Paulo Fonseca de Campos
Faculty of Architecture and
Urbanism at University of São Paulo

Daniella Naomi Yamana
Faculty of Architecture and
Urbanism at University of São Paulo

Daniel de Souza Gonçalves
Faculty of Architecture and
Urbanism at University of São Paulo

Resilient Society, Resilient Design

Digital Fabrication Technologies and the Concept of Place

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Big cities in developing countries face many obstacles related to the built environment when confronted by socio-economic inequalities, which is reflected in the uneven access to basic living infrastructure, such as sanitation and housing. In the light of new approaches to traditional materials and building techniques, the aim of this article is to investigate the use of digital fabrication tools in the production of lightweight precast systems for the social production of habitat in Brazil.

To develop a clear assessment of the possibilities created by these technological alternatives, two academic applied researches are considered as case studies: a modular sidewalk for rain water drainage and a precast building system for housing. The main goal here is to discuss the role of high-tech solutions — such as digital fabrication tools and lightweight precast systems — in promoting urban, community-driven, upgrading initiatives in precarious settlements, accompanied by local economic development.

Introduction

The application of design on an urban scale is of growing importance in environments in an increasingly connected world, where city production takes place amidst complex social, local and at the same time global relationships, offering project opportunities of great relevance. Faced with sophisticated production and consumption relations that take place in the contemporary city, the city itself has become a place of high sociocultural power and intensity and demands design solutions capable of establishing and strengthening bonds of belonging and identity between the inhabitants and the places they occupy in different urban contexts.

The reflection proposed here is based on the implementation of urban intervention projects aimed at improving the social habitat in cities like São Paulo, involving the following key ideas:

The use of digital manufacturing as a disruptive technology, not only from the point of view of its innovative technical possibilities, but, above all, in terms of fostering new social dynamics of production and consumption.

The use of ferrocement or high-performance micro concrete as a technological alternative to develop the lightweight prefabrication and new fields of application, particularly aimed at urban infrastructure and social housing.

The employment of industrialised architecture as a technological alternative for the development of solutions particularly focused on infrastructure and urban habitat.

The applicability of technologies developed within the research project "Resilient Society, Resilient Design" that has been promoted for nearly six years at FAU–USP (Faculty of Architecture and Urbanism at University of São Paulo), through its territorialization in local contexts and on local scales, according to a vision that brings these processes to concepts involving participatory practices in design, such as co-creation and co-governance.

The promotion of physical interventions accompanied by local socio-economic development, promoting, whenever possible, a popular and solidarity economy through technology transfer and collective entrepreneurship.

In this last vector, in particular, one can even refer back to the existing tradition of the social production of habitat in Brazil and Latin America, where the user acquires the status of protagonist and design agent in participatory processes.

In a recent series of articles by Nikos Salingaros et al., the authors propose a reflection based on a system of good practices for social housing, grounded on experience and suitable for general situations.[1] To this end, examples of housing solutions appropriate to the Latin American context and aimed at long-term sustainability are presented in order to lead residents to take root in their built environment. The authors refer in

1 Nikos Salingaros et al., "Socially-Organized Housing: Design That Establishes Emotional Ownership," *Archdaily* (March 2019), https://www.archdaily.com/913586/socially-organized-housing-design-that-establishes-emotional-ownership (accessed in 12/05/2022).

particular to the work of Christopher Alexander, highlighting participation as a basic principle.[2]

In his long career as an architect and urban planner, Christopher Alexander was commissioned to plan and build social housing for various governments. Often, opposing the design requirements established by the government agency that had hired him, Alexander insisted on user participation as the only way to produce built forms that were "loved" by their occupants.[3] In his projects, it was essential to involve future residents while planning their living space, the configuration of accesses and common areas, which did not always please the authorities, who feared seriously weakening their control over urban guidelines.

Contextualization

According to a survey carried out by the National Sanitation Information System, only 52.4% of the Brazilian population is served by sewage collection systems, meaning that 100 million Brazilians do not have access to this service.[4] This data is only a sample of what constitutes housing typologies in areas occupied by low-income populations, more specifically, slums. In Brazil, those are, as a rule, extremely unfavourable, constituting dramatic living situations, taking into account poor sanitation conditions, water and soil contamination, epidemics, landslides and floods.

Therefore, when introducing the theme of technology in the construction of social habitat, it is necessary to clarify the difficulties that a country like Brazil has in this area and the consequent need for effective basic sanitation policies. Faced with the government's inability to offer appropriate solutions, relying solely on conservative management and building methods to intervene in precarious settlements, it is of vital importance to think about alternatives that promote improvements in quality of life for these vulnerable groups.

Within this context, the objective here is to investigate the use of technological alternatives in the improvement and reordering of irregular settlements and seek a better adapted approach to the demands of a given territory. To this end, the "Resilient Society, Resilient Design" research project developed by DIGI-FAB research group (digital fabrication technologies applied to contemporary production of design and architecture) from FAU–USP is presented, exemplifying the use of digital manufacturing processes in the production of high-performance ferrocement building components for housing and infrastructure.

This paper, rather than simply narrating ongoing experiences or describing technologies that can be transferred and used in the construction of social habitat, has as its main concern the discussion of ways in which a guarantee of healthy and dignified living conditions can be granted to marginalised communities considering, however, the need for rationalisation of public resources allocated to social housing and basic infrastructure.

2 Ibid.

3 Christopher Alexander, *The Nature of Order: Books One to Four* (Berkeley, CA: Center for Environmental Structure, 2001-2005), quoted in Salingaros, "Socially-Organized Housing."

4 SNIS—National Sanitation Information System, *Diagnóstico dos Serviços de Água e Esgotos – 2017 [Diagnosis of water and sewage services – 2017]* (Brasília: Ministério do Desenvolvimento Regional, 2019), 27.

Digital Fabrication Technologies

As already mentioned, this paper addresses an applied research dedicated to developing building systems for urban interventions, specifically in precarious urban settlements located in the lowlands or floodable areas. For this purpose, it is focused on developing lightweight prefabricated components made with high-performance ferrocement and moulded in formwork produced with the aid of digital manufacturing, designed for infrastructure (sanitation and rainwater drainage) and social housing building elements. As the research deals with areas of economic and social vulnerability, another main purpose of this research is to promote urban improvements alongside economic development, through popular economy ideals such as self-management and community production.

Nowadays, the term digital fabrication encompasses different manufacturing processes that use computer numerical control (CNC) equipment or machines, which can be classified as additive, subtractive or conformative. Additive manufacturing processes, commonly known as 3D printing, occur with layer-by-layer deposition of a base material, which can be liquid, solid or powder. In subtractive processes, the final object is obtained by removing parts of a base material, in laser cutting or milling machines. Lastly, in manufacturing by conformation methods, the base material is mechanically deformed.

Regardless of which process was chosen, the logic behind digital fabrication remains the same: a virtual model is generated by computer (CAD—computer aided design) into which are introduced the parameters pertinent to its manufacturing (CAM—computer aided manufacturing). Then, the program generates a sequence of numerical instructions, named G-code, which commands the computer-controlled equipment (CNC) so that it performs all the tasks necessary to fabricate a given object.[5]

In other words, digital fabrication logic follows a file-to-factory concept, where designs are developed on digital platforms and executed with the aid of CNC machines. The fluidity of this production cycle is possible due to integrated CAD and CAM software, making design and production inseparable within the process. Also, in contrast to machines used in mass production lines, CNC machines are dimensionless and reprogrammable, allowing flexibilization of manufacturing operations. Custom objects can be produced from one to very few units without cost increase, which enables mass customization.

Since the early 1990s, architects have been testing digital fabrication limits in the field of civil construction, seeking to explore complex geometries that would be extremely hard to produce by conventional methods. However, the use of digital manufacturing processes seems to be restricted to monumental buildings, when there are no cost limits, like Olympic stadiums, museums or corporate headquarters. This trend might indicate that digital technologies are not yet available outside the restricted niche of high-tech architecture.[6]

5 Paulo Eduardo Fonseca de Campos and Eduardo Ignacio Lopes, “A fabricação digital aplicada à construção industrializada: estado da arte e perspectivas de desenvolvimento” [Digital manufacturing applied to industrialised construction: state-of-the-art and development perspectives], *Revista Concreto & Construção*, no. 85 (January/March 2017): 22–29.

6 Márcio Minto Fabricio, “Industrialização das construções: revisão e atualização de conceitos” [Industrialization of construction: revision and updating of concepts], *Revista do Programa de Pós-Graduação em Arquitetura e Urbanismo da FAUUSP*, no. 20 (June 2013): 228–248.

Ferrocement Technology and Lightweight Precast Systems

Since the 1980s in Brazil and Latin America, it has been possible to observe a trend towards the development of increasingly lighter building systems and components, providing greater technological density to these products and guidelines for a promising future in the precast concrete segment.

This became possible as parameters were established for the application of the so-called "high-performance concrete" in this area of civil construction, particularly during the 1990s, with the aim of increasing the diversification of products offered to the industrial, commercial and housing markets, an important factor to gain competitiveness for the sector.[7]

When it comes specifically to the evolution of lightweight prefabrication in concrete in Brazil, it is necessary to recognize the fundamental role played by João Filgueiras Lima, known by the nickname Lelé, a modernist architect with a large collection of projects using this building technology.

Since the beginning of his work as an architect in the 1950s, Lelé has developed unique experiences using prefabrication in architecture production. In an interview with the Brazilian architecture website Vitruvius, when asked about his vision about traditional construction processes, Lelé highlighted his intention to produce prefabricated parts using affordable technologies, so populations with specific demands could, assisted by a professional architect, be protagonists in the production process.[8]

> What we argue is precisely the dissemination of a building system that would almost allow self-construction. It's like Lego that we assemble from these components, in a simple way, that could be learned by a low qualified workforce, and fast.[9]

From this thought, in 1979 Lelé developed projects for lightweight prefabricated systems for infrastructure, in slum urbanisation interventions in the city of Salvador, Bahia, promoted by RENURB – *Companhia de Renovação Urbana de Salvador* (Salvador Urban Renovation Company).[10]

The flood drainage project (Figure 1) used ferrocement as material to create lightweight prefabricated thin-wall and high-strength elements. Lelé gives a good definition of the technique when asked about its extensive use over the years of his production:

> Ferrocement is nothing new; it was explored, and very well handled, by the French engineer Joseph-Louis Lambot two hundred years ago. There are even experiments made with boats at that time. In the French Construction Museum there is such

7 Campos and Lopes, "A fabricação digital."
8 João Filgueiras Lima [Lelé], "Technique without giving up beauty: notes on being an architect," accessed May 27, 2022, https://www.vitruvius.com.br/revistas/read/entrevista/18.073/6891?page=2
9 Ibid.
10 Ana Gabriella Lima Guimarães, "A obra de João Filgueiras Lima no contexto da cultura arquitetônica contemporânea [The work of João Filgueiras Lima in the context of contemporary architectural culture]" (PhD thesis, FAU–USP, 2010).

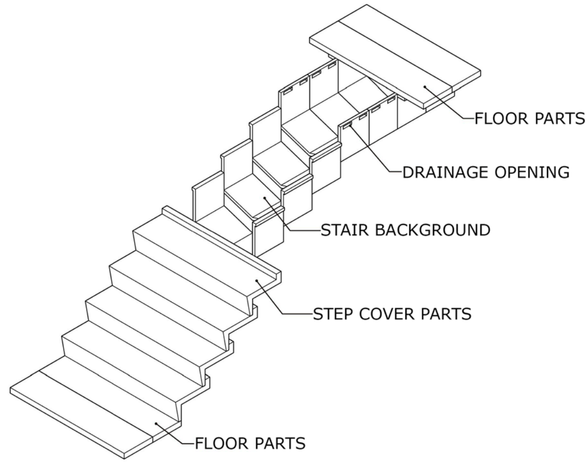


Fig. 1 João Filgueiras Lima (Lelé), Lelé's flood drainage design in RENURB, Salvador, 1980 (J.F. Lima).[11]

equipment that was rescued from the bottom of a lake, and that perfectly expresses all the technical quality of the material. In the 1940s, Pier Luigi Nervi used ferrocement, which he called 'ferrocemento.' There are some nuances between this product, which was explored by Lambot, then by Nervi, and what we practice now. In fact, in these two experiments, the ferrocement had a much higher steel reinforcement content than what we use today, even as a matter of cost.[12]

Ferrocement or reinforced mortar, as defined by Lelé, represented a major technological advance in the production of precast elements, even though it was a partially artisanal technique. Lelé's experiences resulted in an increase in the quality of the works with popular participation, monitoring of the project and execution. The transitional schools in Abadiânia (Goiás), developed in 1982, are examples of projects in which popular participation and training of local labour were fundamental for the quality of the project. Metal moulds were used for the production of ferrocement elements, exquisitely dispensing with the use of any specific machinery for displacement and assembly.[13] The result of this experience was the construction of local schools by the population's own hands, which, now trained and aware of the process, can replicate it in new actions for local demands.

In addition to these early experiences, in the 1990s Lelé also developed large-scale projects with prefabricated systems (Figures 2), mainly in his work at the Technology Centre of the SARAH Network (CTRS),

11 Guimarães, "A obra de João Filgueiras Lima."
12 Lelé, "Technique without giving up beauty."
13 Cristina Câncio Trigo, "Pré-fabricados em argamassa armada: material, técnica e desenho de componentes desenvolvidos por Lelé" (Masters thesis, FAU-USP, 2009).

14 Trigo, “Pré-fabricados em argamassa armada.”
15 Campos and Lopes, “A fabricação digital.”
16 Ibid.
17 SARAH Rehabilitation Hospitals Network, “Conheça a Rede SARAH de Hospitais de Reabilitação” [Discover the SARAH Network of Rehabilitation Hospitals], SARAH Network, accessed May 2022, https://www.sarah.br/a-rede-SARAH/nossas-unidades/

where he explored prefabrication with more resources for the construction and maintenance of the SARAH Rehabilitation Hospitals Network.[14] In this way, Lelé’s production was marked by the development of new prefabrication technologies, which was presented through his projects as a response to the most diverse social demands.

Ferrocement or reinforced mortar has technological foundations developed in Brazil over six decades that enabled it to become a high-performance micro concrete in the last 20 years—either because of its properties of high mechanical resistance to compression and low porosity, or because of the economic possibilities for its application.[15] They are based on the initial experiences with the “ferrocemento” of the Italian structural engineer Pier Luigi Nervi. In the São Carlos School of Engineering at the University of São Paulo (EESC—USP), ferrocement technology has been adapted to Brazilian conditions. Since the 1960s, the ‘São Carlos Group’, the research group formed for the study and development of ferrocement or reinforced mortar, made decisive steps in optimising this technology and its consequent consolidation.[16]

However, in this article, above all, we seek to present the recent advances in research that made possible to unite ferrocement or reinforced mortar developed over 60 years in Brazil to new digital manufacturing technologies, in order to contribute to establishing the foundations for their practical application in Brazil and other similar contexts, as described below.

Fig. 2 SARAH Rehabilitation Hospitals Network — SARAH Macapá and SARAH Fortaleza.[17]

Digital Fabrication Technologies and the Concept of Place

Digital manufacturing is the result of a continuous process of inserting digital technologies not only into products, but also into industrial automation processes throughout the second half of the twentieth century, and now into the twenty-first century.

Innovations related to the introduction of these technologies have been presented as disruptive, as they may represent an opportunity for paradigm breakdown, which will have a significant impact on the market and the future economic activity of companies, as well as on the basis of present social structure. It is also an answer to the exhaustion of a productive cycle originally based on classic Fordist standards, boiling down to the announcement of digital manufacturing as the trigger of the Third Industrial Revolution.

On the other hand, under the label of maker culture, there is the idea that, based on the concept of do-it-yourself (DIY), a kind of rebirth of the counterculture is happening, linked to anti-system social movements which broke out in the 1960s, especially in the USA, and are now linked to the emergence of the new digital manufacturing technologies. The movement would be able to overcome old contradictions of capitalist society, such as the exploitation and alienation of labour, while enjoying the benefits of digital technologies in design, production, circulation and consumption of goods.

Gershenfeld, who in his iconic book *FAB: The coming revolution on your desktop – From personal computers to personal fabrication* ponders the fact that, thanks to the convergence between computing and fabrication, today it is possible to convert bits into atoms, printing objects from their images or virtual modelling.[18]

Recently, Gershenfeld adds: "Digital fabrication will allow individuals to design and produce tangible objects on demand wherever and whenever they are needed. Widespread access to these technologies will challenge traditional business models, international cooperation and education."[19]

Despite the lively enthusiasm that nurtures the expectations of Gershenfeld and the adepts of the maker movement, whose ecosystem is the worldwide network of digital fabrication laboratories known as Fab Lab, it is worth emphasising a certain technicist, uncritical and ahistorical feature that is still observed in these environments, marked by an unshakable faith in state-of-the-art technologies and little concern with reflecting on what Antunes and Braga classify as the emergence and global scale growth of "infoproletariat" or "cyberproletariat."[20] From this perspective, the information sector, which makes intensive use of new technologies and is considered one of the most dynamic and daring sectors of the contemporary economy, refers to "working conditions […] as precarious as the workers from the 19th century."[21]

18 Neil Gershenfeld, FAB*: The coming revolution on your desktop – From personal computers to personal fabrication* (Cambridge, MA: Basic Books, 2005).

19 Idem., "How to Make Almost Anything: The Digital Fabrication Revolution," *Foreign Affairs*, vol. 91, no.6 (November/December 2012): 43-57.

20 Campos and Henrique José dos Santos Dias, "A insustentável neutralidade da tecnologia: o dilema do Movimento Maker e dos Fab Labs" [The unsustainable neutrality of technology: the dilemma of Maker Movement and Fab Labs], *Revista Journal*, vol.14, n.1 (May 2018): 33–46; Ricardo Antunes and Ruy Braga, eds., *Infoproletários – degradação real do trabalho virtual* [Infoproletariat – real degradation of virtual work] (São Paulo: Boitempo Editorial, 2009).

21 Antunes and Braga, *Infoproletários*, quoted in Campos and Dias, "A insustentável neutralidade da tecnologia."

22 Campos and Dias, "A insustentável neutralidade da tecnologia."

Finally, the question posed is to grasp all new forms of labour exploitation and technology appropriation processes as problems that occur in different ways in central and peripheral countries, and so with very different characteristics and complexities. Even though the maker movement presents alternatives of interest regarding its emancipatory dimension, it is clear that it cannot be placed as a universal solution to local problems with different complexities.

In turn, to understand the existence of a popular economy, which is, by definition, self-managed, points to a possibility—to some extent due to a fracture in the hegemonic system—of using technological tools from the maker movement as dialogical mediation among different social actors, with the aim of strengthening local cultures and potentialities.[22] Therefore, it is necessary to establish, as a programmatic variable of this alternative, the connection between technology and the territory where it is being introduced, respecting, consequently, the differences and specificities of each location. It is not by chance that the territorial question is deliberately ignored by the ideo-political model that presented itself as an alternative to the welfare state, due to globalisation that flattens the complexity of local social life.

The digital technologies of the maker movement can greatly contribute to the development of the popular economy, as a fundamental piece in social processes of emancipation. Through network formation, mediated by rapid communication of problems and solutions, the digital prototyping of three-dimensional physical models can be an extremely useful instrument, since it can foster information flow and technology transference, facilitated by the web. CNC machines enable local prototyping and production of objects designed in different places.

The remarkable growth in the appropriation of these technologies can be illustrated by Brazil's first Fab Lab implantation in 2011: The Fab Lab SP in the FAU–USP, in São Paulo. Today, eleven years later, the country already has more than one hundred laboratories registered and spread throughout national territory (according to the platform fablabs.io).

Since 2015, the city of São Paulo has also the largest public network of digital fabrication laboratories in the world: the municipal network Fab Lab Livre SP (Free Fab Lab SP). There are 13 laboratories currently implemented, many of them located in peripheral areas. These laboratories offer various workshops, accessible to any citizen who wishes to participate, and support the execution of several projects developed by civil society with technical assistance. For this reason, the experience of these fab labs, as a public facility, has shown more coherence and effectiveness in the face of problems discussed here. It is interesting to note how democratisation of access to advanced technologies present in these laboratories came to be seen as an acquired social right.

Municipal laboratories also have potential to become local articulators of public administration, since they can group different spheres of government when serving citizens, establishing new centralities in peripheral areas and mutually reinforcing actions of different fields, such as health, education, culture, science and technology.

As a consequence, since the inauguration of Fab Lab Livre SP municipal network, these public laboratories have been functioning as platforms for social projects that seek to solve local problems, especially the ones located in peripheral communities of São Paulo. As a case study, we will focus on the project "Resilient Society, Resilient Design", which assembles several actors from academia, public institutions and within the local community to offer technical training workshops for residents of precarious settlements in São Paulo.

The project aims, by means of training people in socially vulnerable situations, to create an autonomous production cycle of precast lightweight systems and components to promote urban improvements along with economic development of the region.

In this sense, it is essential to rethink the role of technology in the context of peripheral countries and understand how digital fabrication tools can assist social processes in solving problems that are largely bound to the territory and the local scale.

Case Study

Even before the global economic crisis caused by the Covid-19 pandemic, Brazil's accelerated impoverishment drove several families from large urban centres to precarious living conditions without basic infrastructure such as sanitation. This phenomenon can be observed especially in peripheral areas of major cities like São Paulo, where in recent years there has been an increase in the amount of informal settlements and slums. In neighbourhoods located near the banks of the Tietê river, the lack of basic infrastructure is aggravated by major floods during the rainy season, which implies an urban, social and environmental degradation of this territory.

One of the most endangered areas near the Tietê river is Jardim Pantanal, a neighbourhood that, being in an environmental protection zone, does not have access to regular public services nor basic sanitation. In addition, the permanent residence of the population and their sense of belonging is often threatened by fear of expropriation, since land ownership is an unresolved issue due to environmental protection laws.

Despite the constant threat of expropriation, the local population is known for joining forces to carry out urban upgrading initiatives in so-called "*mutirões*" or mutual aid initiatives. For instance, one "*mutirão*" was performed to lay out pipelines for distributing drinking water inside the neighbourhood. However, since most of the streets in Jardim Pantanal are neither asphalted nor paved, the drinking water pipelines become uncovered and damaged over time, causing water contamination (Figures 3).

Fig. 3 [opposite page] Manima Street in Jardim Pantanal neighbourhood, São Paulo, 2017 (authors' photo).

As a highly organised community, Jardim Pantanal inhabitants concentrate around civil society institutions, such as AMOJAP (Association of Residents and Friends of Jardim Pantanal), whose ultimate goal is to achieve land regularisation for the local population. With the aim of carrying out urban upgrading projects to improve the quality of life of Pantanal's residents, the DIGI–FAB (digital fabrication technologies for the production of contemporary design and architecture) research group from FAU–USP, under the coordination of Prof. Paulo Fonseca de Campos, initiated the "Resilient Society, Resilient Design" research project alongside AMOJAP. Its objective was to create two building systems for the urbanisation of precarious settlements: one modular sidewalk for rainwater drainage and another for popular housing.

Both building systems were designed as lightweight prefabricated ferrocement components, an easily replicable and low-cost technology, so that they could be produced by the community itself. The proposed idea was to implement a small production unit in Jardim Pantanal that doubled as a teaching centre, where local residents could learn how to execute lightweight prefabrication and use it to improve their own neighbourhood. Bearing in mind that public investment in this region is scarce, this kind of enterprise could be sponsored by the government as a viable alternative to large construction companies.

To carry out the "Resilient Society, Resilient Design" project, the methodology adopted was based on a practical approach. The DIGI–FAB research group held weekly meetings at Fab Lab SP (FAU–USP) to design and experiment with ways to incorporate digital manufacturing tools in the formwork process so as to enable technology transfer of the process as a whole. Reduced-scale and life-size models were prototyped using CNC drilling machines and laser cutters to test assembly process, fitting and material resistance.

According to the initial premises of the project, by incorporating digital fabrication into the production process of lightweight prefabricated elements, it would be possible to rely on the precision and speed of CNC machines instead of traditional carpentry tools.

One methodological aspect that should be emphasized here is the participatory process of the AMOJAP team. Periodical visits to Fab Lab SP were scheduled so AMOJAP members could see the prototypes and machinery in action, as well as input suggestions to improve the initial design. Additionally, DIGI–FAB researchers would often visit Jardim Pantanal to assess and discuss local issues regarding floods, public spaces, housing and urban infrastructure.

This approach was instigated by the already mentioned implementation of 13 public Fab Labs in the city of São Paulo, the Fab Lab Livre SP Network (Figure 4), as a social and digital inclusion initiative. Thus, in addition to producing lightweight prefabricated elements, residents of Jardim Pantanal would be able to assemble their own wooden formwork in nearby public Fab Labs, as well as share the digital files with other communities who wish to do the same.

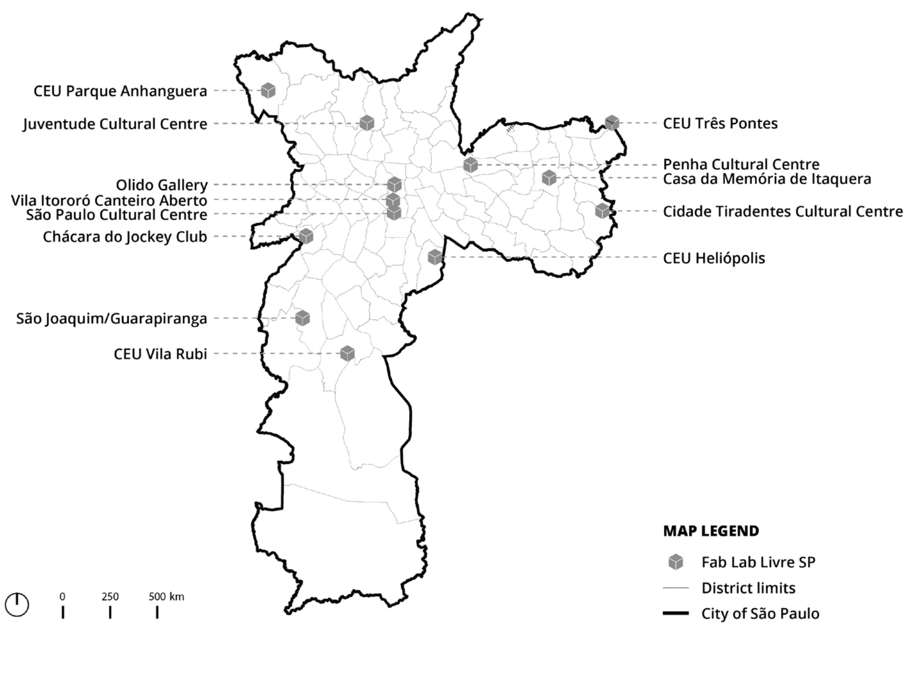


Fig. 4 Fab Lab Livre SP Network, São Paulo, 2022 (elaborated by the authors).

Therefore, the activities undertaken at Fab Lab SP (FAU–USP) and at the public Fab Labs Livres SP in the East Zone of São Paulo (CEU Três Pontes, Itaquera and Cidade Tiradentes) would develop a complementary type of research, focused on digital modelling and fabrication tools. It is believed that, in the long run, this link with Fab Labs could encourage new community projects and partnerships with university research groups.
In this context, the university can act in convergence with other local public policies, integrating them with civil society initiatives committed to social welfare and promoting digital fabrication as a tool for innovation through social transformation.

Modular Sidewalk for Rainwater Drainage

The first building system proposed by DIGI–FAB research group was a prefabricated modular sidewalk designed to drain and correctly dispose of rainwater, as a means of surface water drainage. Complementarily, it also performs as an urban reordering instrument, defining and separating circulation flows in public spaces. Basically, the building system consists of two main components: the gallery, a prefabricated element made of high-performance ferrocement; and the sidewalk, made of conventional reinforced concrete (Figures 5).

In addition to rainwater management, the modular sidewalk system can house urban infrastructure pipelines, doubling as a service

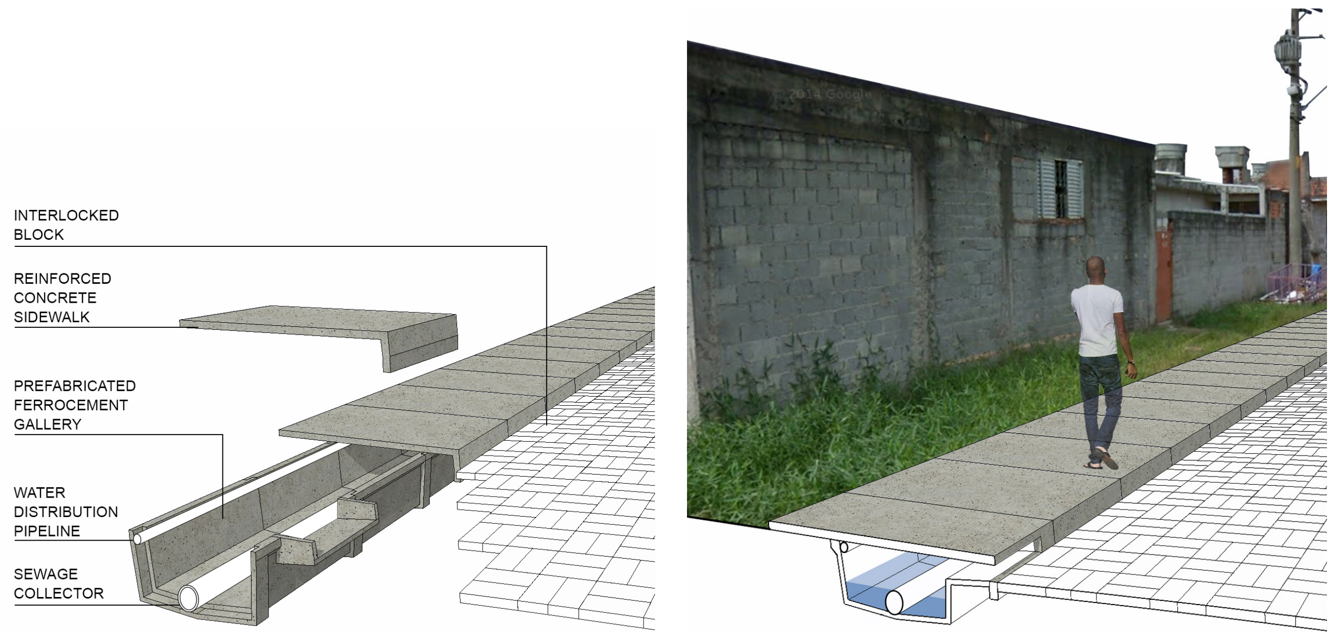


Fig. 5 Modular sidewalk building system components (left) and implementation (right), São Paulo, 2017 (elaborated by the authors).

23 Fonseca de Campos, *Microconcreto de alto desempeño: la tecnología del MicroCAD aplicada en la construcción del hábitat social [High-performance microconcrete: the microCAD technology applied in the construction of social habitat]*, (São Paulo: Mandarim, 2013).

gallery. Due to the lack of basic sanitation in Jardim Pantanal, this use is of vital importance considering the public health agenda, as it protects water distribution pipelines and accommodates a sewage removal network. Thereby, in addition to avoiding drinking water contamination, it is possible to remove all waste water discharge that is currently being disposed of near the population.

This approach was based on a previous project called "Aceras Drenantes" (Drainage Sidewalks), formulated in Uruguay by Prof. Paulo Fonseca de Campos, in 2006 (Figures 6). Conceived within the Irregular Settlement Integration Programme (PIAI), its main goal was to create a social programme associated with productive ventures that could be managed by the residents of a peripheral community.[23] During the Uruguay experience, although there was no continuation of the project, a prototype of the sidewalk module was designed and executed on a 1:1 scale.

Recognizing its technical potential and social reach, DIGI–FAB research group remodelled the 'Aceras Drenantes' project to incorporate digital fabrication processes as a way to disseminate high-tech tools in architecture and construction. The first step was to adapt the original formwork design in traditional carpentry as a digital model to be executed by a CNC milling machine. In Brazil it is traditional to use wooden formwork for reinforced concrete, therefore 18 mm-thick marine plywood was adopted as the base material as it has great structural resistance and durability.

The practical research was carried out in FAU–USP's Fab Lab SP, where several scale models and prototypes were developed and presented to AMOJAP representatives, resulting in a 1:1 prototype made of marine plywood (Figures 7).

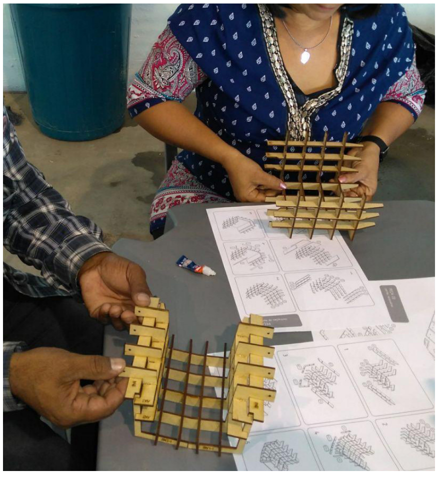
To further the discussion and participation of Jardim Pantanal residents, a local workshop was organised to test the user experience of assembling the proposed formwork using a set of instructions and laser cut small-scale models (Figures 8). The place chosen for the workshop was intentionally a site near the Tietê river, a piece of land which local children use for recreational activities. This site was indicated by AMOJAP as a possible location for the small production unit, so the workshop was also an opportunity to associate the project with the place.

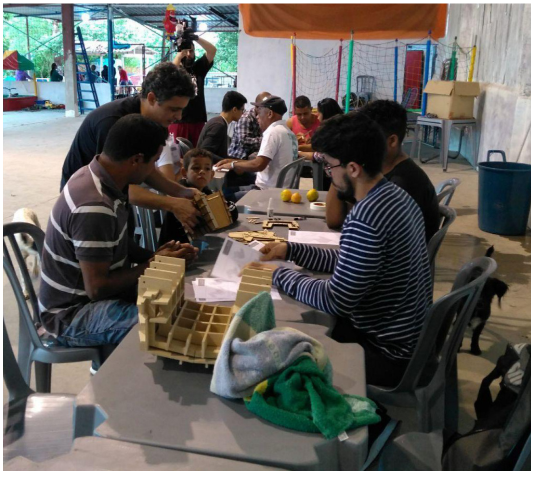
[opposite page]

Fig. 6 "Aceras Drenantes" (Drainage Sidewalks) 1:1 prototype, Uruguay, 2006 (Paulo Fonseca de Campos' photo).

Fig. 7 1:1 scale prototype of the plywood formwork in Fab Lab SP, São Paulo, 2017 (authors' photo).

Fig. 8 Workshop in Jardim Pantanal with local residents, São Paulo, 2018 (authors' photo).





24 Amanda de Souza da Silva, "Jardim Pantanal: atores e interesses, desalento e esperança [Jardim Pantanal: actors and interests, discouragement and hope]" (Masters Thesis., EACHUSP, 2016), 17–20.

25 Mutual Aid Housing Cooperative action that took place in Vila Nova Cachoeirinha neighbourhood, São Paulo.

Precast Building System for Housing

Jardim Pantanal neighbourhood, as already mentioned, suffers from major floods during the rainy season which, in the most severe cases, could lead to partial or complete destruction of houses.[24] Although they are not frequent, these events aggravate local residents' quality of life and may affect the health and financial stability of these families.

Bearing in mind their aspiration for permanence and a consolidated life, the DIGI–FAB research group suggested the development of a building system for popular housing units that offered a safe and habitable level during floods by raising the ground floor. This proposal was based on previous well-known examples of settlements that coexist with water, such as riverside villages in the Amazon river, stilt houses in mangroves near the coast of São Paulo or wetlands in the southern region of the United States.

For this purpose, the housing unit model "Housing Prototype One" (Figure 9), originally built in the "Mutirão Cachoeirinha Leste" ("Cachoeirinha" Mutual Aid Housing Cooperative), was used as a reference for structure and layout.[25] The building system was developed by the Urban and Social Equipment Development Centre (CEDEC) at São Paulo Municipal Urbanisation Company (EMURB) and relies on prefabricated ferrocement profiles—beams and pillars—that are later concreted in loco. Since it is a self-supporting structure, the walls can be made from any material available, from concrete blocks to plywood. Keeping up with the proposed production logic, all formwork for prefabricated ferrocement components should be done following the same process as the previous project—3D modelling in computer software and a CNC milling machine.

Fig. 9 "Housing Prototype One" for Cachoeirinha Mutual Aid Housing Co-operative, São Paulo, 1989 (Paulo Fonseca de Campos' photo).

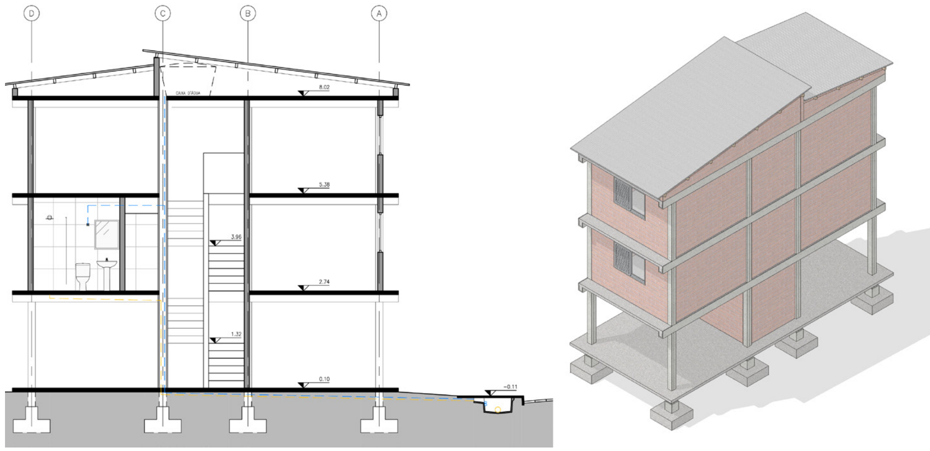


Fig. 10 Housing unit proposed (right), in the longitudinal section (left), all layout modifications are visible, São Paulo, 2017 (elaborated by the authors).

Maintaining the same structural design, adaptations were made to keep the house habitable during intense floods. One of the most important changes was elevating all wet areas — bathroom, kitchen and laundry room — to the upper floor (Figures 10). As a result, the resident family would be able to maintain its daily habits during floods, such as cooking and personal hygiene, a difficulty reported by the population of Pantanal.[26] Another significant adaptation was the introduction of a vertical circulation core in the housing unit, allowing its construction as terraced houses, a common building typology in this region.

Lastly, the ground floor should preferably house external activities only, such as a parking garage, laundry or recreation area in order to prevent water damage or material losses. However, on the condition that the resident is aware of the consequences, the ground floor could be occupied with closed rooms and even a small family business, a typical activity in irregular settlements.

Final Considerations

This article seeks to demonstrate the viable use of ferrocement lightweight prefabrication combined with the new digital manufacturing tools through applied research in the field of social habitat in Brazil. Both the use of ferrocement lightweight prefabrication and the adoption of digital manufacturing tools were based on a series of design requirements to be met.

Firstly, lightweight prefabrication within a model of community production emerges as a technology with high added value that can

26 Nayara dos Santos Egute, "Quando a água sobe: análise da capacidade adaptativa de moradores do Jardim Pantanal expostos às enchentes [When water rises: an analysis of the adaptive capacity of Jardim Pantanal residents exposed to floods]" (PhD thesis, FSPUSP, 2016), 87–157.

improve conventional building methods. However, when inserted into a scenario of mutual-aid building practices, this technology can play an important social role as an enabler that, insofar as it is accompanied by a technology transfer process, can emancipate the marginalised population so they can act for their own interests.

Within this proposal, ferrocement technology is as an economically feasible alternative. Thanks to the popularity of reinforced concrete in Brazil, all materials required for ferrocement lightweight prefabrication can be easily found in any region. Also, transfer of this technology is facilitated by prior technical knowledge in reinforced concrete. As a result, the initial investment for a prefabricated ferrocement component production unit, or the adoption of this technology in existing companies, is considerably reduced. Nonetheless, possibly the greatest benefit of this building method is its fast and easy execution, enabling public policies that are more efficient in meeting the demands of the population for urban improvement.

Secondly, the incorporation of digital manufacturing tools could be interpreted as a revision of the proposal for São Paulo's context, in which there is a goal to democratise access to information and the replication of productive processes. With this in mind, the local community is expected to be able to work with digital fabrication tools in order to fully appropriate the productive process. For this purpose, the digital technology transfer process will take place in public laboratories in the Fab Lab Livre SP Network, since it provides free technical courses — aimed at teaching how to work with digital fabrication machines and modelling software — and free use of the machinery.

All things considered, we can say that this article proposes a serious reflection on the impacts caused by the introduction of digital manufacturing technologies in peripheral countries such as Brazil, mainly through the so-called international maker movement.

In this sense, it can be seen that the universal conceptions and solutions originated from the maker movement, when disembarking in peripheral countries, do not assure a critical appropriation of digital technologies.[27] In addition, it is concluded that the maker's promise to overcome alienation and exploitation of labour can hardly be fulfilled without an in-depth understanding of the conflicting interests involved in these power relations, which place economic power in opposition to the majority of society interests. There are no chances for the (fallacious) speech: "win-win!"

Despite the enthusiasm fuelled by the maker movement, the ecosystem which the worldwide network Fab Lab is part of, it is not reasonable to consider that the digital fabrication technology would lead to an overcoming of capitalism with new post-capitalist conditions of labour.[28] Projects can be downloaded from a website and produced at home. It remains to be seen, as Bonsiepe says, if with this method of design

27 Fonseca de Campos and Dias, "A insustentável neutralidade da tecnologia".

28 Gui Bonsiepe, "Desobediencia Proyectual" [The Disobedience of Design] (speech at the symposium *Can design change society?*, Berlin, September 2015).

and production, design activity will become popular and what products will be manufactured: "We cannot exclude the possibility that it will end up in massive manufacture of bibelots."[29]

The dissemination of digital technology accelerated on a global scale can be interpreted as an essential part of a singular agenda in the current economic context. Contrary to what is often argued, the flexibilization attributed to such a model is not a means to increase numbers of those employed in labour. In the words of Antunes "... it is an imposition on the labour force so that lower wages are accepted and in worse conditions," by providing informal job openings that spread irregular, precarious work without guarantees.[30]

In addition, there is a striking fact that has been occurring in parallel with the automation of industrial processes, which is the intangibility of the new format adopted to expand the hegemonic economic model, as well as its territorial unlinking, substantively due to financialization of the economy and expansion of the service sector. These two phenomena combine the circulation of various 'commodities' such as increasingly digitized and networked information flow. According to Castillo, among other factors, the immaterial nature of the raw material used in this process demands new forms of organization in high technology contexts, so as to allow information circulation and common intervention — for example, something that is no longer conditioned by physical, geographical, national or other barriers. Organizations consisting of real collectives and virtual "teams" acting in a network are physically located thousands of kilometres away, and sometimes are equally culturally distant.

In this sense, the dominant ideology, according to characteristics already mentioned, relates social life to a logic of such a fragmentary nature that it ends up suppressing the minimal possibility for collective construction in society, in favour of an individualist conception of the subject. Individualist entrepreneurship, according to this view, is a fundamental cog in the functioning of the neoliberal economy. In peripheral countries, fragmentation of social relations inhibits more autonomous cultural construction and links them to central countries according to a logic of dependence.[31]

This article, however, is concerned with the use of the word "empowerment" in the deepest Freirean sense possible, as a synonym of social emancipation, since liberation is a social act and not a process of an individual nature (self-liberation).[32] It is in this context that the maker movement — which is often associated with a new pattern of training presented as maker education or "hands-on" education — is frequently viewed within individualized conceptions of empowerment and entrepreneurship.

Finally, it can be said that digital technologies of the maker movement, generically classified as digital fabrication, have the potential

29 Ibid.
30 Antunes, "Desenhando a nova morfologia do trabalho; As múltiplas formas de degradação do trabalho", *Revista Crítica de Ciências Sociais*, no. 83 (2008): 19–34.
31 Campos and Dias, "A insustentável neutralidade da tecnologia".
32 Paulo Freire and Ira Shor, *Medo e ousadia; o cotidiano do professor* (Rio de Janeiro: Paz e Terra, 1986).

for dialogical mediation between popular culture, technical assistance services, civil society and the state. Therefore, it is urgent, mainly in the socio-economic context of peripheral countries, to experiment with methodological alternatives involving this type of technology from the perspective of assisting social emancipation processes. This is the specific contribution of the case study introduced in this article, as a possible means to advance in a community-based digital paradigm.