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RESETTLEMENT OF FORCIBLY DISPLACED PEOPLE: CASE STUDY OF BENTO RODRIGUES FOLLOWING THE ENVIRONMENTAL DISASTER OF THE FUNDÃO TAILINGS DAM FAILURE

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Abstract
This article aims to study the still ongoing process of resettlement of the village of Bento Rodrigues, in Mariana, Brazil, from the Fundão tailings dam rupture moment, through the temporary resettlement solution proposed in the city of Mariana, and finally the approval of the new settlement's urban design in 2018, more than two years after the disaster. In 2022, more than six years after the disaster, the community has not been resettled yet. Through varied literature research, we will discuss the resettlement process of this community by analyzing the community's participation in it, the urban design process and two of the urban design solutions presented for the new settlement. Through the study of this resettlement process, it will be possible to identify some key factors that have influenced it and that can significantly influence the success or lack thereof of whole community resettlement operations of forcibly displaced people.

Streszczenie
Niniejszy artykuł ma na celu zbadanie wciąż trwającego procesu przesiedlenia wioski Bento Rodrigues, w Marianie, w Brazylii, od momentu pęknięcia tamy wód pokopalnianych Fundão, poprzez tymczasowe rozwiązanie przesiedleńcze zaproponowane w mieście Mariana, aż do zatwierdzenia projektu urbanistycznego nowej osady w 2018 roku, ponad dwa lata po katastrofie. W 2022 roku, ponad sześć lat po katastrofie, społeczność nie została jeszcze przesiedlona. Poprzez pogłębione badania literaturowe omówimy proces przesiedlenia tej społeczności, analizując udział w nim społeczności, proces projektowania urbanistycznego oraz dwa z rozwiązań urbanistycznych zaproponowanych dla nowej osady. Dzięki badaniu procesu przesiedlenia możliwe będzie zidentyfikowanie pewnych kluczowych czynników, które miały na niego wpływ i które mogą znacząco wpłynąć na sukces lub jego brak w przypadku operacji przesiedlania całej społeczności przymusowo wysiedlonych osób.

Keywords: Fundão tailings dam; forced displacement; Bento Rodrigues; Brazil

Słowa kluczowe: tama wód pokopalnianych Fundão; przymusowe przesiedlenie; Bento Rodrigues; Brazylia

INTRODUCTION

The failure of the Fundão tailings dam located near the city of Mariana, in Brazil, on November 5, 2015, resulted in what was classified at the time as the country's biggest environmental disaster. According to the Brazilian Institute of Environment and Renewable Natural Resources [Ibama, 2015a], the tailings that flowed from the dam traveled 663.2 km along rivers in the Brazilian states of Minas Gerais and Espírito Santo until they reached the Atlantic Ocean. On this route, the tailings flow took the lives of 19 people, destroyed villages, and contaminated the land and waters of part

of the Doce River watershed, affecting the fauna, flora, and the lives of thousands of people whose livelihood depended on these natural resources [Ibama, 2015a].

Bento Rodrigues, a rural sub-district of Mariana, located approximately 4 km from the dam, was the first settlement hit by the tailings wave. With a population of approximately 600 people, the population of Bento had to flee the settlement or reach higher placed areas to save themselves. Subsequently, the community was provisionally relocated in the city of Mariana. Most of the population still lives in Mariana, waiting for the reconstruction and resettlement of Bento Rodrigues in a new location, since the destruction of its buildings and the contamination of soil and water by the tailings made the old Bento Rodrigues settlement uninhabitable.

This article aims to study the resettlement process of the Bento Rodrigues community as a forcibly displaced community. The relevance of this theme fits into the current context and future predictions that link climate change to the greater occurrence of tragic environmental events that will force the displacement of more people and communities around the world, especially in the global south. It is therefore necessary to discuss ways of dealing with these displacements from the perspective of urban planning, architecture, and the adaptability of human settlements.

Therefore, this article will discuss the practices, proposed solutions and results obtained so far for the resettlement of the Bento Rodrigues community. The process of rebuilding the community and resettling the population will be analyzed based on the decision-making and problem-solving processes implemented, the resettlement options offered, the urban planning and design process of the new settlement, the support offered to the displaced people, the community participation in the rebuilding and resettlement process, and the current status of resettlement of those affected.

1. METHODS

This article uses the individual case study method to present the process of resettlement of forcibly displaced people and its subsequent phases. A study of the resettlement process was conducted on the example of the village of Bento Rodrigues. The factor type for the described process was the environmental disaster. An important aspect of the research was to trace all phases from the moment of the catastrophe to the present day. The article's purpose was to describe the process of resettlement of forcibly displaced people. The conclusions formulated about resettlement processes may be important in predicting analogous processes in the forecasted climate migration.

The basic research material was administrative documentation, reports prepared for the needs of public institutions and contemporary scientific literature describing various aspects of the catastrophe. The publication uses informational materials of institutions, foundations, and associations involved in the resettle-

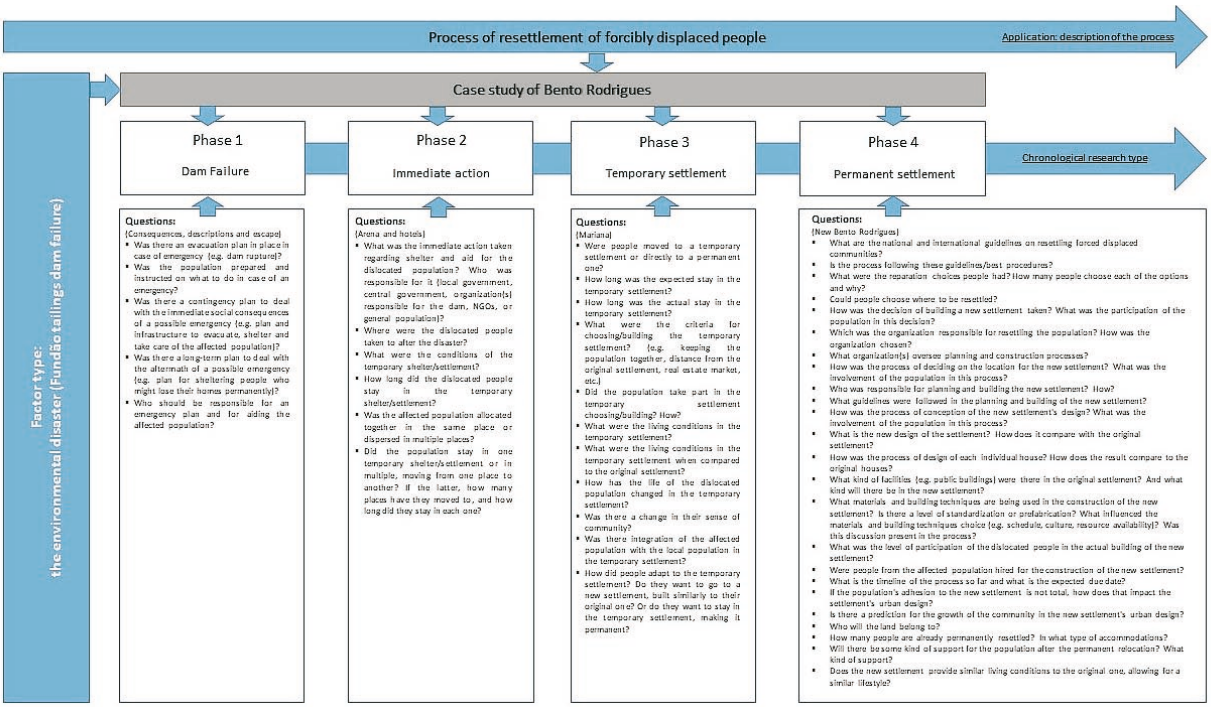

Fig. 1. Flow chart presenting the entire methodology and the role of questions in the research process of the Bento Rodrigues case study; source: prepared by the authors

ment process, verifying data from these sources. Additional materials include versions of plans made for the new housing estate and analyses of the topography of the new housing estate by other authors. The materials were supplemented by information from the media.

2. FUNDÃO DAM FAILURE AND ITS CONSEQUENCES

pouring into the Atlantic Ocean on November 21, 2015 [Ibama, 2015a]. The mud affected 40 municipalities, 36 in the state of Minas Gerais and 4 in the state of Espírito Santo [Ibama, 2015b], causing 19 fatalities and various social, environmental, and economic damages. These damages include among others: the destruction of buildings and infrastructures, displacement of people, interruption of the activity of hydroelectric plants, de-

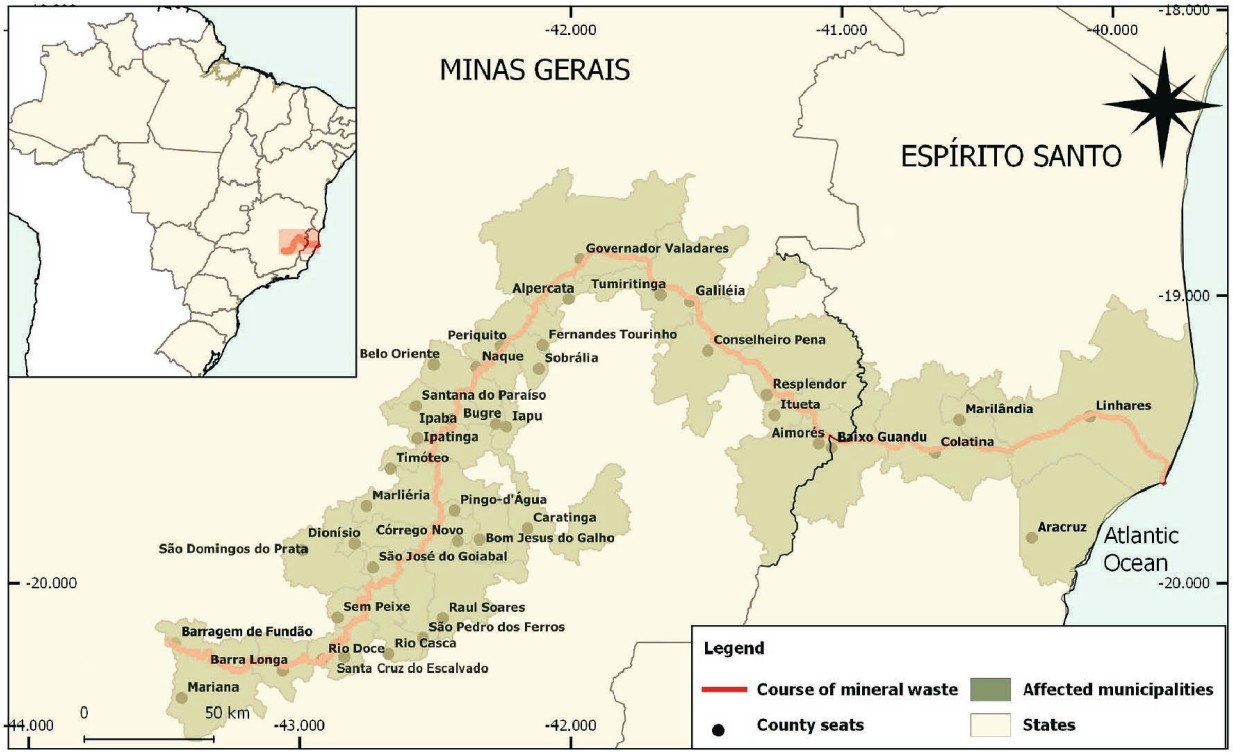

Fig. 2. Course of the ore tailings after the dam rupture in Mariana (Brazil). Affected municipalities in the states of Minas Gerais and Espírito Santo i; source: Max Vasconcelos [Zhouri *et al*., 2017]

The Fundão tailings dam, owned by Samarco Mineração S.A. (a joint venture between Vale S.A. and BHP Billiton Brasil Ltda.) and located in the municipality of Mariana/MG, ruptured in the afternoon of November 5, 2015, dumping 34 million m³ of iron ore tailings into the environment [Ibama, 2015a]. The tailings flow from the dam, which had 56.4 million m³ of tailings originally, continued after the disaster, reaching a total of 43.8 million m³ spilled, a figure that remained stable between July and November 2016, one year after the disaster [Fundação Renova, 2016; Fundação Renova, 2017]. According to a study carried out by Carmo *et al.* (2017) on the failure of ore dams between 1915 and 2016, this can be considered the biggest technological disaster in the world due to the quantity of material released and the extent of the affected environment.

The ore tailings flow, which became known as a "mud wave" or "mud sea", reached a total of 663.2 km of water courses in the Doce River watershed, struction of agricultural areas and pastures, interruption of water supply and fishing activity, destruction of protected areas of the Atlantic Forest, silting of rivers, death of aquatic biodiversity and terrestrial fauna, loss and fragmentation of habitats [Ibama, 2015a]. The tailings course and the affected municipalities are shown below in Figure 2.

The mud wave overflowed the riverbed in the first 77 km of its course, affecting public and private buildings and infrastructures in a degressive manner [Ibama, 2015a]. In this section, 10 villages belonging to 5 municipalities (Mariana, Barra Longa, Ponte Nova, Santa Cruz do Escalvado, and Rio Doce) were directly hit by the mud [Carmo *et al.*, 2017]. Three of these villages are part of a resettlement program established in an agreement made between many governmental agencies and the companies Samarco, Vale and BHP: the villages of Bento Rodrigues and Paracatu de Baixo, in Mariana, and Gesteira, in Barra Longa (*Termo de Transação e de Ajustamento de Conduta* [TTAC], 2016).

Bento Rodrigues was the village located closest to the dam and the one that suffered the most direct damage caused by the rupture [Carmo *et al.*, 2017], with 207 out of its 251 mapped buildings, that is 82%, affected by the mud [Ibama, 2015b]. It was also the village with the biggest number of impacted families covered by the resettlement program, with 289 families in 2020, followed by Paracatu de Baixo with 145 families and Gesteira with 37. There were also families outside of these villages that were covered by the resettlement program, e.g., rural communities in the municipalities of Mariana and Barra Longa [Ramboll, n.d.b].

In this article we will discuss the process of resettlement of these families, focusing on the village of Bento Rodrigues. First, the emergency actions taken regarding the evacuation and sheltering of the dislocated people will be presented. Then, the temporary housing arrangements made for the families – in which most of them still live to this day – will be discussed. Next, the resettlement program established between the companies responsible for the dam and the government will be briefly described. Afterwards, we will focus on the permanent resettlement of Bento Rodrigues, describing the process and community participation up until the approval of the village's urban design, in February 2018. Finally, the information and the processes presented will be discussed, followed by conclusions that may contribute to the literature on the resettlement of displaced communities.

3. EMERGENCY ACTIONS: EVACUATION AND SHELTER

When the Fundão tailings dam ruptured, there were no sound alarm systems in place to warn the population from nearby villages about the disaster [PoEMAS, 2015]. The official warning, according to one of Samarco's representatives, was made by phone call to a few residents, not specifying how many people were contacted or the content of the calls. Along with the residents, the company warned the Civil Defense Agency and Mariana's City Hall [Veja, 06 November 2015b].

The credit for warning the population about the disaster often goes to two outsourced employees from Samarco that decided to go down to Bento Rodrigues and drive through its streets alerting the people. One drove though the village by truck, carrying dozens of people in its bucket and driving them away from the mud wave [Veja, 06 November 2015a; Vital, n.d.]. The other, who was also a resident of the village, drove through its streets on her motorcycle telling people to escape to higher situated places [Passarinho, 5 February 2019; Vital, n.d.]. Nonetheless, not every resident was informed about the disaster [Vital, n.d.].

The account of Bento Rodrigues' population varies greatly, ranging from around 400 people to around 600 – with 600 being the most used figure [Samarco, n.d.a; IBGE, 2015 *apud* PoEMAS, 2015; Minas Gerais, 2015 *apud* Souza & Paaz, 2019; G1, 5 November 2015]. At least 120 people spent the night of the disaster in the Church of Nossa Senhora das Mercês [Estadão Conteúdo, 06 November 2015], located in a higher area of the village [Samarco, n.d.a]. According to Estadão Conteúdo [06 November 2015], they were rescued in the morning of the next day and brought to Arena Mariana, the sports center of the city of Mariana, located about 25 km away from Bento, where other 150 people who were able to flee the village had spent the night.

4. TEMPORARY SETTLEMENT

Arena Mariana served as shelter for the dislocated people from Bento Rodrigues and other villages hit by the mud or in danger of being flooded. Also, it became the distribution center for the donations received, such as food, clothes, shoes, mattresses, bed linen and personal hygiene items [G1, n.d.]. As can be seen in Figure 2, the court of the sports center was furnished with mattresses, while the donations were sorted by volunteers in the adjacent room.

People started being transferred from the sports center to hotels and inns after the intervention of the Public Ministry, who considered that Arena Mariana's space (Figure 3) was not adequate to receive the dislocated families [PoEMAS, 2015]. According to Samarco Mineração [Mineração, 23 February 2016], people started being transferred within 24 hours of the disaster, while according to the National Human Rights Council [CNDH, 2017] the transferring process started three days following the disaster.

Each dislocated family seems to have been placed in one room in the hotels and inns they were provided with (Figure 4). According to Estronioli [3 December 2015], one of the complaints about this arrangement was the lack of privacy, citing as an example a room that was furnished with twelve single beds. There were also examples of smaller rooms, such as one with three single beds [Estronioli, 3 December 2015], and some exceptional cases, where the family from the village of Paracatu de Baixo was settled in a house (with almost no furniture or home appliances) due to the big size of the family – one mother and ten children [Camargos, 28 November 2015].

Fig. 3. Sports center Arena Mariana as first shelter for the dislocated people from Bento Rodrigues.
Main court furnished with mattresses to receive the dislocated people and donation sorting room;
sources: Gustavo Pimentel [G1, n.d.] and Lucas Prates/Hoje em Dia/Estadão Conteúdo [G1, 5 November 2015]

Fig. 4. Each dislocated family was placed in one room in the hotels and inns they were provided with. The example above shows one of the rooms used as temporary shelter for the dislocated people in Hotel Providência.
Source: Elisa Estronioli/MAB (Estronioli, 3 December 2015)

Fig. 5. An image presented by Samarco in a news piece about the relocation of the dislocated families to temporary houses. The temporary houses were provided to the families with furniture, home appliances, domestic utensils, trousseau, food, cleaning products, personal hygiene products, and drinking water; source: Samarco (28 November 2015)

The families received packed meals for lunch and dinner during their temporary stay at the hotels and inns [Estronioli, 3 December 2015]. In a promotional video made by Samarco Mineração [Mineração, 23 February 2016] about one of the hotels that received the dislocated families, Hotel Providência, it is stated that the families were provided with four meals: breakfast, lunch, afternoon snack, and dinner. The dislocated people also had to respect established hours to return if they wanted to leave the hotels during the day, and those located in areas further from the center did not receive transportation vouchers [*Movimento dos Atingidos por Barragens* [MAB], 25 November 2015].

Later, people were transferred from the hotels and inns to temporary houses rented by Samarco. According to CNDH (2017), each family was able to choose between three houses presented by the company. For the selection of the houses, factors such as proximity to relatives, house location and number of people per household were taken into consideration [Samarco, 28 November 2015].

Initially, Samarco presented a plan that contemplated the transferring of 25 families to temporary

homes per week, which meant that all families would be settled by February 2016 [Samarco, 27 November 2015]. However, in a meeting between the dislocated communities and the Public Ministry in the end of November, the communities expressed their desire of spending Christmas in their new home, and not in hotels [Aguiar, 28 November 2015]. The dislocated people also organized a petition, with over 200 signatures, asking for the deadline of the relocation of families to be on December 20. On December 1, Samarco presented to the commission elected by the communities affected by the dam rupture a new plan predicting the transferring of 50 families per week [MAB, 02 December 2015].

The Public Ministry also acted in defense of the relocation of the families before Christmas with this being one of the points of a Conduct Adjustment Term (TAC) proposed to Samarco. When Samarco did not sign the term, the Public Ministry filed a public civil action requesting, among other points, the payment of a fine for each family not relocated by the company until Christmas [G1, 10 December 2015].

According to Samarco [Samarco, 24 December 2015], 351 families out of the 355 impacted by the dam rupture in the cities of Mariana and Barra Longa were relocated in houses rented by the company or in relatives' houses by December 24, 2015. This meant that 908 people were relocated in time to spend Christmas at a new home. The four families, numbering eight people, that remained in hotels did so by their own choice [Samarco, 24 December 2015].

The temporary houses were provided to the families with furniture, home appliances, domestic utensils, trousseau, food, cleaning products, personal hygiene products, and drinking water (Figure 5). The company stated that the transfer of families would follow the criteria defined in meetings between the company, representatives elected by the dislocated people within the communities, the Public Ministry, and other relevant organizations [Samarco, 27 November 2015; Samarco, 24 December 2015].

One of the criteria defined was that families with elderly people (65+ years old), children, pregnant women, newborns, disabled people, and people dependent on medical care would be given priority for leaving the hotels and inns, and be transferred to temporary houses [Samarco, 27 November 2015]. According to MAB [25 November 2015], the dislocated people made allegations that the transferring of the families did not follow the criteria defined.

According to a report issued in 2019 by Ramboll (n.d.a), there was a total of 330 temporary houses rented for the dislocated families in the cities of Mariana and Barra Longa, while other 119 families received financial compensation or were located in hotels. Ramboll inspected 184 temporary houses in the city of Mariana in 2018 and only 47.8% were considered adequate. In 2020, this figure rose to only 50.5% [Ramboll, n.d.b], and in 2021 to 51.6% [Ramboll, 2021a]. Detailed data on the temporary houses' adequacy are shown in Table 1.

The map presented in Figure 6 shows the location of the temporary houses visited by Ramboll in the city of Mariana and information on their risk assessment and need for relocation. From this image we can verify that the dislocated families were settled in a dispersed manner in the city. This arrangement could be explained, among other reasons, by the availably of houses in the market at the time of the rental operation.

According to Barreto, Rosa & Mayorga [2020], the physical distance among the dislocated families, who were formerly neighbors, along with the change from rural to urban space and lack of yards in the new homes are factors that contribute to the families' feelings of uprootedness and not belonging to the new space. The communities also express an almost idealized vision of their lives in the villages prior to the disaster, showing a desire for having the new settlements as similar as possible to the ones they lost [Barreto, Rosa & Mayorga, 2020].

Tab. 1. Classification of the temporary houses in Mariana according to risk and habitability

Inspection Date	Adequate	Geotechnical Risk	Environmental Risk	Uninhabitability	No Information	Total
2018	88	32	8	56	0	184
July 2020	93	22	9	57	3	184
February 2021	95	19	9	57	4	184

Source: Data collected from Ramboll (n.d.b) and Ramboll (2021a)

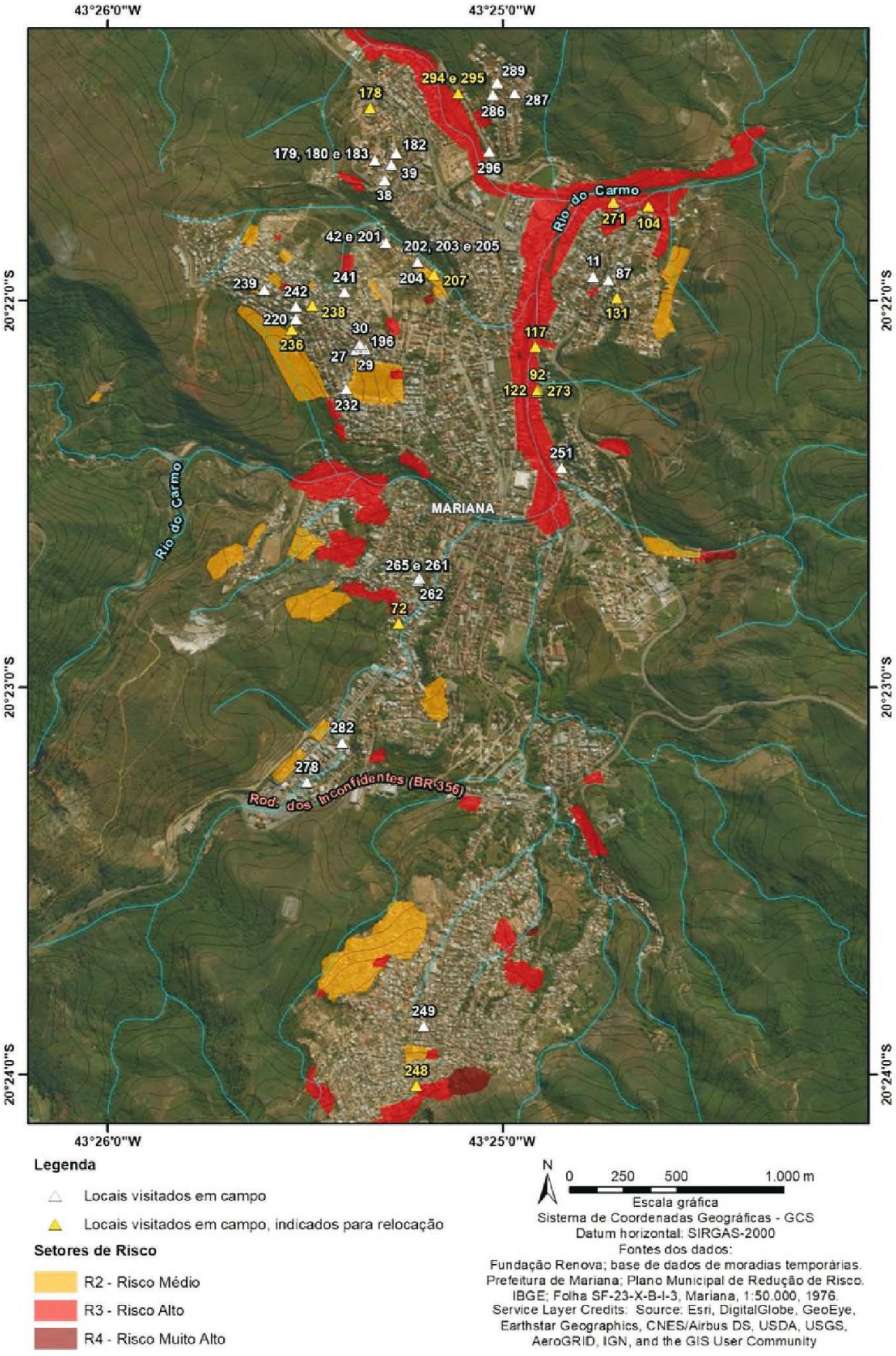

Fig. 6. Location of the temporary houses visited by Ramboll in Mariana (white and yellow triangles); source: Ramboll (2019)

5. TTAC: TRANSACTION AND CONDUCT ADJUSTMENT TERM

The *Termo de Transação e de Ajustamento de Conduta* (TTAC) is an agreement signed in March of 2016 between the Union, the state of Minas Gerais, the state of Espírito Santo, and other governmental agencies, and the companies Samarco, Vale, and BHP. This agreement establishes programs that aim to recover the environmental and the socioeconomic conditions that existed prior to the rupture of the Fundão tailings dam and its consequences. These programs would be developed and executed by a new autonomous foundation, founded by the companies Samarco, Vale, and BHP. This foundation would be supervised and have its actions validated by an Interfederative Committee, known as CIF, constituted by the public authorities [TTAC, 2016].

This agreement was criticized by the Federal Public Ministry (MPF) in numerous occasions [*Ministério Público Federal* (MPF), n.d.]. The Public Ministry claimed that the agreement protected the companies' assets over the affected population and the environment (MPF, 02 March 2016), and the regional attorney of the republic criticized the lack of public participation in it [MPF, 29 May 2016]. The population affected by the dam rupture was against the agreement as well [CNDH, 2017]. According to MAB (2016), although the agreement mentions the participation of the affected population numerous times, it does not clearly establish how such participation would take place and does not guarantee the participation in the decision-making parts of the process.

The foundation created by Samarco, Vale and BHP received the name of *Fundação Renova* and is responsible for the development of 42 programs, which were divided in two categories: socioeconomic programs (programs 1 to 22) and socioenvironmental programs (programs 23 to 42). In the socioeconomic category, Program 08 is dedicated to the reconstruction, recovery, and relocation of the villages of Bento Rodrigues and Paracatu de Baixo, both in the municipality of Mariana, and Gesteira, in the municipality of Barra Longa [Fundação Renova, n.d.a; TTAC, 2016].

6. PGO8: RECONSTRUCTION, RECOVERY, AND RELOCATION OF BENTO RODRIGUES, PARACATU DE BAIXO, AND GESTEIRA

The program for the reconstruction of the villages of Bento Rodrigues, Paracatu de Baixo and Gesteira is established in the TTAC in subsection II.1, clauses 76 to 78. The program's actions are determined in clause 77, translated bellow in Table 2.

Tab. 2. Translation of Clause 77 of the TTAC defining the actions of Program 08.

CLAUSE 77 **The following actions, to be developed by the FOUNDATION, are part of this PROGRAM:**
a) choice, along with the communities, of the new location for the resettlement;
b) acquisition of the areas chosen along with the communities;
c) design and approval of the urban project and other engineering deliverables of the new settlement;
d) deployment of energy, water, sanitation, street, paving, drainage, and access infrastructures;
e) design and approval of the architectural project and subsequent real estate construction;
f) resettlement of public buildings, such as schools, health centers, squares, covered courts and religious temples, equivalent to the PREVIOUS SITUATION and in compliance with the public policy standards;
g) demolition of remaining structures and subsequent cleaning;
h) collective negotiation in a participatory instance to define the location, discuss the PROJECTS and monitor the construction work;
i) depending on the peculiarity of each specific case, the possibility of assisted self-resettlement, exchange and/or indemnification for the IMPACTED who so desire will be considered; and
j) provision of temporary housing for the displaced people for a period of up to 3 (three) months after the definitive solution for their housing.

Source: Translation by the authors from the original in Portuguese taken from TTAC [2016, pp. 48-49]

In clause 78, the TTAC defines that the rebuilding of the villages should be finished in 36 months counting from the signing of the agreement, in March of 2016. This, along with clause 77j, indicates that the initial prediction was for people to stay at their temporary houses between three years and three months and three years and six months, considering that the families started being settled in the temporary houses in November 2015 and would be able to move to the permanent settlement from March to June 2019. However, until this date, June 2022, the construction of the permanent settlements is not finished.

7. RESETTLEMENT OF THE DISLOCATED PEOPLE

There are four modalities regarding the resettlement of the displaced communities from the villages of Bento Rodrigues, Paracatu de Baixo, and Gesteira, and the rural communities hit by the mud wave in Mariana and Barra Longa. These modalities are collective resettlement, family resettlement, reconstruction, and indemnification [Ramboll, n.d.a].

Collective resettlement is the resettlement of the dislocated families in the new villages built by Fundação Renova, while family resettlement is the resettlement of each family separately, outside of these villages. The families that opt for family resettlement can choose to be resettled anywhere in Brazil [Ramboll, n.d.a].

8. RESETTLEMENT OF THE COMMUNITY OF BENTO RODRIGUES

As mentioned previously, the village of Bento Rodrigues, in the municipality of Mariana, was the one closest to the Fundão tailings dam and the one which suffered the most direct damage from the dam's failure and subsequential tailings flow [Carmo *et al.*, 2017]. The village had approximately 600 inhabitants according to most of the researched accounts.

According to a report issued in 2019 by Ramboll (n.d.a), 91% of the families from the community of Bento Rodrigues in the resettlement program chose the collective resettlement modality. This figure dropped to 83% in June 2020 and to 78% in March 2021, even with the rise in the number of families in the program [Ramboll, n.d.b; Ramboll, 2021a]. In April 2022, only 209 families were in the collective resettlement modality [Fundação Renova, 2022], 42 less than in 2019 (Ramboll, n.d.a). Detailed data on the modalities chosen by the families of Bento Rodrigues are shown below in Table 3.

Along with the drop in adherence to collective resettlement, dropped the dissatisfaction of the community with such modality. Within the families that chose this modality the dissatisfaction rate went from 40.6% in September 2019 (102 out of 251 families) [Ramboll, 2020], to 24.3% in September 2020 (58 out of 239 families) (Ramboll, 2021a), and then 15.7% in March 2021 (36 out of 230 families) [Ramboll, 2021b].

There is a possibility that these data are correlated: the dissatisfaction of the families with collective resettlement could make more families opt for family resettlement, bringing a drop, therefore, in the percentage of dissatisfied families in the collective resettlement modality. This possibility is also discussed in the report of April 2021 made by Ramboll (2021b) to the Federal Public Ministry. Furthermore, according to *Cáritas Brasileira Regional Minas Gerais* [Cáritas, 2021], the migration of families to the family resettlement modality indicates that the dislocated people are hopeless due to the several delays on the final date of delivery of the new settlement to the community.

The drop in adhesion to collective resettlement by the families of Bento Rodrigues should be regarded with concern. The fewer people opt for collective resettlement, the lower is the prospect of maintaining or reestablishing the community's social ties and culture. On the other hand, the higher the percentage of families that opt for this modality, the better are the chances of the resettlement program to be successful in reestablishing the conditions and the way of life existent in the village prior to the disaster.

Tab. 3. Bento Rodrigues: families' resettlement choices.

Date	Collective	Family	Reconstruction	Indemnification	Total of families
2019	251	21	0	3	275
June 2020	239	43	0	7	289
March 2021	230	57	no data	no data	294
April 2022	209	no data	no data	no data	no data

Source: data collected from Ramboll (n.d.a; n.d.b; 2021a) and Fundação Renova (2022)

9. RECONSTRUCTION OF THE VILLAGE OF BENTO RODRIGUES

According to Samarco [Samarco, 02 May 2016], the company mapped 17 possible lands for the reconstruction of Bento Rodrigues following such criteria as: site accessibility, soil characteristics, water availability, and topography. The community of Bento then narrowed the possibilities down to three: the lands known as Lavoura, Carabina, and Bicas [Samarco, 02 May 2016], which can be seen in Figure 7.

The community of Bento Rodrigues visited the three lands [Samarco Mineração, 02 May 2016] and, on May 7, 2016, chose through vote Lavoura as the new land for collective resettlement. Representatives of 223 families out of 236 were present, amounting to 94% of participation, and Lavoura was elected with 206 votes, or 92% of the votes [Vale, 09 May 2016; Samarco, 2016a; Freitas, 07 May 2016]. However, since it was allowed only one vote per family through the figure of the head of the family, who was male in most cases, the rights of participation of women and adolescents in the selection of the new location of the village were not respected [CNDH, 2017].

According to a study made by Samarco (n.d.b), Lavoura is located 8.94 km away from the original village of Bento Rodrigues and 7.87 km away from the city of Mariana. Also, it is only 1.88 km away from Mariana's landfill [Samarco, n.d.b], which, according to Barreto, Rosa & Mayorga (2020), was being used as the city dump. The proximity of Lavoura to the landfill raised concerns about this being the location chosen for the new settlement (Souza & Paaz, 2019; Xavier, 2018). These concerns were aggravated by the fact that Lavoura is located below the landfill and the same water course runs between both areas [*Cáritas Brasileira Regional Minas Gerais & Comissão de Atingidos e Atingidas pela Barragem de Fundão* (Cáritas & CABF), 2021].

The landfill issues were addressed by a technical study on the environmental health and soil quality of the terrain [Cáritas, 2017 *apud* Xavier, 2018], and by the signing of a term of commitment between Fundação Renova and the Mariana City Hall, where the foundation agreed to make the necessary interventions to ensure the proper functioning of the landfill before the resettlement of the community [Fundação Renova, 09 October 2018].

In June 2016 Samarco made a survey on the expectations of the community of Bento Rodrigues for the new settlement and houses, with 92% of the families present. The survey would be used as support for the architectural and engineering projects made for the new village [Samarco, 2016b]. According to Xavier (2018), the first project was presented in November, but the population claimed that it was not adequate to their way of living and that it was similar to a gated community.

Fig. 7. Location of the three possible lands for the new Bento Rodrigues; source: Samarco (02 May 2016)

Fig. 8. Design process of the concept for the new settlement of Bento Rodrigues approved in assembly in January 2017. (A) Original urban plan. (B) Urban plan adapted to current legislation. (C) Conflicts between the urban plan and the terrain of Lavoura. (D) Final urban plan adapted to the new terrain; source: Adapted from Fundação Renova, Dávila & Synergia (n.d.)

Fundação Renova then developed a new urban conceptual project that was unanimously approved during an assembly that involved 190 of the dislocated families, a total of 80% of the eligible families, in January 2017 (Fundação Renova, 31 January 2017). In order to respect the voting rights of all the dislocated people, the criteria for this vote were different than the ones for the terrain election. Thus, the quorum count was made by the family, where only one representant per family had to be present. However, every Bento Rodrigues resident older than 16 years old was allowed to vote [CNDH, 2017].

The approved project was based on the original design of Bento Rodrigues, which went through adaptation to comply with the current legislation (e.g., streets at least 10m wide, blocks shorter than 200m, land lots facing the street) and the available areas and restrictions present in the terrain of Lavoura [Fundação Renova, Dávila & Synergia, n.d.; Xavier, 2018]. The design process is summarized in the images of Figure 8.

However, the topography of Lavoura was different from the one of the original village, hence the terrain would have to undergo substantial earthwork for the construction of the new settlement. In June 2017, the environmental government agencies and CIF rejected the project. It would have to be better adapted to the topography of the site, diminishing the amount of earthwork, and be placed in a flatter area [Xavier, 2018].

Until mid-2017, about 19 versions of the urban design for the village had been presented [Xavier, 2018]. Also, the efficacy of the community participation in this process was questioned, since the plans were presented to the population with graphic and oral technical languages that were not easily comprehended by the dislocated people [Xavier & Carneiro, 2020].

According to Xavier (2018), the State Secretariat for Cities and Regional Integration (SECIR) and the State Secretariat for the Environment and Sustainable Development (SEMAD) determined the organization of workshops by Fundação Renova in order to optimize the urban design process and include the dislocated families in it. These workshops took place from 14 to 28 November 2017 and consisted of discussing, with the assistance of two models (Figure 9), two urban design projects with the families. The aim was to gather information on the families' perceptions of the best and worse qualities of each project and use this information later to produce a new urban design [Xavier, 2018].

Each project was presented and discussed with the families separately. The first project was presented by a professional from Fundação Renova, then professionals from Cáritas discussed it individually with each family, adding information on their specific land lot, neighbors, among others, and finally the families exposed their opinions and suggestions on the project (Figure 10). Then the same process took place with the second project [Xavier, 2018].

On February 8, 2018, a new urban design was approved by 99.4% of the dislocated families of Bento Rodrigues (Figure 11), with 179 out of 180 votes. According to Fundação Renova, the project preserves the original characteristics of the village and its patrimonial, urban, and cultural aspects as much as possible, especially in regard to the neighborhood relations. This project is a result of the workshops that took place in November and had the participation of 164 families [Fundação Renova, 09 February 2018].

The approved design kept the structure of the original Bento Rodrigues village with the main street, the São Bento Street, running from North to South. It also placed the Church of São Bento at one end of the street and the Church of Nossa Senhora das Mercês at the other, among other spatial references to the old village. However, the different topography leads to very different results regarding the spatial relations established in the village [Teixeira, Medeiros & Pereira, 2020].

The visual axis that previously existed between both churches, for example, ceases to exist in the new village because of the different topography, as can be seen in Figure 12. The proposed urban design also creates different types of land lots. In the original Bento, the lots located along São Bento Street were roughly on the same level of the street. In the new village, those lots are terraced, which makes the yard of the houses difficult to access [Teixeira, Medeiros & Pereira, 2020].

As of June 2022, the construction of the village of Bento Rodrigues is not yet finished, therefore no families of the collective resettlement modality were permanently resettled. As for the families that chose the family resettlement modality, some have received their permanent houses, however, no information on where such families were from originally (Bento Rodrigues, Paracatu de Baixo, Gesteira or rural communities) was found [Fundação Renova, n.d.b].

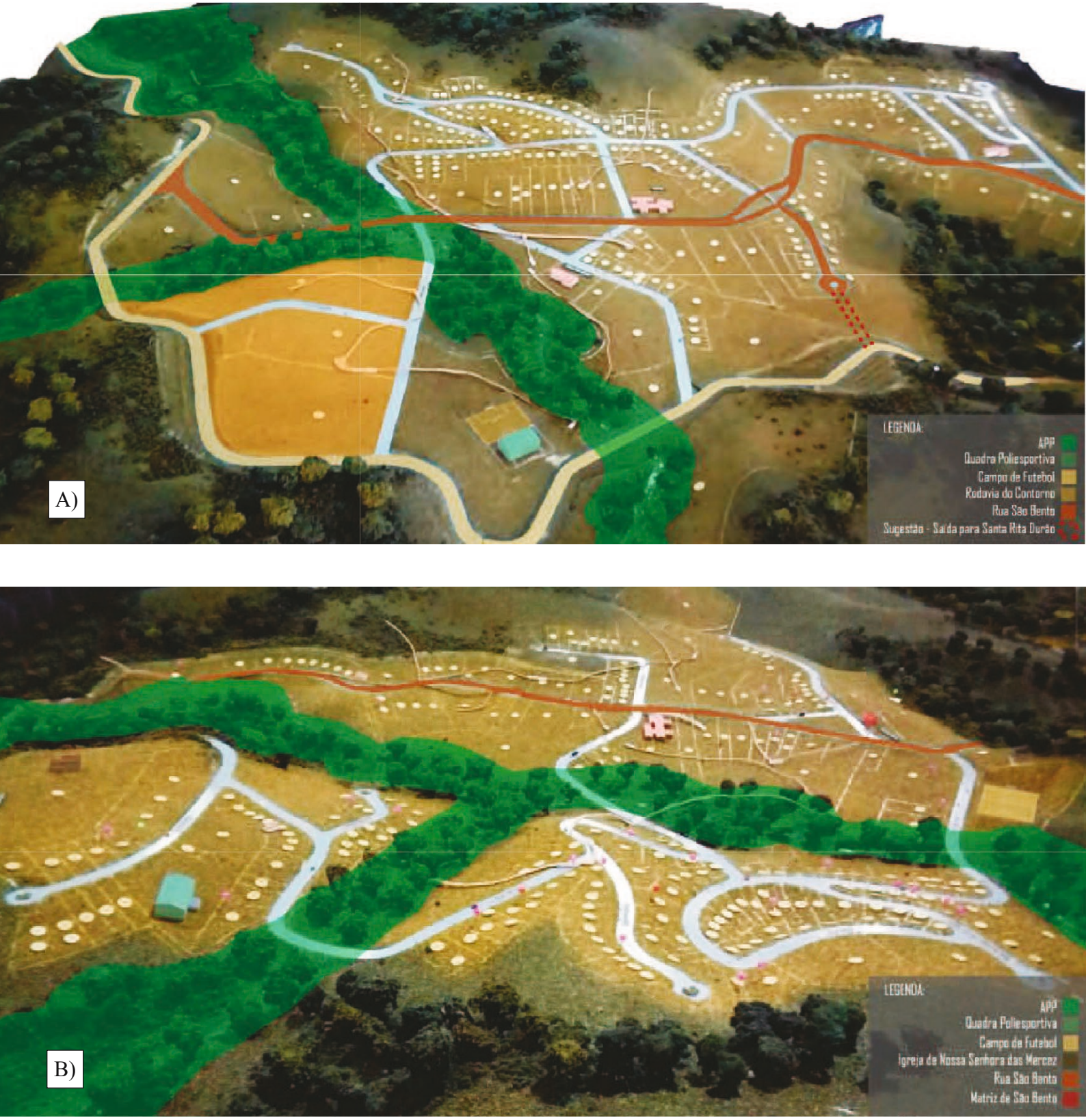

Fig. 9. Models in scale 1:750 used in the workshops with the dislocated families of Bento Rodrigues. (A) Project 1 for Bento Rodrigues. (B) Project 2 for Bento Rodrigues; source: Celiane Xavier [Xavier, 2018].

Fig. 10. Feedback board colored blue for positive feedback, yellow for negative ones, and green for suggestions on the urban designs presented to the families; source: Celiane Xavier [Xavier, 2018]

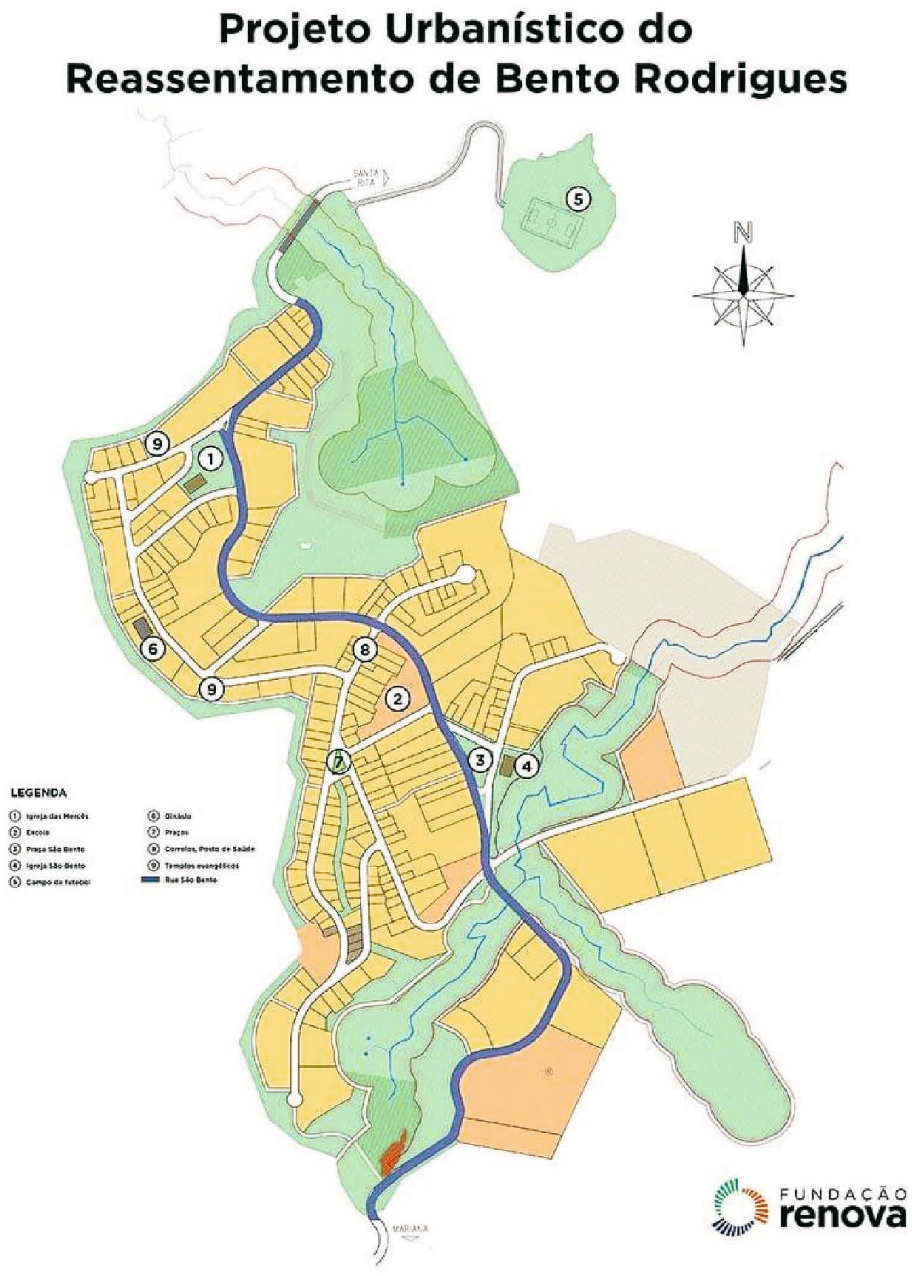

Fig. 11. Approved urban design for the resettlement of the village of Bento Rodrigues. (1) Church of Nossa Senhora das Mercês. (2) School. (3) São Bento Square. (4) Church of São Bento. (5) Soccer field. (6) Gymnasium. (7) Squares. (8) Post office, Health center. (9) Evangelical temples. (Blue) São Bento Street; source: Fundação Renova (09 February 2018)

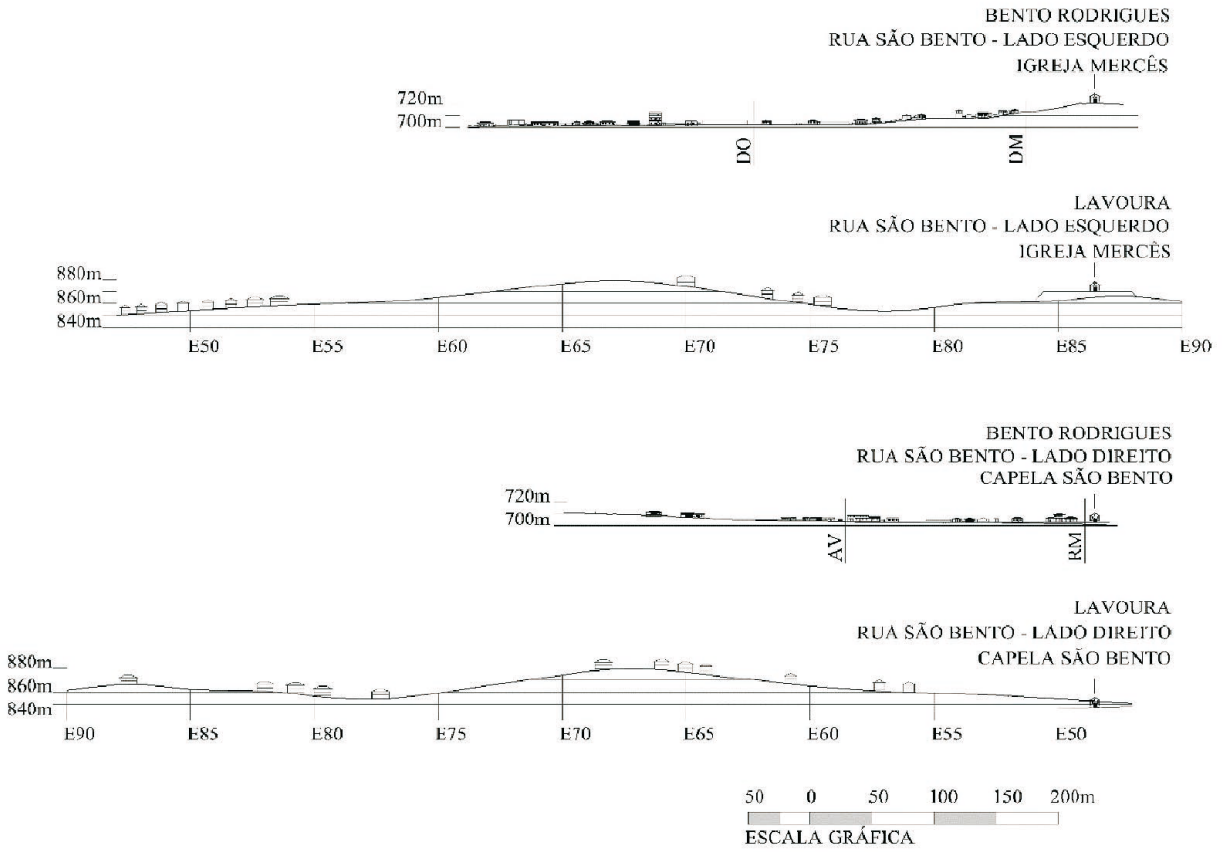

Fig. 12. Longitudinal profiles of São Bento Street in the old and the new Bento Rodrigues villages. (A) Left side profile of the old village. (B) Left side profile of the new village. (C) Right side profile of the old village. (D) Right side profile of the new village; source: Maria Teixeira, Mirelli Medeiros & Ana Pereira [Teixeira, Medeiros & Pereira, 2020]

10. DISCUSSION

The Bento Rodrigues resettlement operation is similar to the construction of a new city, involving not only the construction of houses and buildings, but also of all the infrastructure and services necessary for the well-functioning of a village. Forsyth & Peiser (2021) identify two main types of resettlements (or retreats, as they call it) involving comprehensively planned new settlements (e.g., neighborhoods, villages, towns) like the Bento Rodrigues one: whole community resettlements and new community resettlements. Whole community resettlement occurs when one community is relocated as a whole to a new settlement, while new community resettlement occurs when people from different places and backgrounds are resettled together in a new settlement [Forsyth & Peiser, 2021].

According to this definition, the resettlement of Bento Rodrigues was conceived as a whole community one, where the dislocated families would be resettled as a community at a new village, the new Bento, after around three years of living in temporary houses in Mariana. This type of resettlement has the advantage of maintaining the community's social ties, as noted by Forsyth & Peiser (2021), which was one of the goals stated by the governmental authorities involved in the resettlement process and Fundação Renova.

Although the families could opt for family resettlement outside of the new village, or even for financial compensation, three years after the disaster more than 90% of the dislocated families still chose to be resettled as a community (Table 3). This was a good indicator for the success of the resettlement and a great basis to achieve the goal of maintaining social ties and culture, or at least facilitating their reestablishment. However, after the first deadline of resettlement was not met, in 2019, the adhesion to the collective resettlement dropped each year, leading us to question whether this endeavor will succeed as a whole community resettlement or if there will be too few inhabitants for the social ties and culture to persevere.

This drop in adhesion after the failure of meeting the initially proposed resettlement date indicates that dislocated communities might compromise to waiting long periods of time in order to be relocated together; however, once the resettlement date is continuously postponed, the uncertainty of the future leads people to opt for dispersal (family resettlement in the case of Bento Rodrigues). Therefore, time is an important variable in whole community resettlement operations, and it is important to carefully assess the timeline of resettlement and abide by it, so that the expectations created in the dislocated community are met, increasing the adhesion to the collective resettlement and the chances of its success.

Along with the drop in adhesion to collective resettlement, the effects of the dispersal of the community in the temporary housing arrangement, the long period of time that families have spent in the temporary houses, and the change from rural to urban environment leads us to question to what degree the community of Bento Rodrigues will have maintained its social ties and culture – the biggest benefit of the whole community resettlement model – when it is finally resettled. Without maintaining these ties, it is possible that, although originally conceived as whole community resettlement, Bento Rodrigues' residents may need to recreate their social ties and culture in a similar manner to how a new community would. This, however, can only be assessed in the following months and years after the permanent resettlement of Bento.

One of the factors that can contribute to time saving in resettlement operations is the involvement of the displaced people in the process. Including their participation from the beginning can accelerate the resettlement process by reducing the amount of rework needed. The opposite of this happened with the Bento Rodrigues process, where the new village's urban design had to be reworked many times, with at least 19 proposals made according to Xavier (2018). Only after a more profound popular participation (required by governmental agencies) and the compliance of the presented masterplan with public policy standards was the final urban design approved, but only in February 2018 – more than two years after the disaster that caused the community's displacement.

The dislocated people's participation in the process is also important to guarantee some level of choice, since leaving their homes was not a decision they voluntarily made. Also, as stated by Forsyth & Peiser [Forsyth & Peiser 2021, p. 2], "currently many climate change related resettlement programs are voluntary but as time goes on the choice may be less whether to move but where".

Moreover, the participation of all dislocated people should be guaranteed. During the process, it is possible to divide people in groups and treat them as units, as were the family units in Bento Rodrigues. However, this should not be reflected in the participatory instances of the process, especially regarding decisions that affect the community as a whole. This will avoid situations similar to what happened in the Bento Rodrigues resettlement process, where people, especially women and younger people, were left out of the land choosing vote because the vote was by family instead of by person.

The displaced people, after being forcibly removed from their homes, may idealize their old village, houses, and way of life, and want everything in the new settlement to be exactly the same as it was previously, as signaled by Barreto, Rosa & Mayorga (2020), in Bento Rodrigues. This should be taken into consideration when designing the new settlement, and actions such as maintaining the same neighborhood relations, as was done in Bento, should be encouraged. However, simply copying the old village's plan and adjusting it to the new site is not necessarily the best approach. As seen in Bento Rodrigues, the resulting urban design may not fit the new land.

Also, when trying to copy the original plan, the result might be the creation of spaces and spatial relations that are very different from the ones that existed in the previous settlement. It is therefore also important to recognize the limitations of each tool used and combine more than one to consider all three dimensions in the design process. In Bento Rodrigues, for example, the biggest concern was with creating an urban plan similar to the original one, in an effort to maintain the same structure and building relations of the original village. However, this resulted in very different terrain profiles and cross-sections and, therefore, different spaces and spatial relations. In the case of the churches of São Bento and Nossa Senhora das Mercês, studied by Teixeira, Medeiros & Pereira (2020), it could have been more valuable to maintain the visual connection between both buildings than to simply place them in the same street, for example.

The urban and architectural designs should be inspired by and make references to the original ones, while providing an environment where the dislocated people can live a lifestyle similar to the one they previously had. These references can be done through the visual axis, streets' layout, squares configurations, landmarks, and public and service buildings placement, for example. It can also be done by giving the same names to the streets or numbers to the houses.

However, as shown from the Bento Rodrigues experience, the new design should consider the topography, resources and already existing structures and references of the new terrain, like any new urban design project should.

One of the challenges of designing whole community resettlement might be the communication with the dislocated people and their expectations. As seen in the case of Bento Rodrigues, the families had difficulty understanding technical language and tools, such as the masterplan – as expected of anyone not familiar with the urban planning field. Also, they expressed the wish of having the new village as similar to the old one as possible. These factors combined can help explain the decision to focus mainly on the plan when designing the new village, simplifying the process. However, it is important to find the means to discuss and design the new village in a more holistic manner. The workshops that took place in November 2017 and used models to communicate the urban designs to the dislocated families may present a hint on how this can be done in resettlement operations.

CONCLUSIONS

More than six years after the rupture of the Fundão tailings dam, no family has been resettled in the new Bento Rodrigues village, which is still under construction. This, along with the initial expectation of being resettled in approximately three years and the constant decrease in the dislocated families' adherence to collective resettlement are not good indicators for the thriving of the resettlement operation. Although the process is not yet complete and its success or lack thereof can only be assessed after its completion, we can already learn from it and use it as a roadmap for future resettlement processes.

After the analysis of the Bento Rodrigues case, it is possible to conclude that *time* is a very important variable in whole community resettlement operations of forcibly displaced communities. While waiting in appropriate temporary dwellings, a displaced community may compromise to be resettled in a few years in order to be placed in an environment similar to their original one. With this time, the process can involve stronger participation of the community and result in urban and architectural designs that better fit the community's needs and the settlement's new environment. This can generate a better end-result and increase the satisfaction of the dislocated population with the new settlement, since they will have participated in its conception and, potentially, its construction.

However, poor time management and ineffective processes may prolong the resettlement operation, leading to the postponement of the resettlement date. This situation may create insecurity in the dislocated community, leading people to opt for dispersal instead of waiting for a resettlement that is not guaranteed to happen within an acceptable timeframe – as seen in Bento Rodrigues (Table 3). This also leads to another important factor in these operations: *expectations*. It is important to set goals for the various stages of the resettlement operation and achieve them, in other words, it is important to meet the expectations set. In this way the dislocated people can measure the progress of the resettlement and feel secure in the process, therefore maintaining or even increasing the community's adherence to collective resettlement.

Both *time* and *expectations* management depend on good *communication* between the organizations responsible for the resettlement and the dislocated people and the community itself. Inefficient communication may lead to a lot of reworks and, potentially, the inability to meet the proposed deadlines. Poor communication can also create in the community expectations for the resettlement (e.g., the expectation that it will be exactly like the old one) that cannot be met, potentially leading to the dislocated people feeling disappointed and helpless with the result.

Once the resettlement process of the Bento Rodrigues community is finished, it will be possible to better assess how each of the variables discussed in this article have influenced it. Also, the monitoring of the community in the following months and years will give us more tangible answers on whether this process can be used as a model for future whole community resettlement operations of forcibly displaced people and where it can be improved.

This article makes an in-depth analysis of what happened to the population of Bento Rodrigues after the Fundão tailings dam failure, following the community's resettlement process chronologically from the moment of the disaster until the approval of the new settlement's urban design. By analyzing the multiple phases of the resettlement process (immediate action, temporary resettlement, and permanent resettlement), the article provides a comprehensive picture of the resettlement of the community. This will allow the analysis of the causes and consequences of this endeavor's successes and failures once the community is permanently resettled, which will be important information to have when dealing with a foreseeable growth in communities displacement due to environmental disasters and climate change.

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PHILOSOPHY OF URBAN DESIGN TEACHING WITH THE USE OF INTERACTIVE AND PARAMETRIC DIGITAL TOOLS

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Abstract
Learn, experiment and enjoy it – the joy of understanding should translate into the joy of creation, then the joy of creation fits itself spontaneously into the creative process. Learning means sharing knowledge and joy of leading others into the unknown areas they have not discovered yet. Teaching is a constant interaction and exchange on the intellectual and emotional levels, as well as mental and cultural levels – it is also establishing role models and social attitudes.
Young designers are faced with challenge of translating the virtual world into the physical world in the current era of digital technologies. The use of parametric design programs allows them to create a versatile, functional, but artistic interactive environment, capable of shaping the urban interior within the city. This paper aims to present a design process and effect of an experimental, innovative academic program of semester course "Immersive environments and interactivity in designing architectural interiors and their surroundings". The final projects demonstrate the versatility of understanding and implementing the program and the plasticity of shaping public spaces – valuable skills in a student's path of design self-development.

Keywords: architecture; urban design; interactivity; philosophy of teaching; parametric design

INTRODUCTION

The boundaries between the physical and the digital are increasingly becoming blurred for the past three decades, which affects the a maturing vision of architecture that actively participates in our lives. In the era of rapid development of 21st century information technologies, significant changes are noticeable in many areas involving the design process. The community of architectural professionals is undergoing processes of interdisciplinarity, bringing together experts in space design, programming and artificial intelligence, as well as the sociological and philosophical aspects of human-machine interaction. Innovative realizations coupling virtual reality with physical reality and visionary research projects have become a response to attempts to redefine the concept of architecture and its environment. These processes respond to the dynamically changing needs of individual and collective users of urban spaces, while at the same time being part of the current trend of smart and sustainable city. The world of digital technologies, built from a network of connections and dependencies, has become an active participant in everyday life. The interdependence of the built environment and technological systems has triggered their mutual response and constant redefinition. Ubiquitous data capability has become an integral part of our lives and has begun to permeate all spaces, from devices to buildings and environments. The process of integrating architecture and digital systems in the modern era of their mutual cooperation becomes, therefore, a dominant issue in the design progress. Architectural art is being transformed and is no longer seen as the result of the fully predictable, limited ac-

tions of its creators, and giving it interactive qualities implies its reconfiguration and ability to respond, in real time, to the demands and needs of its users and to environmental conditions. As a result, architectural realizations are personalized and become much more unpredictable and animated. In this situation, it is the user of a given architectural space who becomes the center of development and operational processes, in opposition to traditional architecture, where designers, engineers, developers, etc. determine its quality and spatial organization.

1. INTERACTIVE BUILT ENVIRONMENT AND PARAMETRIC DESIGN

By definition, interactive built environments are built on the convergence of embedded computing and a physical counterpart that meets the requirements of adaptation through interaction. It includes both buildings and environments that are designed to respond, adapt, change and come to life. In addition, the use of interactive tools within architecture and its environment influences human experience by creating immersive environments.

The challenge becomes the realization of human interaction processes with the architectural environment through the tool of interactivity. Interaction, understood as the interaction of people, objects or phenomena with each other, is considered a property of interactivity as a technological process. The term "interactive architecture" (iA) means an architecture capable of continuous internal adaptation to the constantly changing conditions of its content and context. In other words, it exhibits characteristics of independent behavior that develops through its interaction with users and the environment. The didactic intention of the conducted course was to expand thinking about architecture based on modern technologies that foster the creation of experience in space. This activity combines a number of issues from scientific disciplines such as psychological perception of space, philosophy, new media, sociology of space and architecture of urban public interiors. Hence, the design process was preceded by an in-depth analysis of world cases, building a mind map and searching for deficits of the selected urban interior. This leads to the formation of a holistic view of the space and the needs of its users - city residents and tourists.

The Interactive Built Environment Studio managed by Krystyna Januszkiewicz and Anna Pazdur-Czarnowska started in 2018. The subject of this Studio includes a contemporary design actions undertaken in urban spaces that are based on an interactive dialogue between the artifact and the viewer while significantly increasing the place's attractiveness and aesthetic qualities. The studio deal with responsive environments which are defined as those, which engage interaction with the users of these environments through systems that respond to the audience's behaviour. Technologies used include detection and tracking motion through sensor systems, video cameras and/or body-worn sensors. Audio and video effects are generated according to the actual time of the event by software tailored to the accepted choreography of time and media type. The media choreography software is used to read and process the stimuli sensory input and generate responses in images and sound in real time. Moreover, such environments may contain interactive tactile devices. Myron W. Krueger is considered the precursor, who, from 1969, worked on "sensitive environments" to create spaces responsive to user's gestures and movement, using a system of sensors and video cameras. As early as 1970, he created installations such as Glowflow, Metaplay and Physic Space using video projections which the viewer could modify, considered a cornerstone of interactive art. Nowadays, Krueger's concepts are developed and increasingly often become attractive public spaces in the city, organizing the public zone. As a result, these types of installations have become a permanent part of the means of contemporary art's expression. The presented cases of responsive environments demonstrate a new artistic medium based on a commitment to real-time interaction between humans and machines. This medium consists of sensors, display and control systems. It receives input from or about the participant and then generates output in a way, which can be recognized as a response to its behaviour. The relationship between what constructs an input and an output is arbitrary and variable, allowing the designer to intervene in the participant's action and the results obtained. For example, physical movement may results in sounds or voices used to navigate in a visual space defined by a computer. It is the relationship between the action and response that is important. Visual beauty and auditory response are secondary. The response is the medium!

Within almost four months of the overall designing period, students presented a variety of concepts. The chosen urban interiors differed in function and the type of space limitation. Some were confined by a square net of trees, while others presented a clear border of building's facades surrounding the chosen interior [Fig.1 and 2].

The design concept EcoAr [Fig.1] was located in the city centre, at Pawel Adamowicz Square in Szczecin. It is an elongated type of urban interior bounded on two

sides by a roadway strip and a green line. The project aims to diversify the current appearance of the urban space by using elements based on pro-environmental solutions. Moreover, it offers a wide range of interactive attractions for passers-by and tourists. The central axis of the floor is formed by a strip of pavement tiles with a built-in kinetic effect sensing the weight of a passer-by. The mechanical energy of the tiles is accumulated and transformed into electrical energy which powers the illuminating effect of the gates in the square. In addition, the edges of the cycle path have been fitted with sensors to detect the movement of cyclists and to emit illumination in the outline of their edges. The openwork gates form a partial canopy over the square, offering lighting attractions activated by two systems, which are a part of an ecological, sustainable design trend. The energy from photovoltaic panels on the upper surface of the forms and spiral wind turbines, so-called Vertical axis wind turbines, power the light sources hidden in the lower layer of the gates' lintels. When the system detects human presence, the lighting intensity increases. The square is surrounded by lush low and medium-high greenery, which purifies the air, dampens noise, diffuses street sounds and has an aesthetic function.

The design concept is based on the use of renewable energy sources, kinetic energy, wind energy and electricity. The designed form is therefore self-sufficient and at the same time based on HCI (Human-Computer Interaction) technology, creating a new aesthetic and behavioural experience for the users of the square.

A lighting structure was a core form of Kaskada Project. Located within the pedestrian walk closed from the shorter side with the facade of Kaskada shopping mall entrance, this project was an activity point for the visitors and their children. The labyrinth consisted of colorful elements, which were successively activated when crossing its parts. In the final phase, the entire maze was illuminated, as well as the facade of the shopping gallery. It was designed as a futuristic playground for children, who can pass it while the adults are engaged in shopping. The colourful lights were building another layer of immersive xperience after dark. Additional attractions of the maze were water and reflective curtains, activated by the movement of users. The ecological function was fulfilled by the use of TiO2 surfaces –the sunlight activates TiO2 and allows it to clean the air from harmful NOX particles contaminating the air of every largely populated city [Munafo, Goffredo, Quagliarini, 2015].

A similar curriculum structure was also applied to the subject of parametric design. The Parametric Design is treated here as a catalyst for social innovation by exploration of the role of interactivity in the public space. The digital design space is defined by computer, mathematical and algorithmic logic. Implications of digital formats by functions and polynomials have yielded applications with expanded spatial capabilities. For example, NURBS parametric fluid geometry allows accurate modeling, without analytical approximations, of arbitrary curves and surfaces, with a single set of commands [Januszkiewicz, 2012]. Digital space, having introduced an interactively and dynamically organized base time, can trigger such spatial operations as evolution, transformation, hybridization and mutation. The extension of animation takes advantage of the properties of compound time, which can be viewed as nonlinear, differently understood from the time of the fourth dimension of architecture animation. The nonlinear time reading system is the opposite of kinematic modulation. It is being used increasingly in the formation and representation of architecture and in technology. Digital tools, therefore, are also changing the previous relationship of space and time in architectural design [von Weizsäcker, 1979].

2. THE LEARNING AND TEACHING STRATEGIES

The **principal learning and teaching strategies** of the subject was the creation of design projects, from which students gained experience, knowledge and skills required for shaping design projects using digital tools based on NURBS. Moreover, the understanding and applying the principles underlying the theory of digital and parametric design in architecture and the interactive environment and the city.

The teaching strategy associated with the researching process was regular, tutor-led, based on research tutorials in which small teams presented ongoing research work, discussed and evaluated these results. Teaching also included discussion and evaluation of research experimentation and research presentations. During design tutorials assessments were made in comparison to each student's individual progress and development, relative to his or her own past performance and participation. This allowed an absolute measure of progress made by individual students and teams.

The Educational Aim of the following Subject was that students learnt architectural design and the use of digital tools based on NURBS in the design process. This was the start to the digital design thinking, the way in which the digital designer is beginning to think, employing digital tools and interacting with representational media. The subject also aimed to develop the learner's interest, knowledge and skill of contem-

Fig.1. EcoAr project at Adamowicz Square. Students: Julia Franecka, Ernest Białous; source: author's didactic materials

Fig. 2. Firefly Project – concept of a public space design. Students: Julia Klein, Laura Koperska, Anna Hardziej; source: Author's didactic materials

porary architectural and urban design, including the relationship of contemporary architectural projects and spaces to urbanism and urban settings. Emphasis was placed upon learning advanced design concepts, skills and knowledge related to the making of architectural design proposals. Participants in the subject were beginners in using advanced design tools such as: Rhino and Grasshopper, 3D max or Maya. They used to prepare projects traditionally and design the project's representation by the use of popular design tools such as: AutoCAD, ArchiCad, Sketchpad and Photoshop or Corel Draw. Therefore, students have learned to understand not only the logic of the advanced software, but also the logic of its use in the design process.

The subject included a series of examples of contemporary design actions undertaken in urban spaces that are based on an interactive dialogue between the artifact and the viewer while significantly increasing the place's attractiveness and aesthetic qualities. The student's case study includes the history of interactive designs of kinetic facades; from a primal Institute of the Arab World from 1987 (by Jean Nouvel), through the sensorial spatial forms as main design components of a dutch group Studio Roosegaarde, to uniquely innovative attempts on use of the artificial intelligence conducted by such architects as the Turkish group Ouchhh (urban sculpture Monolith). The use of AI is a new trend combining architecture and art. The

gathering and analysis of data as well as its further processing works on both the internal level of architectural forms located in urban interiors, and the external level of complicated sensorial systems that gather data from the environment [Chaillou, 2019]. The author examines the examples of interactive architectural structures in urban space while recognizing the innovative direction of their development - the direction based on the pioneer solutions for the technological systems based on artificial intelligence. The definition of interactivity as a coupled effect between the human and the machine is still being developed based on new models of intelligent behavior in architecture.

3. DESIGN PROCESS

The design process consists of several stages during which a given design task is solved.

Stage 1: Project Analysis (Weeks 1–2). Work on the project begins with a detailed analysis of the project brief and formation of initial concept. The design team prepares initial project statements summarising design goals, objectives such as: initial design analysis of the project programming, site, clients etc. These initial analyses are based on an outline the student prepares, individually and with subject tutors;

Stage 2: Programme Analysis (Weeks 3-4). Preliminary strategies outlined in stage 1 are used as the basis for establishing the criteria used to undertake detailed site and brief analysis for the proposed project. The student undertakes various forms of investigation into the physical, social and material features of the project site and situation, studying how relevant existing architectural spaces and urban surroundings are used; how the site relates to existing and proposed infrastructures. Initial design concepts in handmade sketches and models also in Rhino are explored and presented in Power Point files.

Stage 3: Diagrammatic Exploration and sources of shipping forms inspiration (Weeks 5-6). As the main project constraints become better understood through initial site and programme analysis, initial design ideas and alternative design strategies are developed for potential solutions to the design problem outlined in the project brief. Design Students undertake a series of studies, in traditional design media, (handmade sketches, handmade modelling), which begin to visualise spatial strategies, structural ideas and their potential effect on the social life of the proposed project. Alternative building programming strategies are explored, showing how the project can adapt itself to proposed activities and the usage. Summary: Individual presentation.

Stage 4: Initial Design & Modelling (Rhino-Grasshopper) (Weeks 7-11). Alternative designs are digitally visualised and modelled in relation to their urban surroundings, showing how the project will affect existing circulation patterns, uses, and future development. More specific details are studied regarding the various systems that need to be accommodated in the project, including building structure, enclosure, openings, entrance, internal divisions, different uses, and potential for future growth and change. Choices are made for specific designs and systems to be further developed. Selected systems are developed in a step–by–step process leading to more detailed designs.

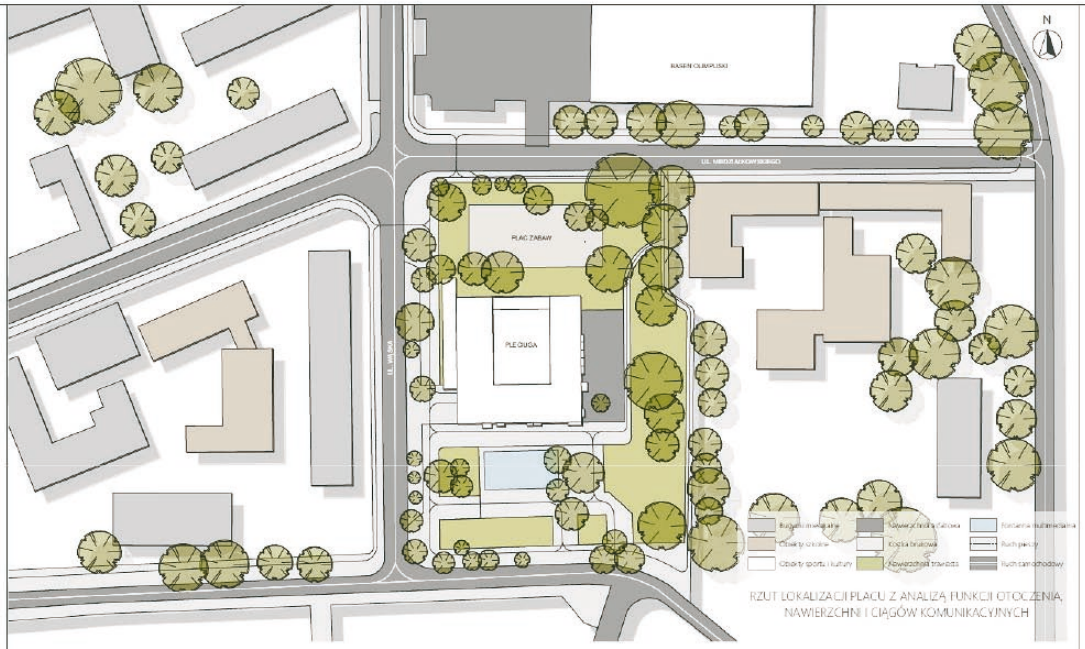
Stage 5: Design Development and Integration (Rhino-Grasshopper, 3D max, Maya, Autocad) (Weeks 11-15) During this stage different strategies for solving the problems related to specific features of the project, including overall building structure, enclosure, growth, internal prehensive, design proposal, are being clarified. As the project becomes more clearly modelled, drawn and visualised, its performance is then tested, repeatedly, in relation to the design team's initial design objectives. A combination of physical and digital modelling processes is used to create a detailed project design, which is fully visualised in terms of the project's brief, site, and proposed uses. The final project is presented at the end–of–semester.

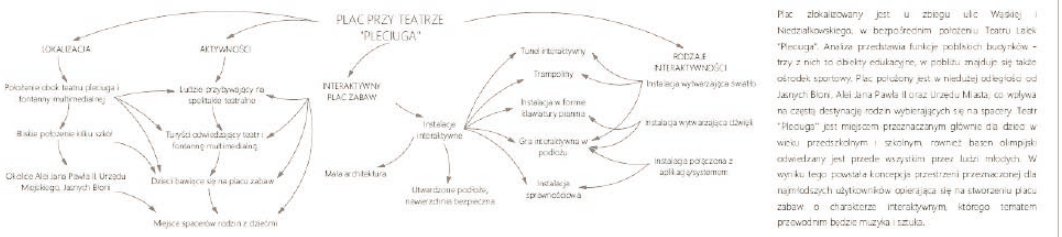
4. DESIGN PROJECT SUBMISSION

The printed format consists of an A2 cardboards project documenting key project images, graphics, models, diagrams, quantitative data and an accompanying text [Figure 3 and 4]. Project presentations, including verbal description and discussion of project development, results, media, documents and models are being prepared.

At the end of the course students are expected to:

1. Have acquired a range of technical skills and knowledge related to the making of conceptual architectural interactive design projects and have gained understanding, knowledge and abilities related to establishing design goals, objects, and project results.
2. Have learned how to make digital and physical architectural models that show the detailed organisation, assembly and design of an interactive design project in relation to its urban setting and surroundings.
3. Have learned how to record and describe patterns of use, operation and performance of a design project described dynamically, in re-





Plac zlokalizowany jest u zbiegu ulic Wąskiej i Niedziałkowskiego, w bezpośrednim położeniu Teatru Lalek "Plecuga". Analiza przedstawia funkcje pobliskich budynków - trzy z nich to obiekty edukacyjne, w pobliżu znajduje się także ośrodek sportowy. Plac położony jest w niedużej odległości od Jaroych Błoni, Alei Jana Pawła II oraz Urzędu Miasta, co wpływa na czestą destynację rodzin wybierających się na spacery. Teatr "Plecuga" jest miejscem przeznaczonym głównie dla dzieci w wieku przedszkolnym i szkolnym, również basen olimpijski odwiedzany jest przede wszystkim przez ludzi młodych. W wyniku tego powstała koncepcja przestrzeni przeznaczonej dla najmłodszych użytkowników opierająca się na stworzeniu placu zabaw o charakterze interaktywnym, którego tematem przewodnim będzie muzyka i sztuka.

Koncepcja zagospodarowania terenu przy teatrze "Plecuga" zakłada stworzenie placu zabaw o cechach interaktywnych. Na terenie parku zaprojektowane zostały instalacje sprawnościowe, most w formie fortepianu, huśtawki, kopuły ze ścianką wspinaczkową i rozdłem, gra interaktywna w podłożu, podświetlane trampoliny, tunel interaktywny oraz fontanny kaskadowe w powierzchni, dzięki czemu podczas ciepłych dni możliwa jest zabawa z wodą. W samym rozplanowaniu przestrzeni dominuje linia swobodna i ścinne nawiązanie do okręgów. Kolorystyka opiera się na żółtych i pomarańczach z dodatkiem bieli i szarości. Na placu wykorzystano drewno, metal i tworzywo sztuczne. Całość uzupełniono kwiatami i krzewami odpowiednimi dla miejsc przeznaczonych dla dzieci.

Fig. 3. Pleciuga's interactive playground – final design boards. Students: Adrianna Orłowska, Katarzyna Stojałowska; source: author's didactic materials

lation to time and how to conceptually create, test and modify design assumptions in relation to a specific, detailed design proposal.

4. Have gained experience in relations to the initial design objectives, project briefs, including key project constraints, as well as in relation to specific design processes, tools and concepts.
5. Have learned skills related to the making and refining of a design project in relation to contemporary architectural interactive design discourses and urbanism.
6. Have gained understanding and knowledge of how to document, present, and communicate design results.

The approach adopted in this is based on the school of research-by-design, a type of academic investigation of the architecture field (in particular, urban design and landscape design), through which design is developed as a method of inquiry. The didactic process, proposed here as a process of shared knowledge, represents a precious opportunity to undertake an experimental research path [Frankel 2010, Roggema 2017] In

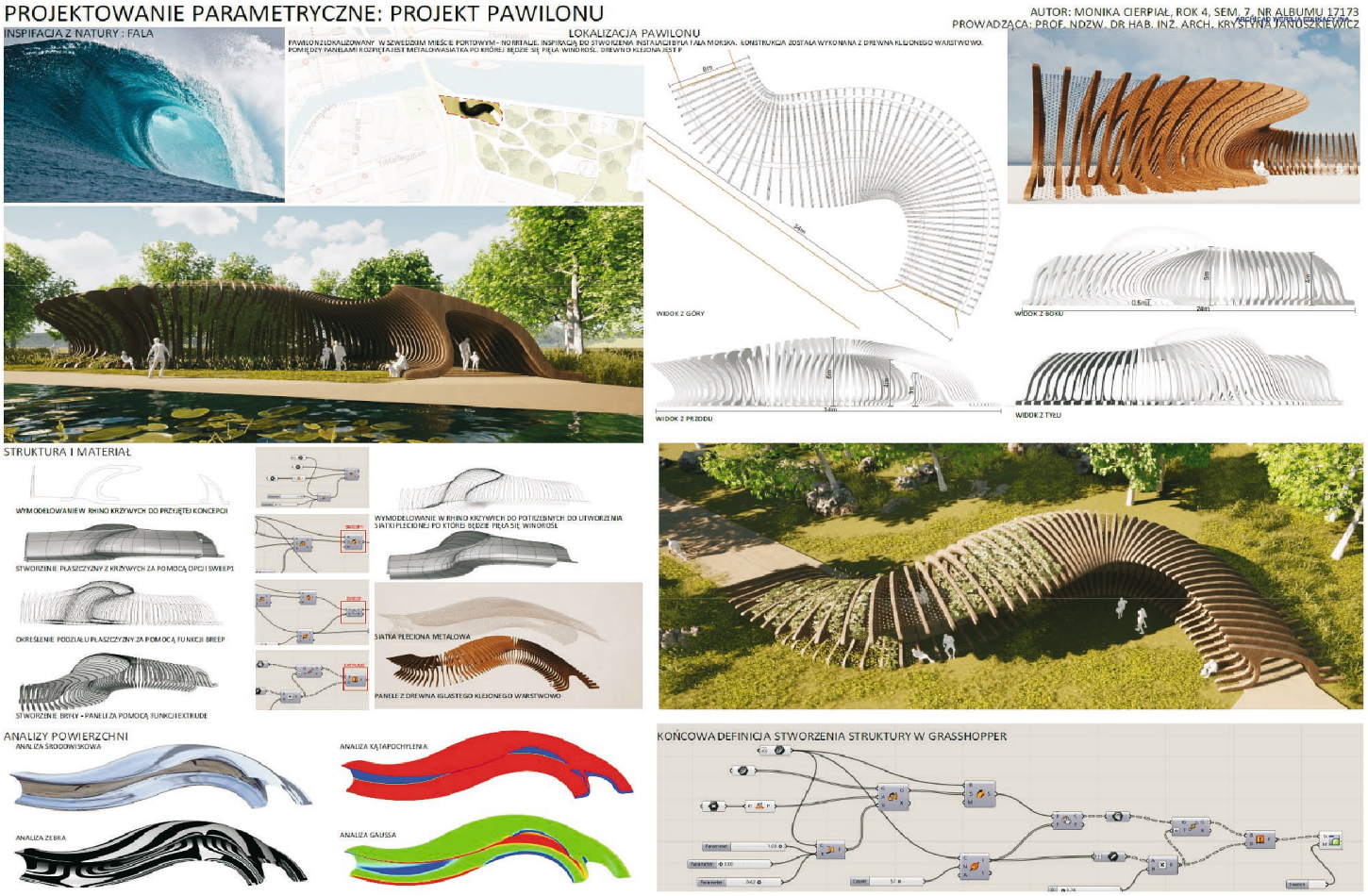


Fig. 4. Parametric Design Studio – Wave Pavillion Project. Student: Monika Cierpiał; source: Author's didactic materials

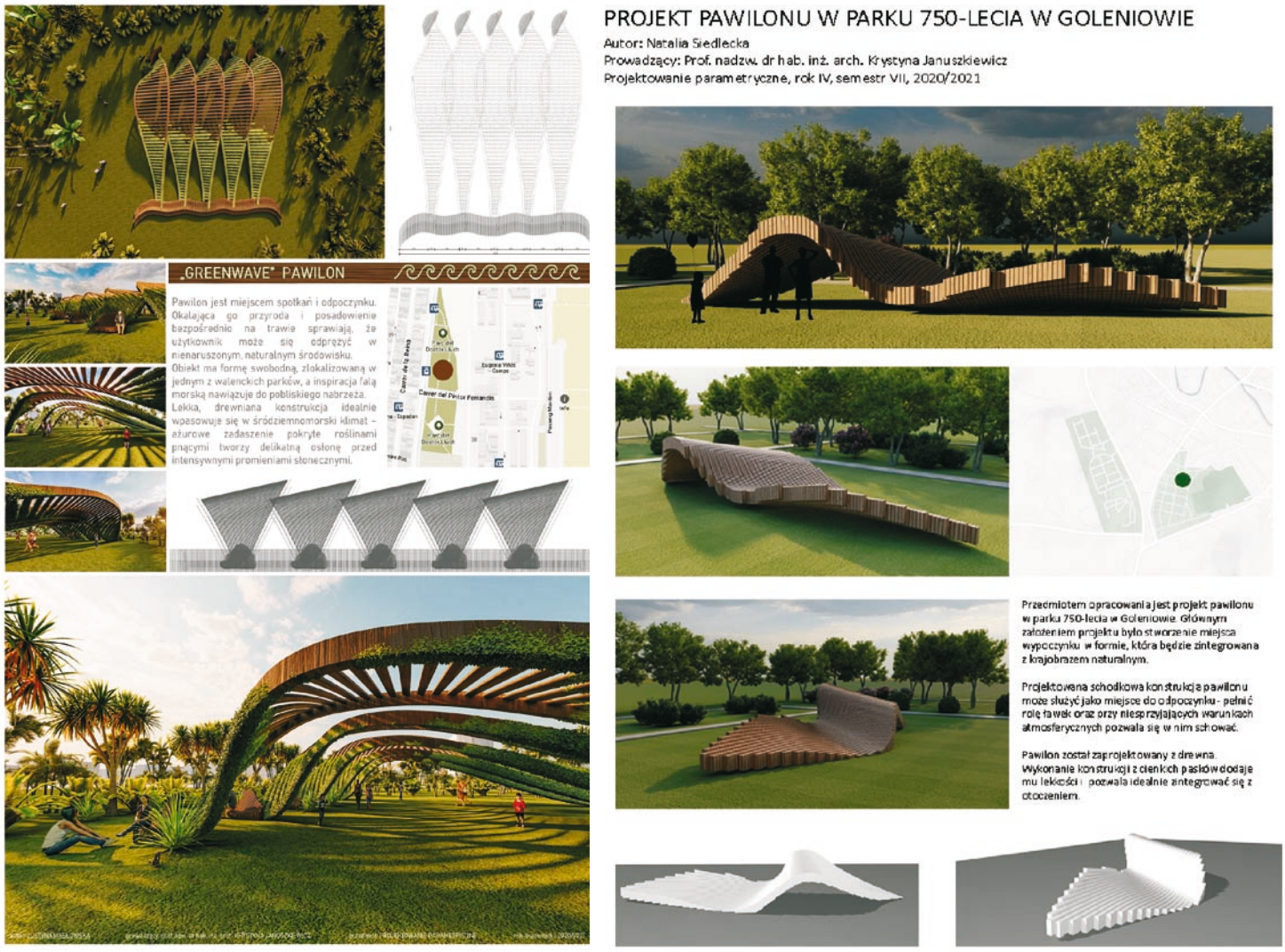


Fig. 4. Parametric Design Studio - Greenware Pavilion (left), student: Justyna Masłowska, Wooden Pavilion (right), student: Natalia Siedlecka.

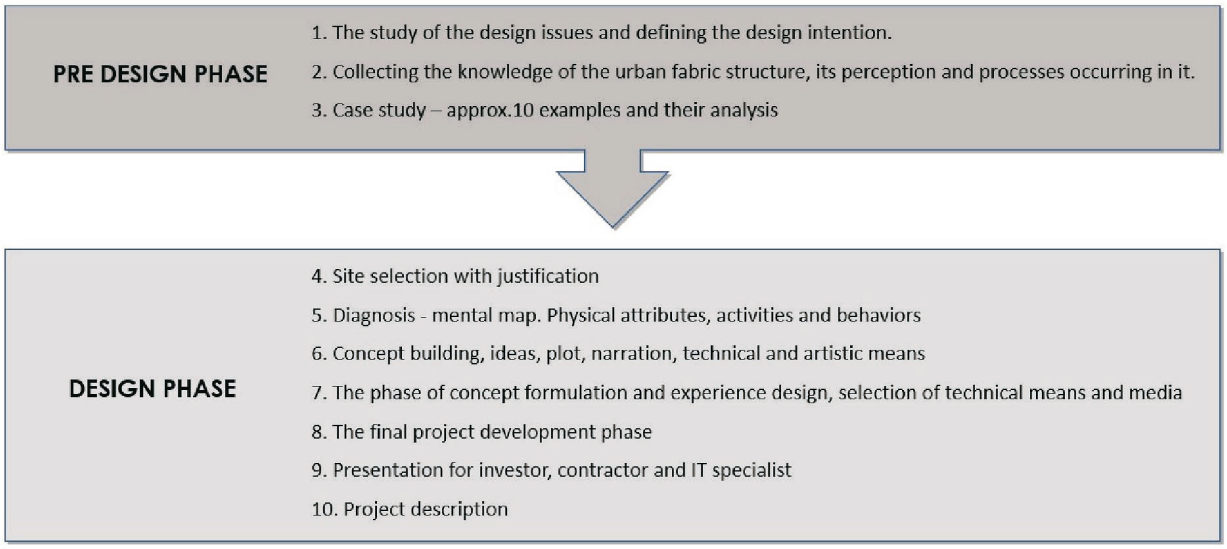


Fig. 5. Research-by-design method adopted to didactic program. Design steps creating the Pre Design and Design Phase; source: author's didactic material

this case, there is the opportunity to build a structured and conscious methodology, in which each step is explained and understood building an awareness of the diachronic and spatial implications.

The didactic program has been mainly inspired by Michael Brawne's analogy between design and a sketch of scientific research as a problem-solving sequence. The process has been divided into two main parts, which were then followed by a sequence of steps [Figure 5]. The Pre Design phase allowed the students to firstly collect a certain amount of basic theoretical knowledge focused around a chosen urban interior of Szczecin. The Design Phase presented a practical part of the program, where the aforementioned objectives have been considered in an individual project of interactive environment. The same sequence of steps has been used according to the parametric design program.

The aforementioned design process is presented below, based on two projects from the Interactive Environment Subject.

5. PRE DESIGN PHASE

The students Angelika Bajko and Paulina Ossolińska started their design journey by focusing on the current environmental issue – a threat of bee extinction. A preliminary analysis of the problem revealed a wide range of threats, most of them provoked by human activity. The aspect of the disappearance of the pollination process of flowers and the depiction of man as an intruder in the animal world became particularly interesting to them.

This idea was then developed by a sketching process. The creation of the form, structural elements and basic shapes have been instantly enriched by technological solutions [Figure 6]. For instance, the idea of a honeycomb shape evolved into the shape of paving tile. The over scaled shape of a flower has been enhanced with the sensor mode of opening its petals by the touch – responsive reaction.

The two, next steps of Pre Design Phase were based on a thorough research of worldwide examples of urban interiors and public spaces. a detailed analysis of the designers' past achievements provided further creative inspiration, but also helped to gain knowledge and guard against copying existing ideas. The collected examples had to be analyzed by the students and presented to the group. During this step, students learned about the design path and its intricacies. In this case the authors of the project have described the idea as follows: the idea behind the immersion plant development project is to get closer to the problem of air pollution and engage with the topic of environmental protection. The role of humans is to symbolically transform into a pollinating bee. Thanks to the interactive installation, we have the opportunity to contribute to the development of buds by touching the flower stems.

6. DESIGN PHASE

The Design Phase was started by the choice of location and further development of the concept idea. The BEES Project was located on the Lotników Square in Szczecin – open public space surrounded by a two lane street [Figure 7]. The students immediately recognized main characteristics of the place by seeing it as a busy area, with good capacity of the main traffic route and an open, free space with catering and public facilities.

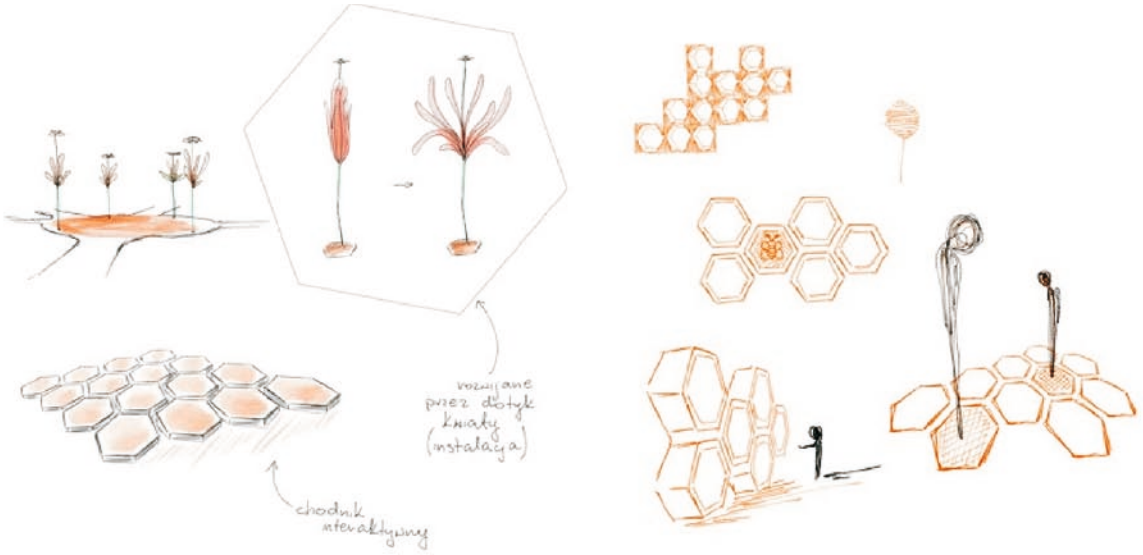


Fig. 6. Basic ideas of the Pre Design Phase. Searching for a form and its use. Flowers opening by the influence of touch and a pedestrian walk built out of honeycomb tiles; source: students: A. Bojko, P. Ossolińska

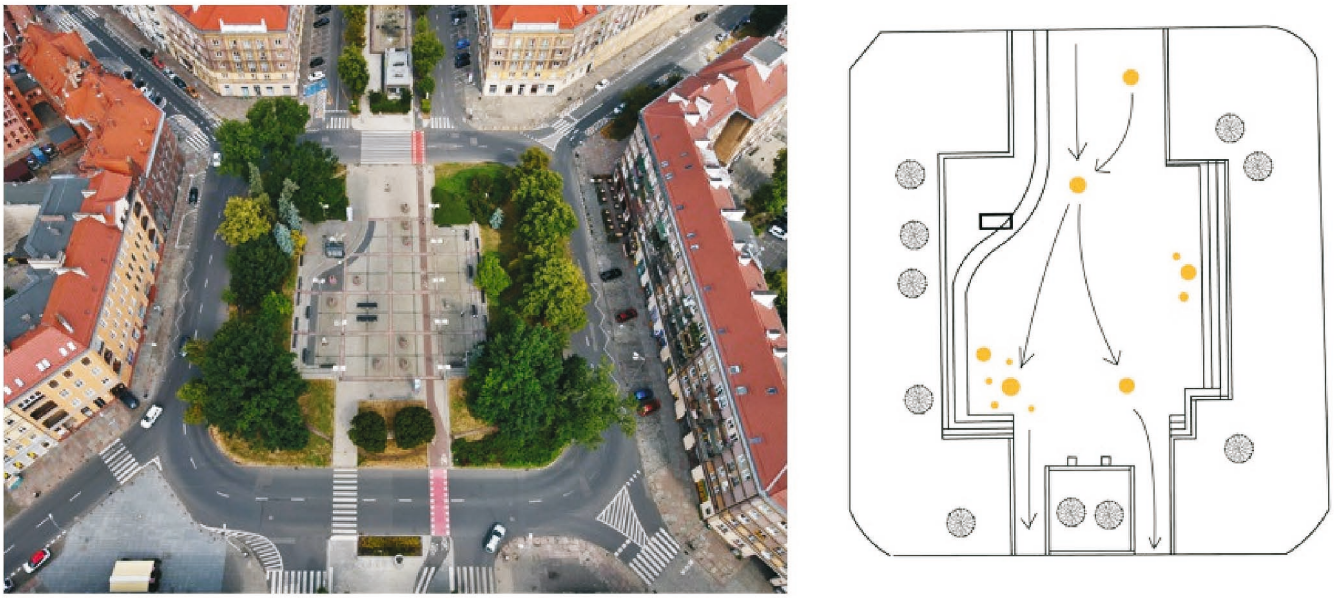


Fig. 7. Lotników Square in Szczecin. The aerial view and the analysis of main people meeting spots; source: students: A. Bojko, P. Ossolińska

The square is urbanized by a touristic trail with a bike path. It serves as a kind of stop on the road of historic sights and points of interest in Szczecin. The surrounding steps and the Colleoni monument allow stopping and generate gathering points for users. The next design step has evolved around the concept itself and its core parts: Idea, Environment, Interaction and Solutions [Figure 8]. The created Mind Map has organized the chaos of ideas and allowed the students to focused step-by-step on the design process.

The students identified the components for the four groups building the design concept. The environment group responded to ecological problems and their technological solutions. They looked for ways to enrich the form with nature-friendly elements. The idea group was built around the theme of bees and the pollination process and their salutary effects on the environment. It also emphasized the smallness of man in the face of the power of nature. The interaction aspect was defined by specific new media art solutions based on the human-computer interaction system, or sensor-response sensory interaction. In the solutions group, the students proposed forms inspired by the theme of bees, which was a summary of the previous three groups.

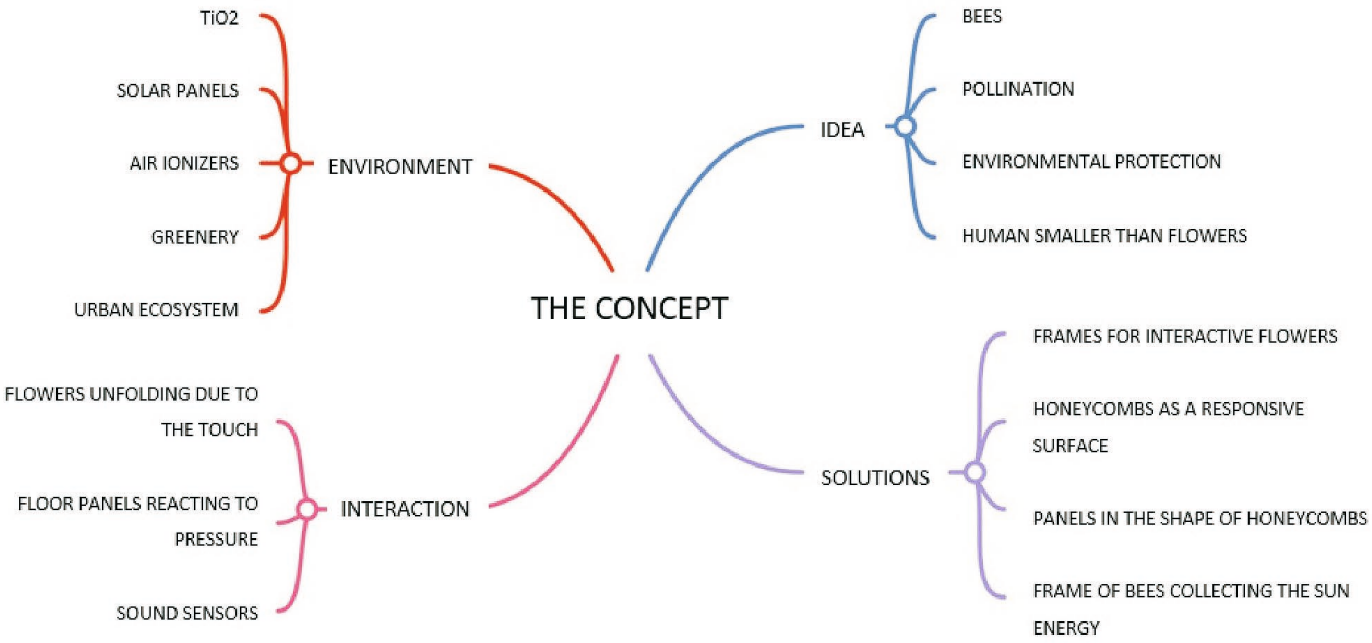


Fig. 8. Mind Map around the core concept. The main groups of issues: Idea, Environment, Interaction, Solutions; source: students: A. Bojko, P. Ossolińska

The overall form and its night and day view has been presented in the set of 3D renders [Figure 9 and 10].

One of the chosen projects has been presented below and designed by a student's duo – Natalia Rzepka and Aleksandra Moroz. The form has been located within a courtyard of the Szczecin's city hall [Figure 11]. The central facade is permanently illuminated in green. Two mirrored spatial forms and a red ball in the center invite passers-by to approach and participate in the fun. At the human touch, sensors in the floor activate an open-circuit lighting system that shines on the ground. The purpose of the lighting is to encourage people on the square to come closer and gather around the mirrors. This allows making new acquaintances and fostering interpersonal contacts. When a sufficient number of people gather, soft music begins to sound. Another highlight is the animation of the façade using the 3D mapping technology, showing the stages of vegetation. In a few minutes the green wall changes from a solid wall into a green, moving structure. This shows the beauty and value of greenery in the city and its symbolic tree – Magnolia. The rose ball in the center displays a gently moving foggy animation that reacts to the touch of a human being [Figure 11]. The task is to find the map of the city underneath, which further emphasizes the location of the object, and it is also a great attraction to open up to another human being and start working together with a common goal.

7. PARAMETRIC MODELLING – BASIC COURSE

The Parametric Design Studio leaded by Januszkiewicz started in 2012 as one of the first events in Poland for digital modelling, parametric design and digital fabrication in architecture. The focus of this Design Studio is on how to use Rhino3D with Grasshopper efficiently when modeling basic and more organic and fluid geometries, how to start using Grasshopper from scratch with a beginner-friendly learning approach, and how to understand the logic behind parametric modeling. This basic course provides an introduction to parajetric thinking and complex 3d modelling and algorithmic design methodologies. Rhinoceros3D is a powerful 3D Nurbs-based modelling program with incredible precision and customisability that is increasingly become industry standard in many design fields. Participants will gain a practical understanding of parametric geometry and more complex topological surfaces [Tedeschi, 2014].

This course provides an introduction to complex 3d modelling and algorithmic design methodologies. During the parametric design classes [Figure 12] the tutors and students also discussed and critically evaluated to identify appropriate materials and manufacturing techniques as well as the assembly process and connections. Considering the budget, manufacturing capability and process of construction it was decided to use plywood and CNC milling for manufacturing of

Fig. 9. The day view on the BEES Project form (by students: Angelika Bojko and Paulina Ossolińska)

Fig. 10. The night view on the BEES Project form (students: Angelika Bojko and Paulina Ossolińska)

Fig. 11. Magnolia Project on the semi-opened courtyard of Szczecin's City Hall by students: Natalia Rzepka and Aleksandra Moroz

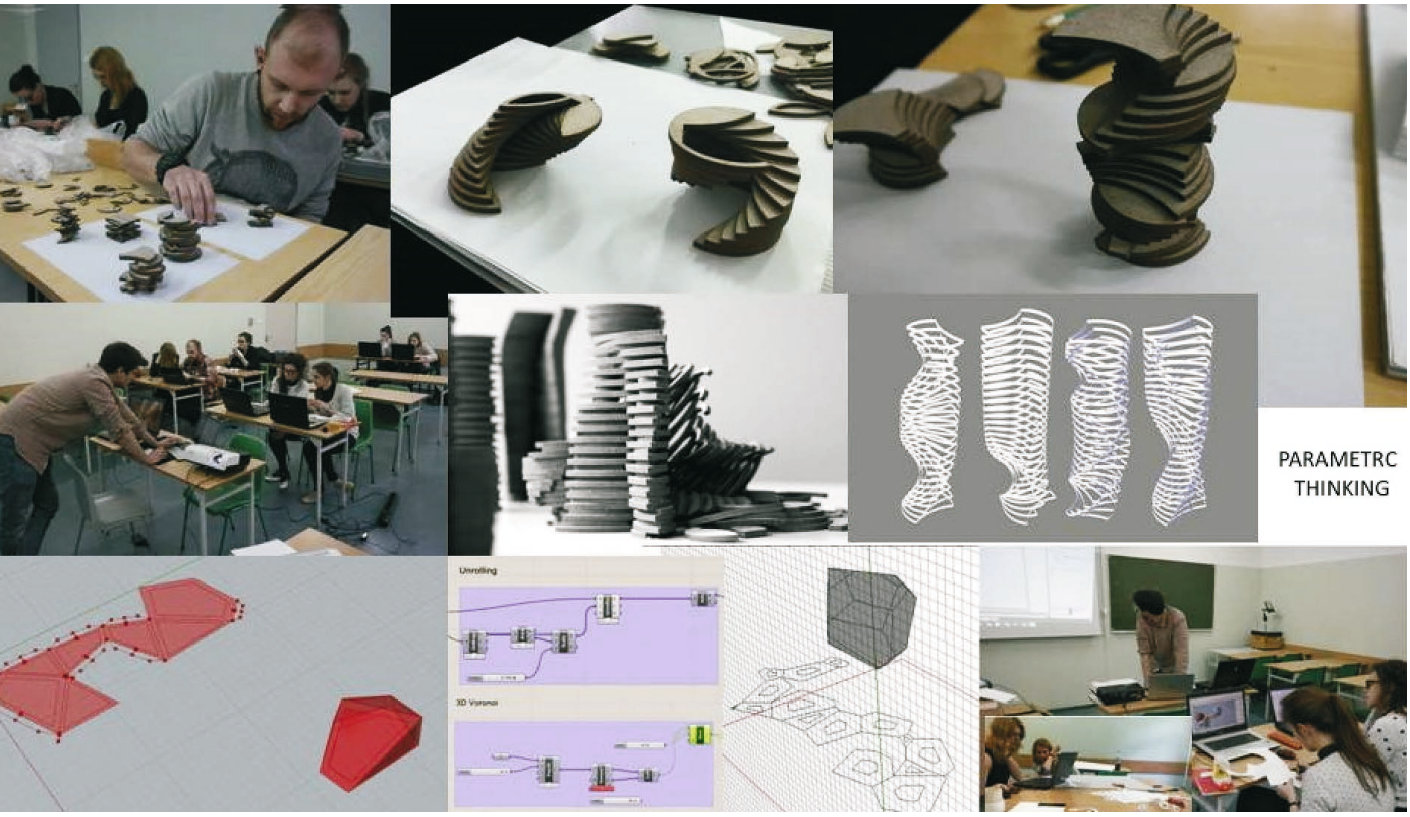


Fig. 12. Parametric Design Studio, Parametric Thinking Workshop; source: author's didactic material

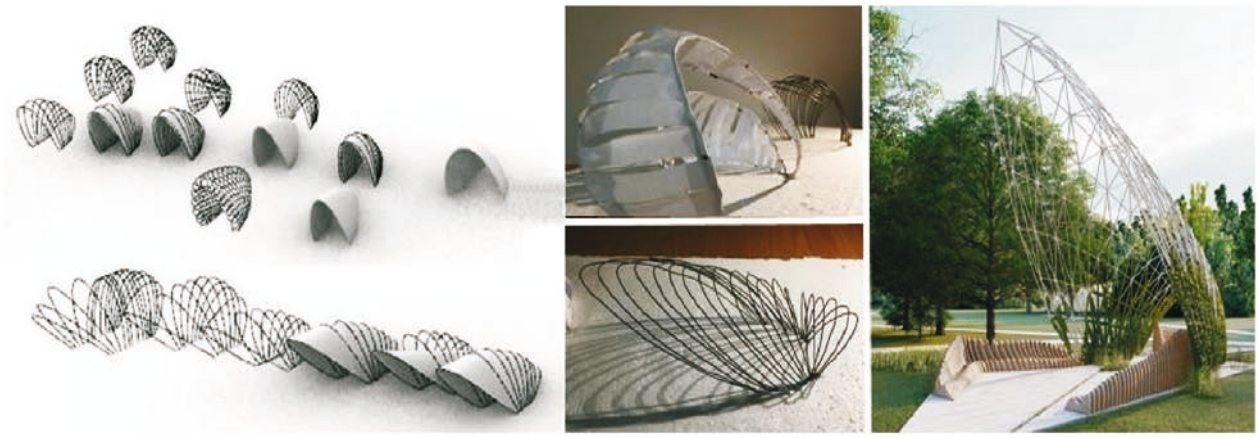


Fig. 13. Designing a parametric pavilion in the public space: digital and physical models by student Aleksandra Smal

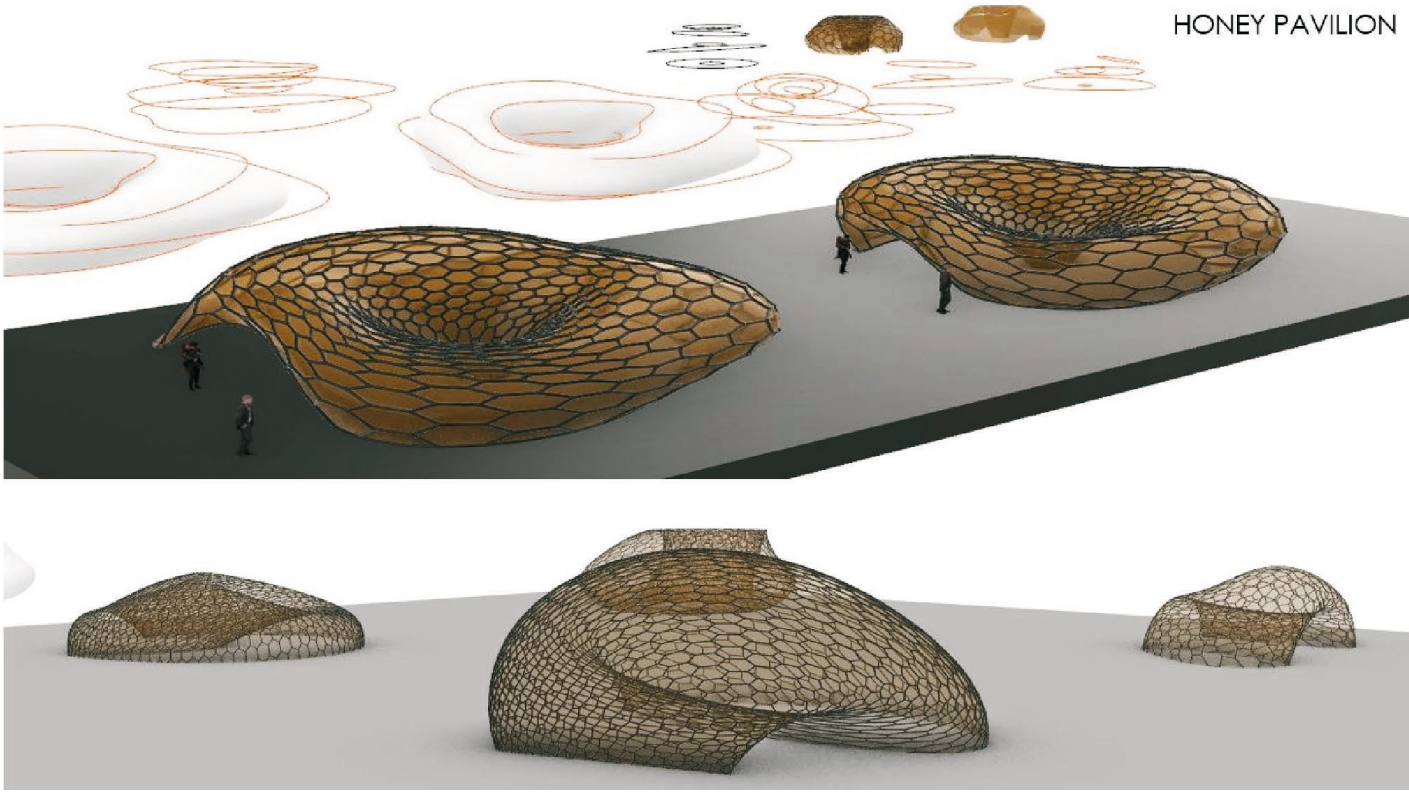


Fig. 14. In the search of form and surface (student Maciej Nestorowicz)

each piece in the frame. Through development of computation and prototyping a simplified way of assembly and fixing techniques, using notches, was identified. This also allowed the team to achieve flush edges at the joints, as the depth of each notch was half the width of a piece [Koralevic, Parlac, 2015].

This course provides an introduction to complex 3d modelling and algorithmic design methodologies. Rhinoceros3D is a powerful 3D Nurbs-based modelling program with incredible precision and customi-zability that is increasingly become industry standard in many design fields. Participants will gain a practical understanding of basic geometry and more complex topological surfaces.

Fig. 15. Honey Pavilion by student Maciej Nesterowicz. The final 3D render.

Following 3D renders present the effects of the teaching program based on the same research-by-design method as Interactive Design.

The focus of this Parametric Design Studio is on how to use Rhino3D with Grasshopper efficiently when modelling basic and more organic and fluid geometries, how to start using Grasshopper from scratch with a beginner-friendly learning approach, and how to understand the logic behind parametric modelling. The parametric designs present general knowledge about interactivity, NURBS programming and is followed by the explanation of design process [Figure 13-16]. The results introduce chosen projects prepared by the students from both, interactive and parametric design studios.

8. DISCUSSION

The recent decades more than anything else have revealed the ambivalence not only of the articulated expectations about the digital public sphere but also of the 'real' development itself. This thematic issue of Media and Communication highlights some of the criticalities and specificities of the evolution of the public sphere during this period where digital communication ecosystems are becoming increasingly central. The different articles offer a polyphonic perspective and thus contribute significantly to the debate on the transformations of the public sphere, which—in the time of the Covid-19 pandemic – dramatically affect the very essence of our democracy. Today the range of the interactive and parametric studies and designs include the analysis of the new interactive design trends observed in public spaces. Urban interiors keep evolving both in definition and meaning. Early theoretical analysis of public urban spaces was based mainly on the research on a human visual perception and overall esthetics. They related to the need to combine art, architecture and city into one. However, it is Camillo Sitte first who brought up the aesthetics of public spaces and malleable approach to city design and is being considered the pioneer of the urban analysis. Following the development of this area of art it is worth mentioning that the early theories either ruled out or diminished the human factor and the role of consumers in a particular space. a rapid increase in this field can only be observed in the span of the recent decades, during which the urban manifestos started including concepts like "place-making" or social participation in creation of urban *genius loci*. The urban tissue undergoes changes through active actions of designers cooperating with local citizens as well as bypassers. The interaction between human and space which allows the former to manipulate the latter is becoming more significant. The examples of such a shift include passive interactions like 3D mapping or design means actively engaging person, which are a core of this paper. In 2004, columnist George Lawton, in an article titled "Machine-to-machine tech-

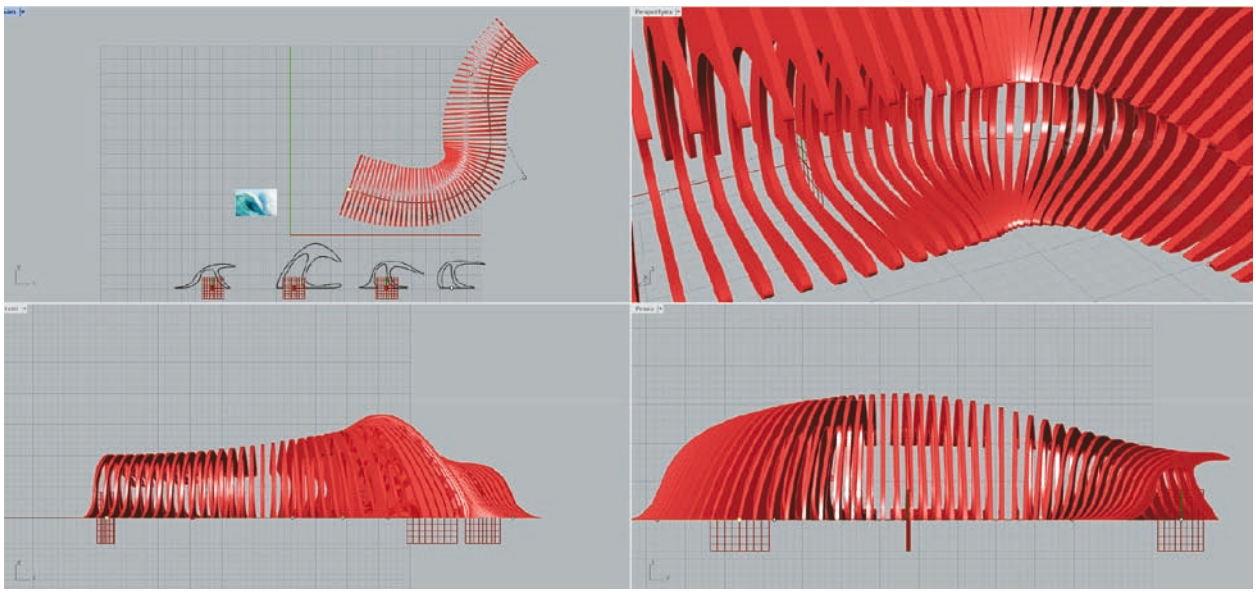


Fig. 16. Wave Pavilion by student Monika Cierpiał. Inspiration of shape modeling and surface contouring and the final design render

nology gears up for growth" for Computer "magazine, writes'' that there are already more mechanical, electrical or electronic machines in the world than people, and the number of those that are interconnected is growing. According to him, the idea of M2M is based on the premise that "machines are more valuable if they are networked, and a network is more valuable the more machines connected in it." In terms of sensing the place itself, quoting McCullough - interaction design must serve the basic human need for getting into place. Like architecture, and increasingly as a part of architecture, interaction design affects how each of us inhabits the physical world [McCullough, 2004]. Digital media expanding the scope of influence of visual arts has opened new research areas on the psychology of perception.

In digital design, virtual space appears as an inevitable medium for articulating the design space. Virtual architecture is defined by the digital environment in which the design is created. The database, corresponds to the digital space of design-support programs. The virtual potential of architecture should be considered together with the digital environment of the project. The digital design space is defined by computer, mathematical and algorithmic logic. Implications of digital formats by functions and polynomials have yielded applications with expanded spatial capabilities. For example, NURBS parametric curve geometry allows accurate modelling, without analytical approximations, of arbitrary curves and surfaces, with a single set of commands [Januszkiewicz, 2012]. Digital space, having introduced a base time organized interactively and dynamically, can trigger such spatial operations as evolution, transformation, hybridization and mutation. The extension of animation takes advantage of the properties of compound time, which can be viewed as nonlinear, differently understood from the time of the fourth dimension of architecture animation. The nonlinear time reading system is the opposite of kinematic modulation. It is being used increasingly in the formation and representation of architecture and in technology.

The rapid development of computerization after 1990, resulting from the creation of the Internet, allowed for the progressive implementation of interactive surfaces and structural elements into all architectural spaces. Simultaneous progress in the design of virtual spaces has led to the creation of computer-aided tools to support such environments as the creation of computer games, web applications or even special effects in films. Thus, designers brought about the inception of immersive surroundings, which lead to the perception of an artificially created, illusory environment as a real one through the use of technologies such as, for example, CAVE (Cave Automatic Virtual Environment) or HMD (Head-mounted display) [Pazdur-Czarnowska, Yatsiuk, 2021].

Currently available sensors can detect almost anything, from complex gestures to CO_2 emissions and hair color. The interconnected digital world means that, in addition to sensory perception, data sets ranging from Internet usage to traffic patterns and crowd behavior can be the drivers of interactive buildings or environments. The technologies required are simple enough to enable designers who are not computer experts to prototype their ideas in an accessible way and communicate design intent. New developments and ideas, driven by applications, will quickly support advanced thinking in the discipline; however, it is important to understand that their foundations have been in place for some time, going back almost thirty years. The growth and impact of digital technologies in the world of connected networks has led to an explosion of current exploration with the fundamentals of interaction design in architecture. The Internet of Things (IoT) has fairly quickly begun to define the technological context of interactive design as a holistic element of connected networks and environments that affects essentially everything from graphics to objects, buildings and cities. The term "Internet of Things" is first used in 1999 by Kevin Ashton, director of the Auto-ID Center, who, along with David Brock and Sanjay Sarma, applied RFID (Radio – Frequency Identification) technology to identify individual devices connected within a single network. A year later, LG launches the first Internet-connected refrigerator, which at the time was not received favorably by potential customers due to its price and, in their view, unnecessary features [Suresh, Daniel, Parthasarathy, Aswathy, 2014].

CONCLUSIONS

The emergence of digital media generated a whole array of euphoric expectations regarding the reconfiguration of the public sphere: one points to an emanating network society characterized by a dehierarchized structure [Castells, 2011], and by a new autonomy from the 'institutional' power [Castells, 2015]. Others emphasize the prospect of public debates being more inclusive, especially of those segments of the population that had been previously marginalized. The prospect of using innovative didactic programmes in research or teaching projects is currently one of the most desirable postulates of the academic world. Crossing disciplines' methodological and epistemological boundaries is a proven practice that yields

revolutionary results in the conducted research or didactic process. The students, coming from the Faculty of Architecture and Interior Design, are acquainted with the premise and the design processes of interactive environment in the public space and parametric modelling. It has become essential to indicate multimedia techniques currently used in the design of existing urban spaces, such as Lighting Control Engines used on facades, sensory systems reacting to human exposition, DMX control software, timer activated networks and others. Wide area of issues related to computer technologies and the brand-new tool in the form of AI required deep research during the early stages of the design process. Digital out-of-home media and pervasive new technologies are bringing the internet experience into public spaces and stepping up the pace with which brands and products, as well as their virtual representations, penetrate urban environments. This article explores the current phenomenon of pervasive advertising and its underlying perceptions and puts forward a typology for describing a range of applications for the emerging media infrastructure. It argues that the critical dimensions comprise the way in which pervasive advertising and creatives exploit both physical and social contexts by increasingly relying on the effects of illumination, temporality and spatiality [De Blasio *et al*, 2020].

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CONFLICTS OF INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this article.

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