03	0
04	0
05	0
06	0
07	0
08	0
09	0
10	0
11	0
12	0
13	0
14	0
15	0
16	0
17	0
18	0
19	0
20	0
21	0
22	0
23	0
24	0
25	0
26	0
27	15
28	15
29	15
30	15
31	15
32	15
33	15
34	15
35	15
36	15
37	15
38	15
39	15
40	15
41	14
42	14
43	14
44	14
45	1
46	3
47	16
48	2
49	14
50	14
51	14
52	14
53	14
54	0
55	0
56	0
TOTAL	**358**

Fig. 8: Example of a * .xlsx file from the information of the algorithm. Source: Authors, 2019.

3.2 Examples of possible combinations

The following images are six examples of the combination of diverse possible arrangements.





QUANTIFICADOR

DE PAINÉIS OSB PARA USINAGEM

número da combinação:

1 2 2 2 1 2 2 0 1

GRUPO	QUANTIDADE
GRUPO 0	0
GRUPO 1	20
GRUPO 2	20
GRUPO 3	20
GRUPO 4	1
GRUPO 5	7
GRUPO 6	23
GRUPO 7	8
GRUPO 8	20
GRUPO 9	20
GRUPO 10	0

Quantidades geradas pelo Script no Grasshopper

Material utlizado:
Oriented Strand Board (OSB)
Dimensões: 2.400x1.200x9,5mm
Modelo: Home PLus
Marca: LP Brasil
Fornecedor: Leo Madeiras
https://www.leomadeiras.com.br/product/prod-3-OSB_Home_Plus_2400x1200x95mm_LP_Brasil

Máquina de usinagem utilizada:
Fresadora Router CNC
Modelo: Linha S-Duty
Fornecedor: DS4
https://www.ds4.com.br/linha-s-duty

Fresas utilizadas:
6,0mm (4c) x 15mm área de corte x 50mm total x 6,0mm haste. (FTR520)
Fornecedor: Walter&Walter
https://www.fresascnc.com.br/

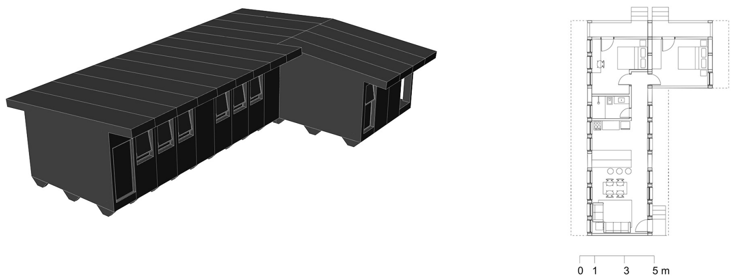
Velocidade de rotação: 13.000 RPM
Velocidade de arrasto: 2.400 mm/minuto

julho e agosto de 2019

TOTAL	499	Painéis
Custo estimado de painéis de OSB:		
499 x	R$ 66,28	(Leo Madeiras - 28/08/2019)
R$ 33.073,72		
Tempo estimado de usinagem dos painéis:		
499 x	20	Minutos
	9980	Minutos
ou (aproximadamente)		
	166	Horas
ou (aproximadamente)		
	21	Dias

PAINEL	QUANTIDADE
01	0
02	0
03	0
04	0
05	0
06	0
07	0
08	0
09	0
10	0
11	0
12	0
13	0
14	0
15	0
16	0
17	0
18	0
19	0
20	0
21	0
22	0
23	0
24	0
25	0
26	0
27	20
28	20
29	20
30	20
31	20
32	20
33	20
34	20
35	20
36	20
37	20
38	20
39	20
40	20
41	20
42	20
43	20
44	20
45	1
46	7
47	23
48	8
49	20
50	20
51	20
52	20
53	20
54	0
55	0
56	0
TOTAL	**499**

Fig. 9: Option with a simple medium-sized room, small closed kitchen, large bathroom, medium bedroom 1, and small bedroom 3. (Combination number: 122212201). Source: Authors, 2019.



QUANTIFICADOR

DE PAINÉIS OSB PARA USINAGEM

número da combinação:

1 2 2 1 1 1 1 1 0

GRUPO	QUANTIDADE
GRUPO 0	5
GRUPO 1	11
GRUPO 2	19
GRUPO 3	19
GRUPO 4	1
GRUPO 5	5
GRUPO 6	16
GRUPO 7	5
GRUPO 8	11
GRUPO 9	19
GRUPO 10	4

Quantidades geradas pelo Script no Grasshopper

Material utlizado:
Oriented Strand Board (OSB)
Dimensões: 2.400x1.200x9,5mm
Modelo: Home PLus
Marca: LP Brasil
Fornecedor: Leo Madeiras
https://www.leomadeiras.com.br/product/prod-3-OSB_Home_Plus_2400x1200x95mm_LP_Brasil

Máquina de usinagem utilizada:
Fresadora Router CNC
Modelo: Linha S-Duty
Fornecedor: DS4
https://www.ds4.com.br/linha-s-duty

Fresas utilizadas:
6,0mm (4c) x 15mm área de corte x 50mm total x 6,0mm haste. (FTR520)
Fornecedor: Walter&Walter
https://www.fresascnc.com.br/

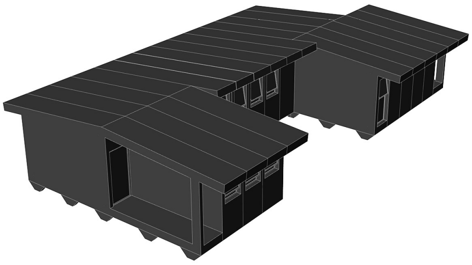
Velocidade de rotação: 13.000 RPM
Velocidade de arrasto: 2.400 mm/minuto

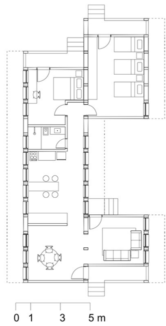
julho e agosto de 2019

TOTAL	478	Painéis	
Custo estimado de painéis de OSB:			
478	x	R$ 66,28	(Leo Madeiras - 28/08/2019)
R$ 31.681,84			
Tempo estimado de usinagem dos painéis:			
478	x	20	Minutos
		9560	Minutos
ou (aproximadamente)			
		159	Horas
ou (aproximadamente)			
		20	Dias

PAINEL	QUANTIDADE
01	5
02	5
03	5
04	5
05	5
06	5
07	5
08	5
09	5
10	5
11	5
12	5
13	5
14	5
15	5
16	5
17	5
18	5
19	5
20	5
21	5
22	5
23	5
24	5
25	5
26	5
27	11
28	11
29	11
30	11
31	11
32	11
33	11
34	11
35	11
36	11
37	11
38	11
39	11
40	11
41	19
42	19
43	19
44	19
45	1
46	5
47	16
48	5
49	11
50	11
51	11
52	19
53	19
54	8
55	8
56	4
TOTAL	**478**

Fig. 10: Option with a simple medium-sized room, small kitchenette, small bathroom, bedroom 1 small and bedroom 2 small. (Combination number: 122111110). Source: Authors, 2019.





QUANTIFICADOR

DE PAINÉIS OSB PARA USINAGEM

número da combinação:

2 1 2 2 3 1 1 3 0

GRUPO	QUANTIDADE
GRUPO 0	10
GRUPO 1	9
GRUPO 2	25
GRUPO 3	25
GRUPO 4	1
GRUPO 5	1
GRUPO 6	19
GRUPO 7	7
GRUPO 8	9
GRUPO 9	25
GRUPO 10	8

Quantidades geradas pelo Script no Grasshopper

Material utlizado:
Oriented Strand Board (OSB)
Dimensões: 2.400x1.200x9,5mm
Modelo: Home PLus
Marca: LP Brasil
Fornecedor: Leo Madeiras
https://www.leomadeiras.com.br/product/prod-3-OSB_Home_Plus_2400x1200x95mm_LP_Brasil

Máquina de usinagem utilizada:
Fresadora Router CNC
Modelo: Linha S-Duty
Fornecedor: DS4
https://www.ds4.com.br/linha-s-duty

Fresas utilizadas:
6,0mm (4c) x 15mm área de corte x 50mm total x 6,0mm haste. (FTR520)
Fornecedor: Walter&Walter
https://www.fresascnc.com.br/

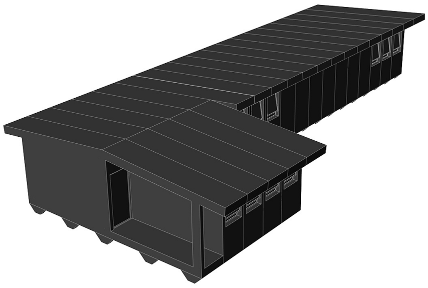
Velocidade de rotação: 13.000 RPM
Velocidade de arrasto: 2.400 mm/minuto

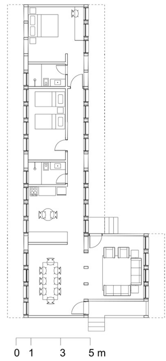
julho e agosto de 2019

TOTAL	631	Painéis	
Custo estimado de painéis de OSB:			
631	x	R$ 66,28	(Leo Madeiras - 28/08/2019)
R$ 41.822,68			
Tempo estimado de usinagem dos painéis:			
631	x	20	Minutos
		12620	Minutos
ou (aproximadamente)			
		210	Horas
ou (aproximadamente)			
		26	Dias

PAINEL	QUANTIDADE
01	10
02	10
03	10
04	10
05	10
06	10
07	10
08	10
09	10
10	10
11	10
12	10
13	10
14	10
15	10
16	10
17	10
18	10
19	10
20	10
21	10
22	10
23	10
24	10
25	10
26	10
27	9
28	9
29	9
30	9
31	9
32	9
33	9
34	9
35	9
36	9
37	9
38	9
39	9
40	9
41	25
42	25
43	25
44	25
45	1
46	1
47	19
48	7
49	9
50	9
51	9
52	25
53	25
54	16
55	16
56	8
TOTAL	**631**

Fig. 11: Option with an enlarged room of small size, large closed kitchen, small bathroom, bedroom 1 small, and bedroom 2 large. (Combination number: 212231130). Source: Authors, 2019.





QUANTIFICADOR

DE PAINÉIS OSB PARA USINAGEM

número da combinação:

2 2 2 2 2 1 2 0 1

GRUPO	QUANTIDADE
GRUPO 0	6
GRUPO 1	16
GRUPO 2	26
GRUPO 3	26
GRUPO 4	1
GRUPO 5	2
GRUPO 6	26
GRUPO 7	10
GRUPO 8	16
GRUPO 9	26
GRUPO 10	5

Quantidades geradas pelo Script no Grasshopper

Material utlizado:
Oriented Strand Board (OSB)
Dimensões: 2.400x1.200x9,5mm
Modelo: Home PLus
Marca: LP Brasil
Fornecedor: Leo Madeiras
https://www.leomadeiras.com.br/product/prod-3-OSB_Home_Plus_2400x1200x95mm_LP_Brasil

Máquina de usinagem utilizada:
Fresadora Router CNC
Modelo: Linha S-Duty
Fornecedor: DS4
https://www.ds4.com.br/linha-s-duty

Fresas utilizadas:
6,0mm (4c) x 15mm área de corte x 50mm total x 6,0mm haste. (FTR520)
Fornecedor: Walter&Walter
https://www.fresascnc.com.br/

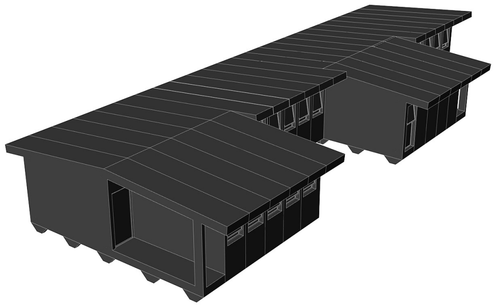
Velocidade de rotação: 13.000 RPM
Velocidade de arrasto: 2.400 mm/minuto

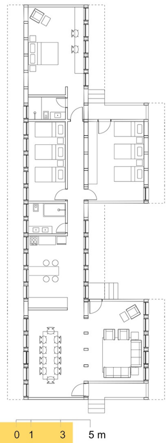
julho e agosto de 2019

TOTAL	648	Painéis	
Custo estimado de painéis de OSB:			
648	x	R$ 66,28	(Leo Madeiras - 28/08/2019)
R$ 42.949,44			
Tempo estimado de usinagem dos painéis:			
648	x	20	Minutos
		12960	Minutos
ou (aproximadamente)			
		216	Horas
ou (aproximadamente)			
		27	Dias

PAINEL	QUANTIDADE
01	6
02	6
03	6
04	6
05	6
06	6
07	6
08	6
09	6
10	6
11	6
12	6
13	6
14	6
15	6
16	6
17	6
18	6
19	6
20	6
21	6
22	6
23	6
24	6
25	6
26	6
27	16
28	16
29	16
30	16
31	16
32	16
33	16
34	16
35	16
36	16
37	16
38	16
39	16
40	16
41	26
42	26
43	26
44	26
45	1
46	2
47	26
48	10
49	16
50	16
51	16
52	26
53	26
54	10
55	10
56	5
TOTAL	**648**

Fig. 12: Option with an enlarged room of medium size, medium closed kitchen, small bathroom, bedroom 1 medium, and bedroom 3 small. (Combination number: 222221201). Source: Authors, 2019.





QUANTIFICADOR

DE PAINÉIS OSB PARA USINAGEM

número da combinação:

2 3 2 2 3 2 3 3 3

GRUPO	QUANTIDADE
GRUPO 0	14
GRUPO 1	14
GRUPO 2	39
GRUPO 3	39
GRUPO 4	1
GRUPO 5	3
GRUPO 6	30
GRUPO 7	17
GRUPO 8	15
GRUPO 9	39
GRUPO 10	12

Quantidades geradas pelo Script no Grasshopper

Material utlizado:
Oriented Strand Board (OSB)
Dimensões: 2.400x1.200x9,5mm
Modelo: Home PLus
Marca: LP Brasil
Fornecedor: Leo Madeiras
https://www.leomadeiras.com.br/product/prod-3-OSB_Home_Plus_2400x1200x95mm_LP_Brasil

Máquina de usinagem utilizada:
Fresadora Router CNC
Modelo: Linha S-Duty
Fornecedor: DS4
https://www.ds4.com.br/linha-s-duty

Fresas utilizadas:
6,0mm (4c) x 15mm área de corte x 50mm total x 6,0mm haste. (FTR520)
Fornecedor: Walter&Walter
https://www.fresascnc.com.br/

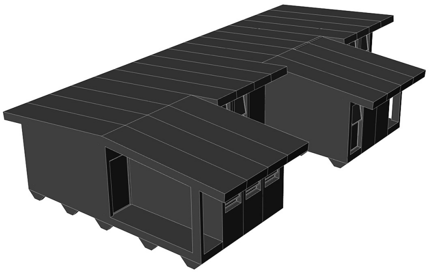
Velocidade de rotação: 13.000 RPM
Velocidade de arrasto: 2.400 mm/minuto

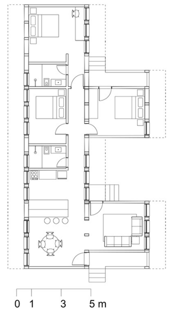
julho e agosto de 2019

TOTAL	950	Painéis	
Custo estimado de painéis de OSB:			
950	x	R$ 66,28	(Leo Madeiras - 28/08/2019)
R$ 62.966,00			
Tempo estimado de usinagem dos painéis:			
950	x	20	Minutos
		19000	Minutos
ou (aproximadamente)			
		317	Horas
ou (aproximadamente)			
		40	Dias

PAINEL	QUANTIDADE
01	14
02	14
03	14
04	14
05	14
06	14
07	14
08	14
09	14
10	14
11	14
12	14
13	14
14	14
15	14
16	14
17	14
18	14
19	14
20	14
21	14
22	14
23	14
24	14
25	14
26	14
27	14
28	14
29	14
30	14
31	14
32	14
33	14
34	14
35	14
36	14
37	14
38	14
39	14
40	14
41	39
42	39
43	39
44	39
45	1
46	3
47	30
48	17
49	15
50	15
51	15
52	39
53	39
54	24
55	24
56	12
TOTAL	**950**

Fig. 13: Option with an enlarged room of large size, large closed kitchen, large bathroom, bedroom 1 large, bedroom 2 large, and bedroom 3 large. (Combination number: 232232333). Source: Authors, 2019.





QUANTIFICADOR

DE PAINÉIS OSB PARA USINAGEM

número da combinação:

2 1 2 1 1 1 1 1 1

GRUPO	QUANTIDADE
GRUPO 0	10
GRUPO 1	10
GRUPO 2	27
GRUPO 3	27
GRUPO 4	1
GRUPO 5	2
GRUPO 6	18
GRUPO 7	13
GRUPO 8	11
GRUPO 9	27
GRUPO 10	8

Quantidades geradas pelo Script no Grasshopper

Material utlizado:
Oriented Strand Board (OSB)
Dimensões: 2.400x1.200x9,5mm
Modelo: Home PLus
Marca: LP Brasil
Fornecedor: Leo Madeiras
https://www.leomadeiras.com.br/product/prod-3-OSB_Home_Plus_2400x1200x95mm_LP_Brasil

Máquina de usinagem utilizada:
Fresadora Router CNC
Modelo: Linha S-Duty
Fornecedor: DS4
https://www.ds4.com.br/linha-s-duty

Fresas utilizadas:
6,0mm (4c) x 15mm área de corte x 50mm total x 6,0mm haste. (FTR520)
Fornecedor: Walter&Walter
https://www.fresascnc.com.br/

Velocidade de rotação: 13.000 RPM
Velocidade de arrasto: 2.400 mm/minuto

julho e agosto de 2019

TOTAL	669		Painéis
Custo estimado de painéis de OSB:			
669	x	R$ 66,28	(Leo Madeiras - 28/08/2019)
R$ 44.341,32			
Tempo estimado de usinagem dos painéis:			
669	x	20	Minutos
		13380	Minutos
ou (aproximadamente)			
		223	Horas
ou (aproximadamente)			
		28	Dias

PAINEL	QUANTIDADE
01	10
02	10
03	10
04	10
05	10
06	10
07	10
08	10
09	10
10	10
11	10
12	10
13	10
14	10
15	10
16	10
17	10
18	10
19	10
20	10
21	10
22	10
23	10
24	10
25	10
26	10
27	10
28	10
29	10
30	10
31	10
32	10
33	10
34	10
35	10
36	10
37	10
38	10
39	10
40	10
41	27
42	27
43	27
44	27
45	1
46	2
47	18
48	13
49	11
50	11
51	11
52	27
53	27
54	16
55	16
56	8
TOTAL	**669**

Fig. 14: Option with an enlarged room of small size, small kitchenette, small bathroom, bedroom 1 small, bedroom 2 small, and bedroom 3 small. (Combination number: 212111111). Source: Authors, 2019.

4 Conclusions

Even though the strategy is organized on a constructive solution, the proposal based on the substitution, reduction, or expansion of the rooms can adapt to different construction solutions that have some type of modular coordination. We understand that the generation of more than five thousand possible architectural combinations shows that the tool offers the variability of architectural solutions to different situations of family organizations and uses of spaces. The two dialog options, interactive and iterative, allow the tool to adapt to different participatory methodologies.

Thus, the present work is an initial step towards the appropriation of the concept of mass customization in the production of architecture through a methodology that appropriates digital tools to affect the participation of future residents in the architectural and large scale productions.

This stage of the research is a starting point for new works and practical applications. We expect that the tool proposed here adapt to different construction and architectural solutions, and real dialogues with future residents, seeking an alternative to the massification of housing in a world whose complexity is increasingly admitted.

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