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CONTENT

PAPERS

USE OF ADDITIVELY PRODUCED ARCHITECTURAL MODELS FOR THE SAMPLING OF TERRACED HOUSES

Stefan JUNK*[,1], Christopher MÜLLER[1], Marco BINNINGER[2]

*[,1] Offenburg University, Laboratory for Rapid Prototyping,

Klosterstr. 14, 77723 Gengenbach, Germany; stefan.junk@hs-offenburg.de
[2] weisenburger bau GmbH, Ludwig-Erhard-Allee 21, 76131 Karlsruhe, Germany;
m.binninger@weisenburger.de

Abstract

The use of architectural models is a long-proven method for the visualization of designs. More recently, powerful 3D printers have enabled the rapid and cost-effective additive manufacturing (AM) of textured architectural models. The use of AM technology to sample terraced houses in a specific use case (sampling center with more than 1200 customers per year) is examined within this contribution. The aim is to offer customers with limited spatial imagination assistance in the form of detailed architectural models of the whole house, which are divided into different modules. For this purpose, the structure of the terraced house is first analysed and examined for flexible design elements. The implementation of different variants of each floor should serve as a basis for the customer's decision on design and equipment. Thus, the architectural models are additively manufactured using Polyjet modeling. The necessary CAAD-data and interfaces, the technical possibilities and limits of this approach as well as the resulting costs are analyzed. The results of the AM process are evaluated to determine their applicability for the sampling of terraced houses. In addition, the evaluation will show that the additively manufactured architectural models will allow a more precise visualization of the building and thus a faster understanding of the design choices.

Keywords

Architectural models, Additive manufacturing, Polyjet Modelling, CAAD, Visualisation.

1 Introduction

With the growing innovation of new, and further development of existing 3D printing technologies, the question of the sensible use of such a technology also arises for companies in the construction industry. For this purpose, this contribution will identify a specific use case for a company in the construction industry and use it to test the 3D printing technology. The test scenario of a modular model house is intended to describe findings and experiences in the use of 3D printing technology for the design of architectural models. In addition, the company's customers will be shown the possibilities for the spatial design of a terraced house as a model and the benefits will be explained. This approach is to be carried out by a test scenario in the form of a small model house, which goes over into an analytical part. The architectural model shall be modular and represent the product terraced house. The benefit of this model house shall be the visualization of different variants of the terraced house of a medium-sized general contractor. These enable the customer to make decisions about details and different development variants of the terraced house even without spatial imagination. The resulting benefit is to be proven in an analytical part by evaluating the model.

2 Literature review

In the last 30 years, many new methods have been developed for 3D printing. All methods have in common that the models are built layer by layer. Likewise, in all processes, the layers are built directly from the CAAD data without additional tools. The market research by Wohlers et al. shows high growth rates for years both in the sale of 3D printers and in the number of additively produced models [1]. For two decades, additive manufacturing has also been used to produce architectural models. Thus, the studies of Ryder et al. showed that the additive methods could be beneficially used despite the high costs involved in the implementation of architectural models [2]. However, according to Gibson et al. the 3D-printed models were still only limited usable due to the small available size and the defective appearance [3].

Since then, the technology has evolved significantly. As Wong and Hernadez show, today printers with a much larger space are available [4]. In addition, today there are systems on the market that can produce both monochrome and polychrome models. According to Stavric et al. can architectural models thus be designed by additive methods as well as by reverse engineering [5]. Even partially transparent models can be created today. In order to find a suitable additive manufacturing process for architectural models, Mancanares et al. developed a catalog with important criteria [6]. The benefits of digital manufacturing become particularly apparent when complex shapes are to be modeled. Zerdad and Paulino impressively demonstrate the application of digital manufacturing for the production of models with organic shapes in the topology optimization of bridges [7].

As Hull and Willet show, the 3D-printed models can be used meaningfully for different functions in all areas of the development process, from the first draft via concept studies to the presentation model [8]. By physically mapping of large quantities of virtual CAAD data, the big data can be better represented and made more comprehensible. Soon et al. impressively demonstrate how additive manufactured architectural models can be used in the classroom to teach traditional construction methods [9]. The combination of 3D-printed physical models and digital models in the form of augmented reality has also been successfully implemented by Narzani et al. [10]. Similarly, Leporini et al. demonstrate the potential applications of 3D-printed models of historic building fragments and terrain models to improve orientation for people with disabilities [11]. The implementation of models at different scales using parameters and the mapping of different textures and materials using Digital Materials is shown by Junk and Gawron [12]. Similarly, Junk et al. show the successful implementation of a model of a single-family house with a terrain model and also present the costs associated with different 3D printing methods [13]. However, as Meijs explains, the reality is different. Many architects are still hesitant to make the leap to 3D printing. In the daily practice in architecture offices, cost and complexity are usually the biggest hurdles [14]. Also, the approaches presented so far mainly show results for individual buildings. In contrast, the use of 3D-printed architectural models for terraced houses, which are built in different variants and in larger numbers, has not yet been investigated in detail.

3 Use of architectural models in the sampling process

With an annual construction output of approx. 500 terraced houses per year, the terraced house business segment of weisenburger bau GmbH generates a noticeable part of the total turnover. In order to take advantage of the comparatively simple construction of a terraced house and to make planning efficient, the company has set up a portfolio of different terraced house variants. Despite this systematized construction and design concept, the attractiveness of individual living remains through seven terraced house models, as well as special request options (e.g. a garage or different roof coverings). Thus, the business field terraced house offers a good research environment due to its fixed models.

In general, weisenburger bau offers seven different terraced house models, which can be individualized by numerous special request options. To illustrate this, an overview of the terraced house models is given in Fig. 1, which will be described in detail in the following. The greatest distinguishing feature here is the roof shape, that can be differentiated into gable, monopitch and flat roofs. Basically, all models have design-flexible and -fixed building components inside.

The first of these models with the type designation “Fox” is considered to be an inexpensive starter house, which has a gable roof and can be used on many plots of land due to its width. Built without basement, the house offers ground, upper and attic floor and a division into four rooms. The next model with the type designation “Jive” is similar to the first. This one, however, has a basement as standard. Also divided into four rooms, the type “Jive” offers the special feature of a separate storage room and a daylight bathroom with shower. The type Nova equipped with monopitch roof has a roof terrace and offers also a basement. Its upgrade version "Nova Star" also offers large window areas and an increase in living space. With generous space, rooms flooded with light, a separate storage room and shower, the upgrade version offers some special features, whereas the standard “Nova” type is advertised as a low-cost variant. Another model with the type designation “Swing” offers a generous amount of space with two children's rooms and a basement due to the standard equipment of five rooms. The gable, due to the gable roof, is equipped with generous window elements. A flat roof is offered with the model of type designation “Style”. With greened flat roof and roof terrace, the Style type can be divided into its normal variant and one with exclusive width and garden room in the basement. The last variant in the terraced house portfolio, the type “Rumba”, has the special feature of 1 ½ floors and dormers set into the gable roof.

Variant: Fox	**Jive**	**Nova/Nova Star**	**Swing**	**Style**	**Rumba**
Roof: Gable	Gable roof	Monopitch	Gable roof	Flat roof	Gable roof
Area: 109 m²	119 m²	124 m² /132m²	129 m²	123 m²	129 m²
					

Fig. 1 Terraced house variants and roof shapes

3.1 Sampling and customer process

In order to incorporate customer wishes and give the customer flexibility, a standardized process is necessary. To this end, weisenburger bau has its own sampling center where a number of equipment options are presented. The sampling department located there is responsible for supporting the customer in his decision about design-flexible building components. Each sampling process begins with the careful preparation of the project-specific documents, which includes, for example, checking the planning documents for technical and regulatory accuracy. On the basis of this, a configurator is set up which shows the customer the various options for individualizing his own home. After the process of preparing and inviting the customer to the sampling exhibition, the actual sampling with the customer begins. In a first step, the special request plans are made. For this purpose, the customer is informed in a personal conversation about his decision-making options for the spatial design. As a means of visualization, two-dimensional working plans - i.e. current execution plans - are used, which are then adapted to the customer's wishes during the appointment or afterwards. The plans, which are redrawn by an architect, are filed with a stamp of approval and the customer's consent, provided that there is no need for technical questions to be addressed to specialist engineers in the follow-up. Furthermore, an interior designer guides the customer through a structured guideline by means of the computer-assisted configurator set up in the process, which is accompanied by associated stations of the sample course. This sample course offers the customer already in in advance the possibility of visualizing, how its own home can look later once converted real. In addition to built-up bathrooms and laid floors, etc., the sampling center also offers an indoor terraced house, which represents the true-to-scale first floor with outdoor area. Once the customer has finished sampling his own home, the results are documented, checked again for technical feasibility if necessary, filed and handed over to production.

One problem in particular emerges from the recurring challenges in the customer process. Customers often find it difficult to reproduce shapes and details by combining several two-dimensional plans. Derived from this problem, customers with limited spatial imagination should be offered assistance through the use of an architectural model. However, this should only be a support in the decision-making process about shapes or the spatial design, for example of a guest toilet.

3.2 Requirements for architectural models for sampling

With this specific use case and the settlement in the sampling department, requirements result to the model. The research environment of the terraced house model, which is predestined by its fixed models, is to be represented. The different variants are to be brought to a uniform footprint of 5.20 m x 11.00 m and the real model is to be built on a scale of 1:50. The idea is not to depict each variant as a stand-alone model, but rather to find identical building components and, if possible, combine them into a model that can be designed variably. This modular structure should affect both the "interior" and the floors, so that each floor can be removed individually and the customer can make decisions about design-flexible building components inside. Attention should also be paid to integrating building components into the model that, in addition to interior walls, are also not flexible. These can be, for example, radiators or bathroom fittings, which are supposed to give the customer a real picture of the actual spatial situation. A negative example are closets or beds, which are regarded as furnishings of a flexible nature and are accordingly not represented. The model should therefore correspond to the real building as far as possible, but should also meet the functional requirements in addition to the visual appearance. This means that it must be easy to handle for the customer and sufficiently stable. For a better overview, these variants are listed in Table 1.

The basis is formed by two-dimensional construction plans of the required terraced house types from current construction projects. This means that there are no standardized plans for each type, but rather plans based on different floor areas and building conditions. It is also possible that, for example, windows are not installed to any standard size and position. A final example is the different sized areas of the rooms. Interior wall sizes vary due to both the floor area and the customer. With this starting point and the requirements of the sampling department, a standard was set about such varying building components that do not affect the usefulness of the model. First of all, all the plans are analyzed and the first step is to compare the terraced house types in terms of their shape. It can be found that the terraced house types differ among themselves both in ground floor and upper floor. Also, the attic and the corresponding roof form can be filtered out as a distinguishing feature. Going further, it can be determined that the spatial design inside differs by more in addition to the specified variants. Accordingly, all floors of each type are analyzed and their variants are located.

Table 1: Variants of terraced houses

Floor	Variant	Number of variants
Ground floor	Toilet room	2
	Kitchen	3
	Porch	2
First floor	Room layouts	2
Top floor	Room layouts	2 (Style, Jive) or 3 (Nova)
Roof	Gable Roof, pitch roof, flat roof	3

4 3D modeling of the architectural models

Now follows the implementation of the two-dimensional plans into a 3D CAAD geometry. For this purpose, the software ArchiCAD from Graphisoft was used. With the help of this CAAD software, the terraced house types and also the variants can be easily modeled (see Fig. 2 a). Furthermore, the modular structure of the floors poses another challenge. The creation of connecting elements cannot be modeled automatically, but must be designed manually. The simple case, the floor connection, can be realized by placing a cylindrical shape taken from the library on the first floor shown in Fig. 3 and a corresponding recess in the floor slab of the upper floor. For this purpose, ArchiCAD provides a function with which shapes can be subtracted from each other.

After the completion of the 3D-CAD geometry follows the reasonable division of 3D model into modules. There are two requirements for the division of the model. On the one hand, there are the requirements of the 3D printer and, on the other hand, the requirements of the product. In the case of 3D printer, the first step is to compare the size of the installation space with the size of the component.

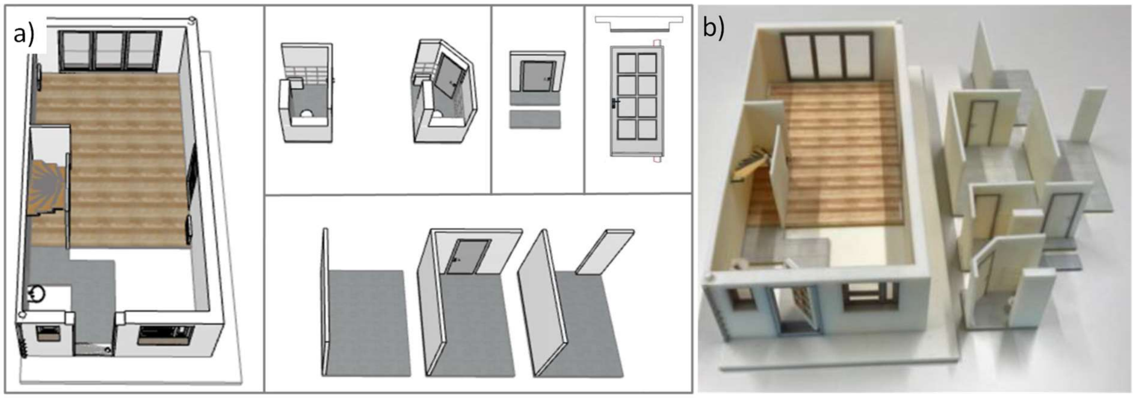

Fig. 2: a) CAAD model of the terraced house (module of first floor) with variants,
b) additively manufactured coloured 3D model with textures (Polyjet modeling).

When switching to the product view, the division of the model is based solely on the requirements. Accordingly, the model should be divided into its individual floors with their fixed structural components and the variable assemblies. In fact, the division of this model is based almost completely from the viewpoint of the product. This is because the requirements result in a division in which no assembly exhausts the capacity of the printer.

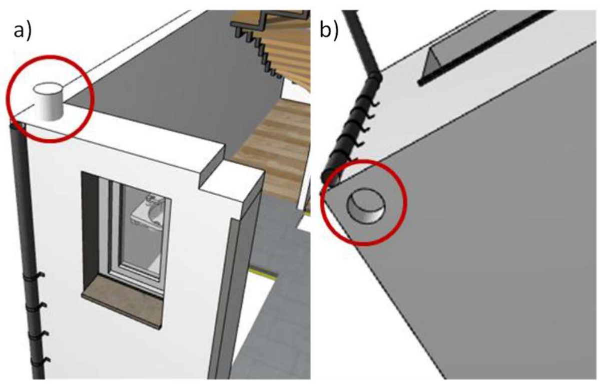

Fig. 3: Additional connecting elements designed in CAAD for the modules:
a) first floor and b) upper floor.

5 Data transfer

The data set can now be transferred into the printer software. However, there is a risk that the data will not be free of errors and thus the quality of the print will be negatively affected. An overview of the possible data flow is shown in Fig. 4. There is the direct data transfer, where there is a risk of errors and post-processing or rework of the parts is not possible. Although the GrabCAD Print software also has an automatic repair function, it is not possible to control this function manually or to rework the parts.

Therefore, in this work exclusively the indirect data transfer over the third-party software Netfabb was selected. With each assembly to be printed, the question arises whether textures or colors are available. Since this is the case for each assembly, almost all of them are saved in VRML format using the export function from ArchiCAD. First, each assembly must be scaled to the correct dimension, since this information was falsified during the export from ArchiCAD. Then, in the repair mode in Netfabb, the assembly is automatically checked for incorrectly oriented triangular facets, as well as holes in the geometry, and can be repaired manually or automatically accordingly. In most cases, manual post-processing is selected here, since the automatic repair function does not always work without errors. The advanced function of detail processing includes a large number of options. Among the functions used are extruding and cutting surfaces. This function is used to "thicken" components such as the railing and window panes. The cutting function is used to cut the gable roof into two parts to make subsequent printing more efficient. A final step before assembly is the coloring of surfaces. All components carry the color "white" or are or are provided with a texture. Reassembling and exporting as a VRML file completes the data processing in the third-party software. With the import of a VRML file into the printer software GrabCAD Print the positioning of the assembly on the platform of the 3D printer follows.

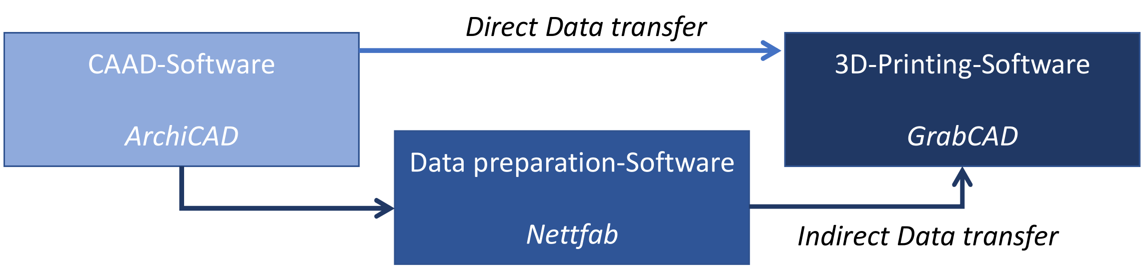

Fig. 4 Data transfer form CAAD Software to 3D-Printing Software

6 Economic considerations

The manufacturing (see Fig. 2b) is accompanied by a cost calculation or analysis. Likewise, on basis of such an analysis the cost/benefit factor is to be able to be made out, in order to be able to give apart from the actual work also a view of a future, meaningful advancement of this. At the beginning of this cost analysis first the data basis is created, while material and machine rates, as well as also the working time for preparation and reworking of the model are seized. For each print job, the printer stores both the predicted material consumption and the production time. With the collection of the printer data it requires in a next step the necessary working times of the employee.

Table 2: Calculation of personal costs, materials costs and machining costs

Cost type	Cost rate	Duration	Costs
Model design in CAAD	24.54 €/h	64.33 h	1.578.71 €
Data preparation		13.00 h	319.01 €
3D-Print preparation		1.25 h	30.67 €
Reworking		16.00 h	392.63 €
Machining (AM)	10.86 €/h	205.63 h	2.233,11 €
Materials	0.12-0.18 €/g	--	614.34 €
Total costs			**5.168.48 €**

For this purpose, the working time was divided into four different work steps. These include, the design using CAAD software, the preparation of the CAD data and the import it into the printer software. On the other hand, the post-processing of the components, i.e. the washing and coating process, is also included. The processing times of the employee are currently only roughly estimated and can still be reduced with increasing experience and better training.

In order to transfer the above data into costs, cost rates are required. Starting with the personnel costs, a cost rate of 24.54 €/h is calculated. This results from the average starting salary of an industrial engineer. Further on, the machine costs are divided into depreciation, electricity as well as rent, maintenance, etc.. The cost rate for depreciation is made up of the purchase price and an assumed useful life of ten years. This results in a machine cost rate of 10.86 €/h. Finally, the material costs must be recorded. For this purpose, a price list of the purchase prices of the different materials for components and support is used. The calculation in Table 2 shows the total costs of the model.

7 Evolution of architectural models for use in sampling process

The benefit and added value of the architecture model in dealing with the customer is examined by means of an evaluation. For this purpose, the personal interview with the employees of the sampling center, supported by a questionnaire, is chosen. With the background of presenting a product, a personal interview can immediately react to ambiguities and explain them practically. First of all, the architectural model, its function and the specific use case should be presented. With the understanding of what the model should aim at, the test persons should then fill out the questionnaire independently.

In order to draw a comparison between the actual state of the sampling process, in which extensive customer questions regularly arise, and the assessment of the process when the architecture model is used, the data from the questionnaire are evaluated. In the area of room layout and possible variants, there is a clear decrease in the number of queries from customers. Further evaluation of the questionnaire shows that the selected 3D printing technology can be used to reproduce details with such high accuracy that the test persons indicated a realistic representation for almost all criteria. In order to consider the temporal aspect in addition to the benefits of spatial imagination, the last question is intended to provide information about the temporal change in the sampling process. It becomes apparent that five out of six test persons estimate a gain in time in the process with the use of the architectural model. This means that the architecture model can also bring a time advantage in addition to its actual objective.

8 Conclusions

At the beginning, the basis for the CAAD data was examined, whereby recurring modules emerged. With the completion of this analysis, modules were developed with which the variants of terraced house types could be delimited. These had to be represented in the form of a 3D-printed architectural model. The data flow from the basis of the 3D CAD geometry to the implementation in the specific printer software provided insights into color assignments in connection with data formats. A CAAD model must therefore be divided up accordingly and exported in different formats. In transition to the start of the production process, a number of insights have emerged in dealing with the polyjet technology used, which must be considered when preparing the data. It became clear that splitting up a model requires knowledge of the tolerances to be maintained in order to ensure an accurate fit when assembling the components. Another finding is the need for a certain strength of the designed geometry to generate sufficient stability.

Nevertheless, the evaluation of the model has resulted in a prototype with future prospects and application in the sampling process. The time savings and assistance for customers with low spatial imagination prove the usefulness of such a model. In addition, the detailed representation resulting from the choice of a 3D printing technology is an important factor of an architectural model in dealing with the customer, since shapes and details are often difficult to recognize from two-dimensional plans. All in all, these insights can be built upon and a prototype can be turned into a customer-ready product.

When looking at costs, it can be seen that while they are high for a model, a lot of development work goes into personnel costs. In addition, the evaluation by employees of the sampling center suggests a clear added value for the sampling process, which should make an investment of this amount justifiable. In conclusion, it can be said that, based on the positive feedback, further development of the model should be pursued.

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MOLLERSTADT’S FUTURE: URBAN DESIGN AS PART OF TRANS-DISCIPLINARY RESEARCH

Astrid SCHMEING

Hochschule Darmstadt, Fachbereich Architektur
Schöfferstraße 1, 64287 Darmstadt, Germany;
astrid.schmeing@h-da.de

Abstract

S:ne (Systeminnovation nachhaltige Entwicklung) is a transformation/research project funded by the German government. It aims at sustainable development, including the reduction of CO2. One project’s task looks at future-oriented urban development with the example of „Mollerstadt“, which is part of Darmstadt’s city center. There are several focus areas in this project concerning building, energy, mobility, and consumption. These are not necessarily viewed from an integrative spatial perspective or in relation to urban design. Next to other seminars and projects which I have taught, my colleagues and I (Prof. Henning Baurmann, Vertr.-Prof. Ulrike Franke, Prof. Jan Kliebe, Prof. Joachim Raab, Prof. Alexander Reichel, Prof. Astrid Schmeing, Vertr. Prof. Michael Schröder and several lecturers) have worked with 190 third-year students on integrative urban designs addressing s:ne’s themes. These designs reveal focus areas (building, energy, mobility, consumption) that have an aesthetic and cultural dimension. In order to enhance public discourse and to participate in the transformative process, these student designs have been presented to a wider public in the Schader-Stiftung.

Keywords

Transdisciplinary research, CO2 reduction, sustainable urban development, urban design, teaching results enriching the transformative process

1. The transfer project

1.1. S:ne Systeminnovation für Nachhaltige Entwicklung/System Innovation for Sustainable Development

Universities of applied sciences are on the move. As part of the “Bologna Process”, the former polytechnics have gained the right to award the same degrees to their students as universities. In terms of research, they have started to think about their research direction and have focused on applied science and transfer. With the transformative research project s:ne „Systeminnovation für Nachhaltige Entwicklung“, the Hochschule Darmstadt has become part of the German program „Innovative Hochschule“ [1]. This initiative fosters transformational research and innovation through financial support, especially at smaller universities and universities of applied sciences.

As claimed on s:ne’s website, the transfer project aims to establish processes related to sustainable development within the region. In order to accomplish this, system innovation on both social and technical levels must occur. Technical innovation alone does not provide change; it is the stakeholders' actions that are central, as well as the regulatory framework. Thus, the project is not about „science“ developing solutions and then making them available to practice; rather, s:ne is looking for ways to bring stakeholders with different experiences, perspectives, and interests together, to formulate new research questions. In conclusion, "creative knowledge" should transcend previous system boundaries [2]. The various project tasks all follow the same methodological steps of problem framing, vision building, and testing solutions by a fixed group of stakeholders. They are all bound to the United Nations' SDGS, the Sustainable Development Goals [3].

1.2. Teaching within the framework of s:ne

Teaching projects are part of s:ne, as well. The link between the two is expected to make classical teaching and learning more responsive to sustainable development and open it up to input from researchers and stakeholders. Inversely, it is intended that student projects enrich the transfer process. A series of design classes taught at the Hochschule's Architecture Department did just this. They addressed s:ne's task „Future Oriented Urban Development“.

The Mollerstadt design studios took place in 2019, with seven professors and six lecturers supervising 190 students. While the faculty invested approximately 1,100 hours of teaching, the students' work was estimated to be as high as 57,000 hours. These projects started quite early in the s:ne process and included content from the different focus areas of „Future Oriented Urban Development“. This proved challenging because, at that stage, the researchers were still mapping out relevant stakeholders, trying to win them for the project, and in the best-case defining transfer questions with them. The students were able to build on s:ne's research proposal, the work of different initiatives, the content of the "Masterplan Darmstadt 2030+" [4] that was in progress at that point, and on the current redevelopment process.

Quite early in the semester, the Department of Architecture and s:ne held a small symposium. The symposium panel was comprised of activists from different initiatives, Darmstadt's Planning Office Manager, and the Technical Manager of Bauverein (Darmstadt's primary real estate service provider). This way, the students got important input, the researchers were able to build relationships with the stakeholders, and--perhaps most importantly--the stakeholders engaged in discussions with each other, resulting especially in the Planning Office Manager becoming more positive about the initiatives' work.

The courses culminated in a series of three events held at the local Schader-Stiftung, a foundation promoting the cooperation between the social sciences and practice. This foundation is an important platform in s:ne, as it provides a forum for communication and cooperation among researchers, stakeholders, and citizens [5].

2. Visioning Mollerstadt

2.1. Mollerstadt as focus space in s:ne

Initially, Mollerstadt—a district next to Darmstadt's pedestrian zone in the city center--was „Future Oriented Urban Development's“ focus space. As such, student works concentrated on this district.

Mollerstadt is named after its designer, Georg Moller. The Grand Duke of Darmstadt, Ludwig I, commissioned Moller to design the new district in the beginning of the nineteenth century, which became one of the leading urban designs in Classicism, harmoniously highlighting the interaction between the city and the surrounding landscape. Just a couple of decades later, the green scenery had disappeared, due to the city's growth during the Industrial Revolution. The district's small-scale parcellation survived not only its densification during the late nineteenth century, but also the quarter's complete destruction during the bombings of World War II, as well as its reconstruction in a modern style during the 1950s. This central part of the city once again became a thriving business district with street-level shops and housing above.

At the beginning of the twenty-first century, the district had declined. Housing and social conditions were poor, and the buildings needed modernization. The district was overloaded with road traffic, especially stationary traffic. Due to the high degree of sealed surfaces, there were problems with overheating during the summer, as well as with water management. Online commerce started to be a problem for local retail stores, and the first vacancies appeared.

In 2005, the district was designated an official redevelopment area. In 2013, the magistrate decided on an integrated concept for the district, aimed at reducing CO2. The concept includes the fostering of energy-oriented restoration and the private greening of facades, roofs, and courtyards, as well as measures of sustainable mobility [6]. It addresses public space as well as private property. In terms of alternative mobility, the program sought to realize the following objectives: new bicycle paths, additional and better parking alternatives for bicycles, more options in car and bicycle sharing, and the amendment of parking space regulations. For example, the obligation that owners of private property had to provide a designated number of parking spaces was reduced if they adapted greening measures instead. Funding programs have been established relating to the greening of facades, courtyards and roofs, as well as the energy-oriented refurbishment of buildings. While the latter has had some success so far, the greening of private property has barely taken place.

While the redevelopment proceeds slowly, there has been considerable climate action in and around Darmstadt. The initiative "Fridays for Future" [7] has been active, as have other initiatives such as „Klimaentscheid Darmstadt" [8] and „Radentscheid Darmstadt" [9]. They have been successful in affecting change. The latter two collected a large number of signatures supporting their programs. Even if their referendums were declined by the city government, many of the initiatives' aims have been integrated into the city's politics. For example, in 2019, the city parliament agreed on the necessity of a transformation of the existing traffic system, and set up a mobility master plan that became part of an overall "Masterplan Darmstadt 2030+", released in 2020 [10]. That plan aims at sustainable urban development based on the concepts of the "City of Short Distances" and "sustainable densification + greening". In 2020, the city decided on the "Sofortprogramm Klimaschutz", meaning an immediate program for climate protection. Part of the city government's coalition contract from 2021 includes a requirement that the city will become climate neutral (as far as the city can influence this) by 2035.

S:ne was established in 2018, during the time of this political process. At that point, it had been obvious that measures taken in Mollerstadt would not be enough for the city to reach climate neutrality by the deadline. So, the transfer project adapted and extended the redevelopment's themes, aiming at (re)connecting relevant stakeholders and bringing about progress in the different fields; namely, mobility, energy-oriented refurbishment of buildings, and energy distribution and consumption.

2.2. Diagrams on mobility, densification, greening, and consumption

Mollerstadt has many qualities of the sustainable model of the "City of Short Distances". It is a densely built urban district, which has a functional mix including housing and good infrastructure for public transport. It lies in Darmstadt's geometrical center and can be reached by bicycle or even by foot easily from all over town. Still, there is a need for improvement and adaptation.

Two master's students, **Eugen Hildmann and Katja Hofmann**, produced a series of diagrams that address the themes of mobility, densification, greening, and functional mix/consumption. They drew input mainly from the "Masterplan Darmstadt 2030+" that is based on the model of the "City of Short Distances", but also from the initiatives' work as well as the discourse in s:ne.

The first series of diagrams concern the aspect of **mobility**. In the future, more space for bicycle parking on single plots will be needed. At the district level, there is a need for bicycle lanes and bicycle parking, both of which compete for space with existing parking lots and traffic lanes. There is also a need for collective parking garages, as well as mobility stations. Actually, the city already plans an additional tram stop at the edge of Mollerstadt, which is not yet fully covered by public transport.

Since the German government plans a 55% reduction of greenhouse emissions by 2030, car traffic is a major focus area. Due to more traffic and cars, emissions increased by 5% between 1995 and 2019 [11]. Also, traffic--especially stationary traffic--takes up a lot of space, which is needed urgently for alternative traffic (such as bicycles), densification, and greening. Furthermore, there is a need for more and better public space.

The following diagrams concern the **greening** of the city. Currently, nearly all of Mollerstadt is sealed. Next to facades and roofs, it is the courtyards that have the potential to provide permeable surfaces, as well as new green areas, that not only help to improve biodiversity and to store CO2, but also to cool the environment. Those unsealed, green courtyards could also have an important social function, providing meeting spaces for the inhabitants.

Densification is another important theme. Darmstadt is a growing city with a shortage of both housing and commercial space. Land prices have risen enormously over the last years, as have rents. In order to save valuable space on the outskirts, the aim is to grow within the city's existing outline and to densify. Though this strategy has been applied all over Germany, in Darmstadt it is especially relevant since the city is surrounded by protected forests on three sides. Mollerstadt is already quite dense, but much of the back building development is neither efficient in its structure nor of good substance. Also, streets are broad enough to consider adding an additional floor to existing buildings.

While the existing **functional mix** is positive in relation to the "City of Short Distances", the crisis of stationary trade endangers this mix. The existing stores in the perimeter block tend to be of the same size--the traditional size of a stationary shop. Bringing in new typologies could help to diversify functions and, thus, to make the city more resilient. Bringing in sustainable sharing functions could be a viable option, as well. While there is still a lot of commerce in Mollerstadt, there is a lack of neighborhood functions. A secondhand shop, rental shop, or repair shop combined with a cafe could bring a neighborhood-feeling to the district, especially since there are many students living there who neither have the money nor the space to buy everything new for themselves.

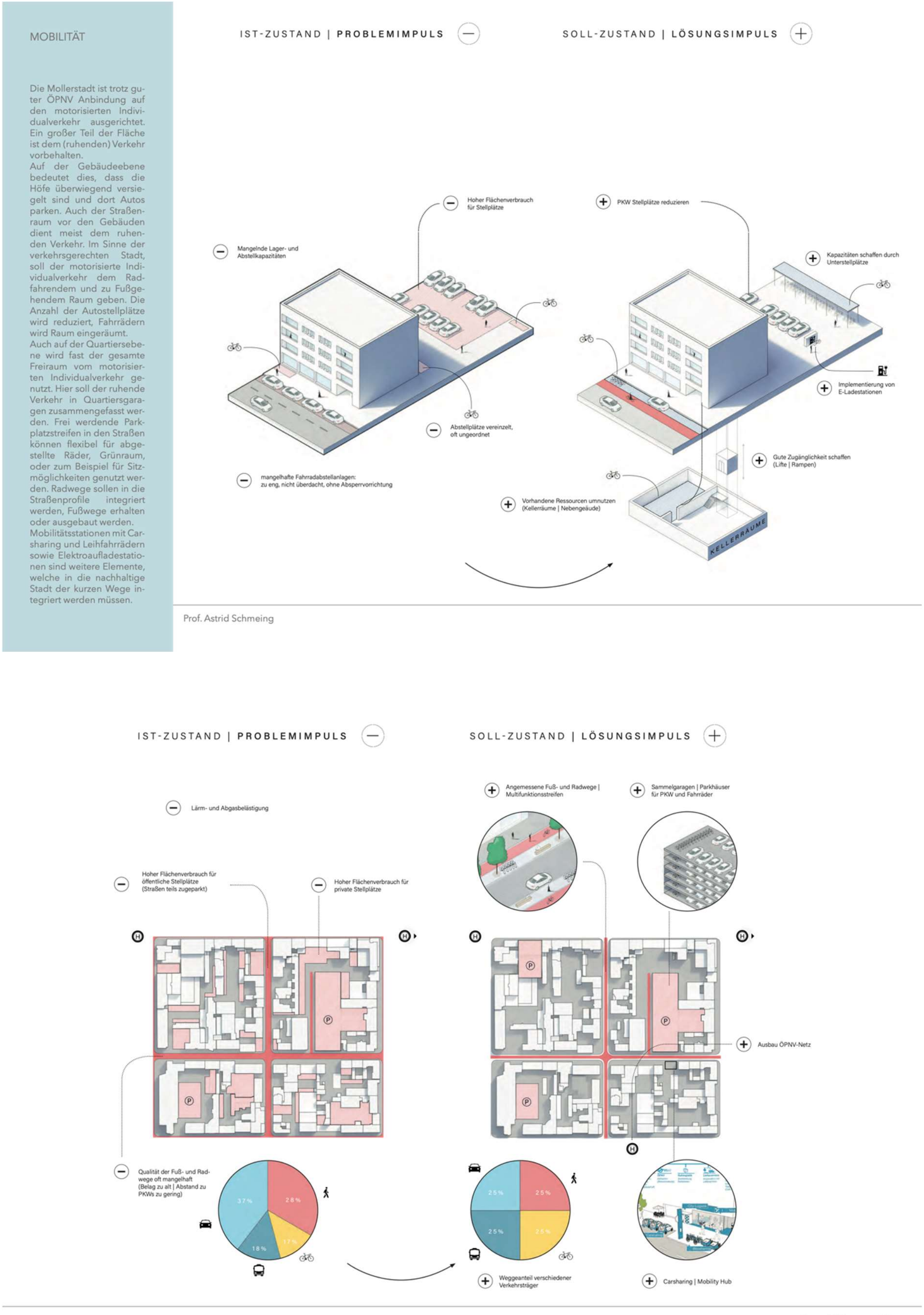


Figure 1. Current and desired situations mobility

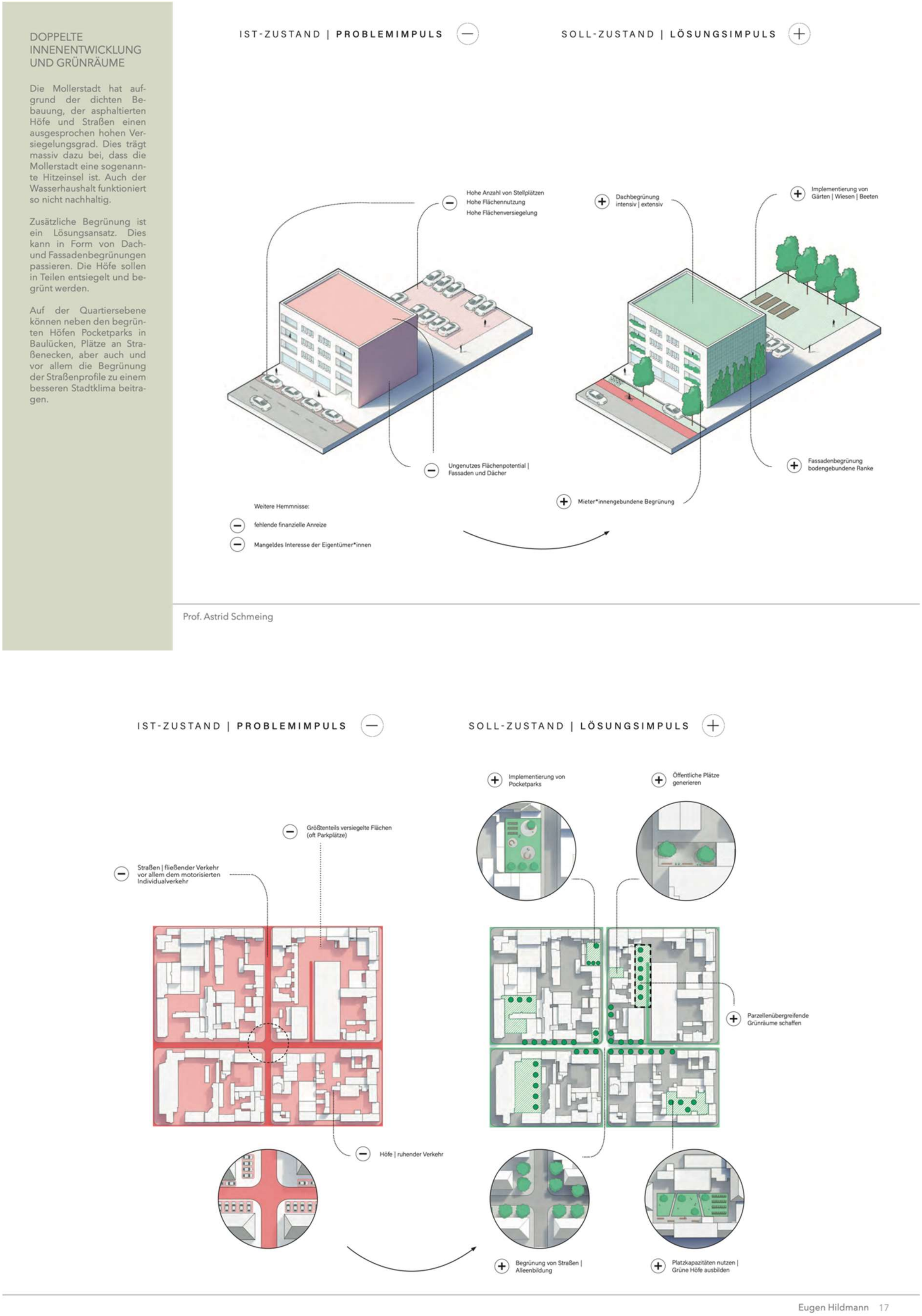


Figure 2. Current and desired situations greening

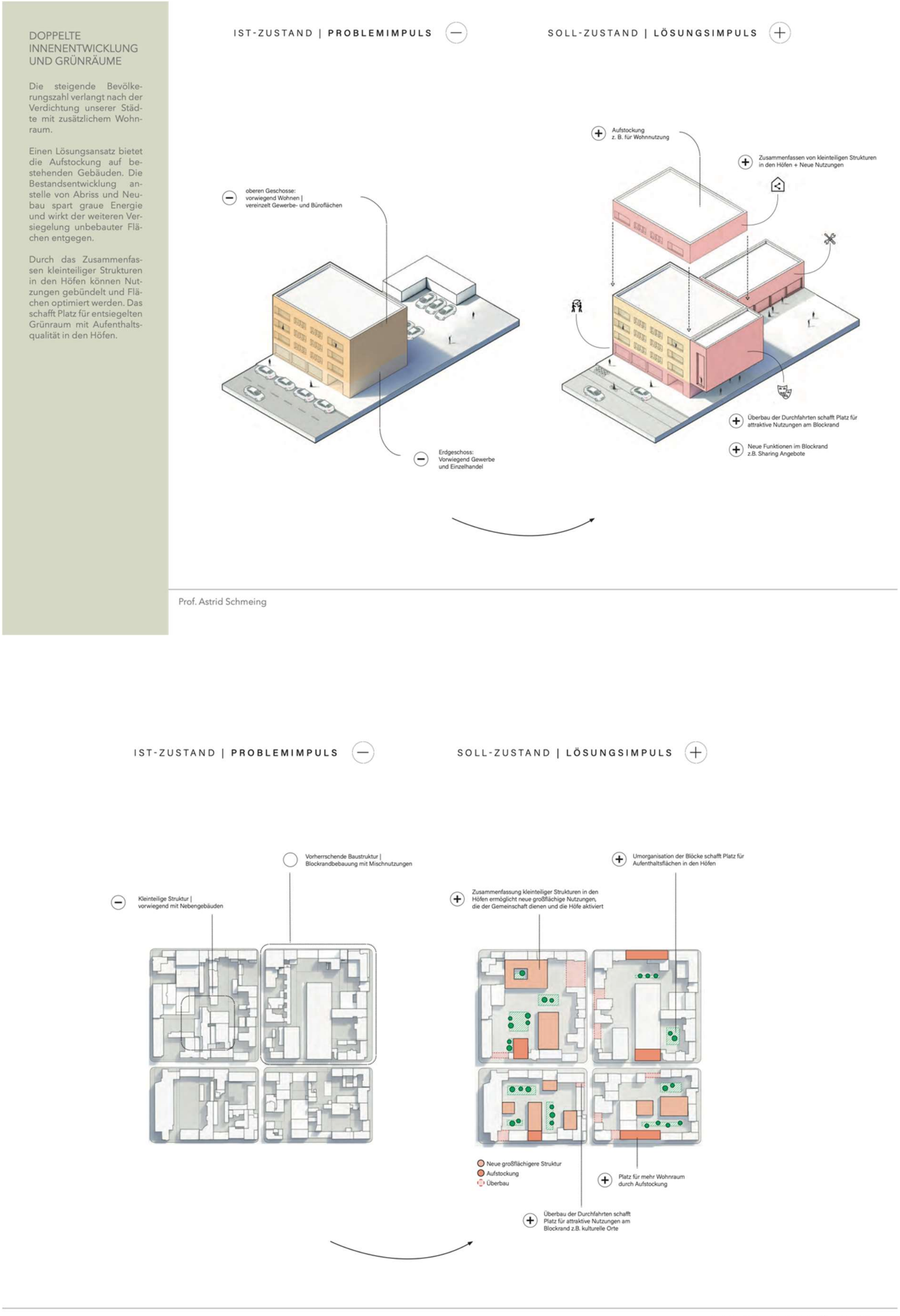


Figure 3. Current and desired situations densification

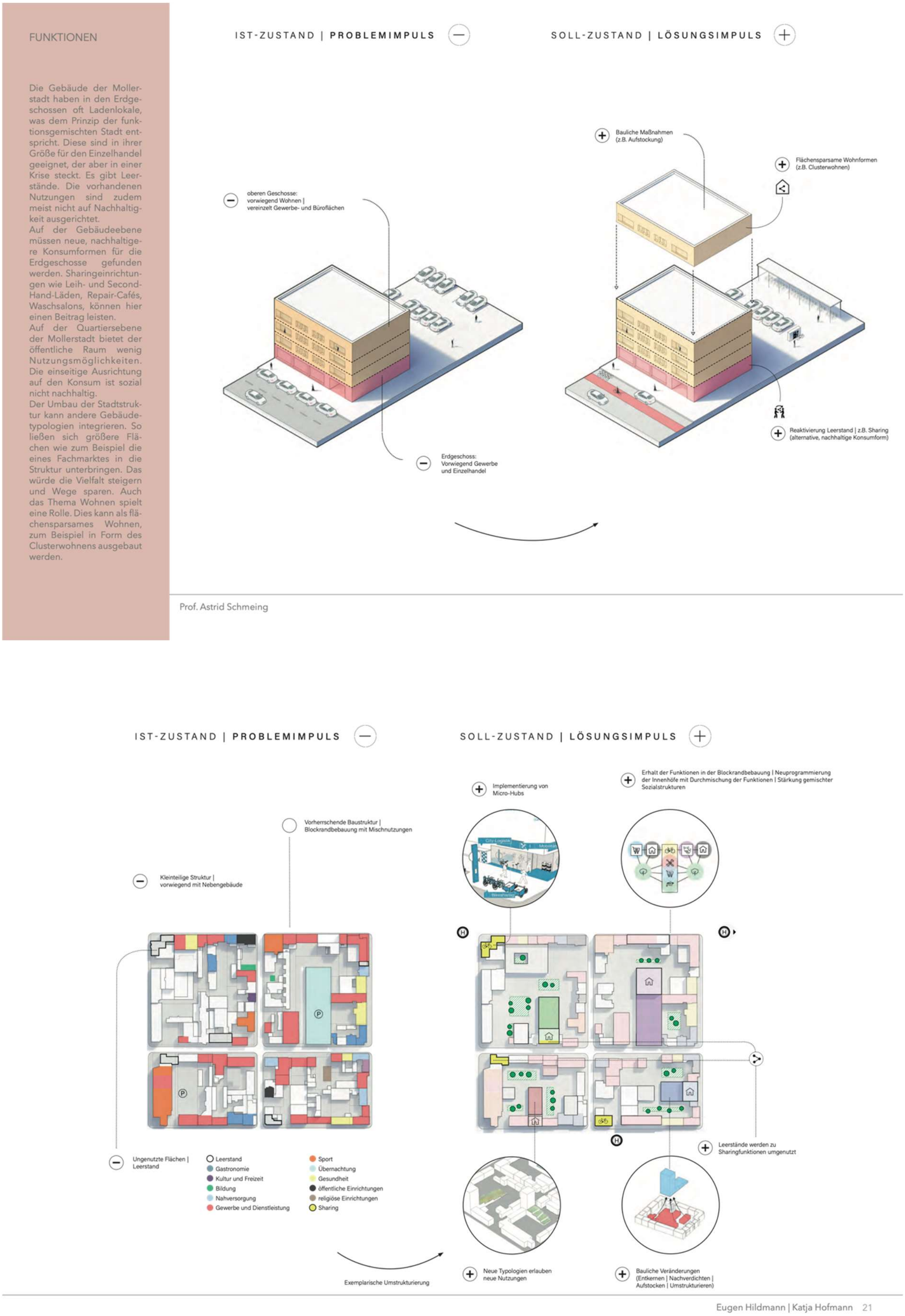


Figure 4. Current and desired situations functional mix

These ideas are not as strongly rooted in the city's politics as densification, greening, and sustainable mobility; rather, they are connected to the initiatives and the early discourse within s:ne.

While most of the measures are in line with city politics, they have either not yet been implemented or not yet been implemented sufficiently. This becomes obvious in the case of stationary traffic which still dominates streets and courtyards. The same is true for the greening of facades, roofs, and courtyards. Clearly the city's actions to change regulations and support greening and modernization have not been fully successful. While investors have applied some of these measures when replacing old buildings with new ones, owners of existing buildings have not done so. It seems to be against their own best interests. This is a major problem in the sustainable remodeling of a district like Mollerstadt, in which the property is mainly privately held.

2.3. Actual students' designs

While the diagrams show different measurements concerning sustainable development, the students' designs go a step further. They integrate those measurements into creative and aesthetic spatial concepts. The schemes show that intelligent design can integrate heterogeneous requirements into an overall concept.

In addition, the students' designs might help to overcome opposition. Most inhabitants do not want their neighborhood to densify and most car drivers do not want to give up their traditional „rights" of occupying most of the public space. Owners do not see the value of greening facades, roofs, or courts. Design can help to show the positive aspects of new developments, can reveal potential qualities, and can, therefore, influence peoples' attitudes.

The following are three design examples, each with a different emphasis.

Aaqib Ali Nawaz and Gabriel Schumacher Gutierrez (supervised by Jan Kliebe and Roman Schallon) started out with the question of mobility. They placed a new hub with a big parking garage on the southwestern edge of Darmstadt, establishing a shuttle into the city. Their analysis shows gaps in the public transport network, so they have suggested new bus stops. In addition, they changed road profiles, bringing in new bike lanes, as well as trees. While they designed all these steps on a diagrammatic level, they got more detailed with respect to the scale of building on a specific site, a kind of triangle, enclosed by major roads and a lot of traffic. They densified the urban context by placing massive buildings, including a high-rise, forming a landmark at the traffic intersection, visible from many sides. The buildings were placed in such a way as to form plazas accompanying the new bicycle path at the north of the site. Functionally, they used the ground floor as a mobility hub with some car and bicycle parking, car sharing, bicycle sharing, and a bus stop. They also brought in functions to animate the public spaces, like a cafe and a restaurant. They put office space on the upper floors.

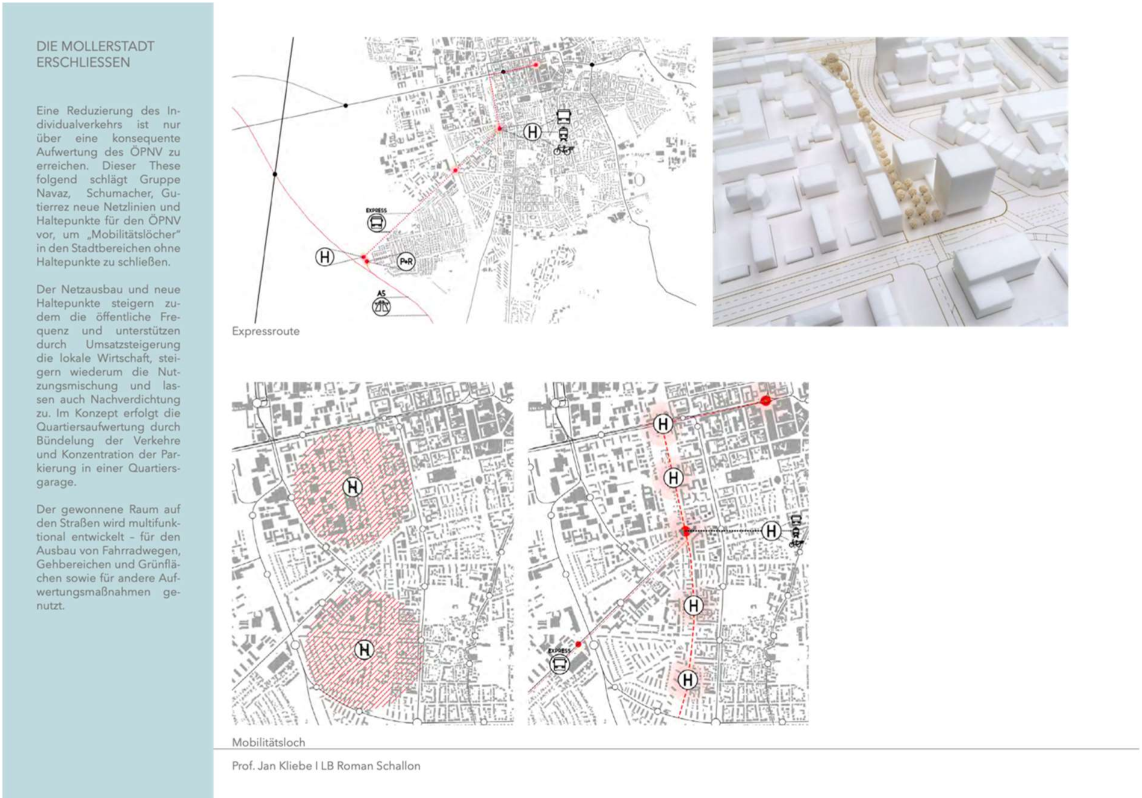
Annika Enders, Nina Scheld, Franziska Grau, and Katharina Haumann (supervised by Astrid Schmeing and Christoph Alker) emphasized the question of the greening of Mollerstadt. They removed the back buildings, replacing the loss of surface area with high rise buildings integrated into the edge of the perimeter blocks. This way, Mollerstadt presents itself simultaneously as „tiny Manhattan", as well as the city's green heart. They took an idealistic approach by neglecting small scale parcelation. Implicitly, their design makes private ownership problematic, potentially preventing a coherent, sustainable remodeling of our existing cities. The students also took a look at the green public spaces framing Mollerstadt, especially the so-called Schweitzer-Anlage and Landgraf-Phillip-Anlage to the west. Both are public greens not performing to their full potential, either in relation to ecology or with regard to their social functions. The students redesigned the space by integrating sport fields and playgrounds as well as water basins and an additional set of plants for increasing biodiversity. By placing plazas at those points where streets hit the green strips, they connect the park with its urban context.

Theresa Mehler, Vera Schmitt, and Louise Wielback (supervised by Ulrike Franke and Marvin Philipp) worked within the small-scale structure, accepting the existing borders. Tearing down most of the rear buildings, they placed new architectures forming well-defined, semi-public courtyards. Although they retained the existing small-scale structure, they eliminated fences and walls so that the semi-public spaces intersect. This approach would need a very detailed zoning plan.

These new plazas and the surrounding ground floors are thought to inherit collective neighborhood functions, facilitating Mollerstadt's inhabitants' identification with their district. The students also unsealed some courtyards to bring in green areas for ecological and social reasons. They did so mainly in the form of urban gardening, which has been quite common in Darmstadt for years now and is strongly supported by activists [12].

1.1. Three evenings in the Schader-Stiftung

There were three thematic evenings held at the local Schader-Stiftung to present the best designs. The first evening emphasized mobility and urban space, the second densification and greening, and the third functional mixtures and the district's identity. Due to the COVID-19 pandemic, the events were held as webinars. While the organization team [13] was present at the foundation, students, invited discussants, and guests attended virtually [14]. The students presented the different urban areas in question via video. The faculty framed students' statements regarding their designs thematically, so that the guests were able to understand both the urban context and its possible transformation. The invited stakeholders who commented on the students' works, played a major role in the interactions. Each evening, there were three discussants—one representative from administration, one from science, and one from business [15]. The 40 to 100 guests per evening formed a mixture of interested citizens, people from the city administration and utilities, scientists, and students. The student works as well as the discussants' statements have been documented and can be downloaded from the foundation's website [16].



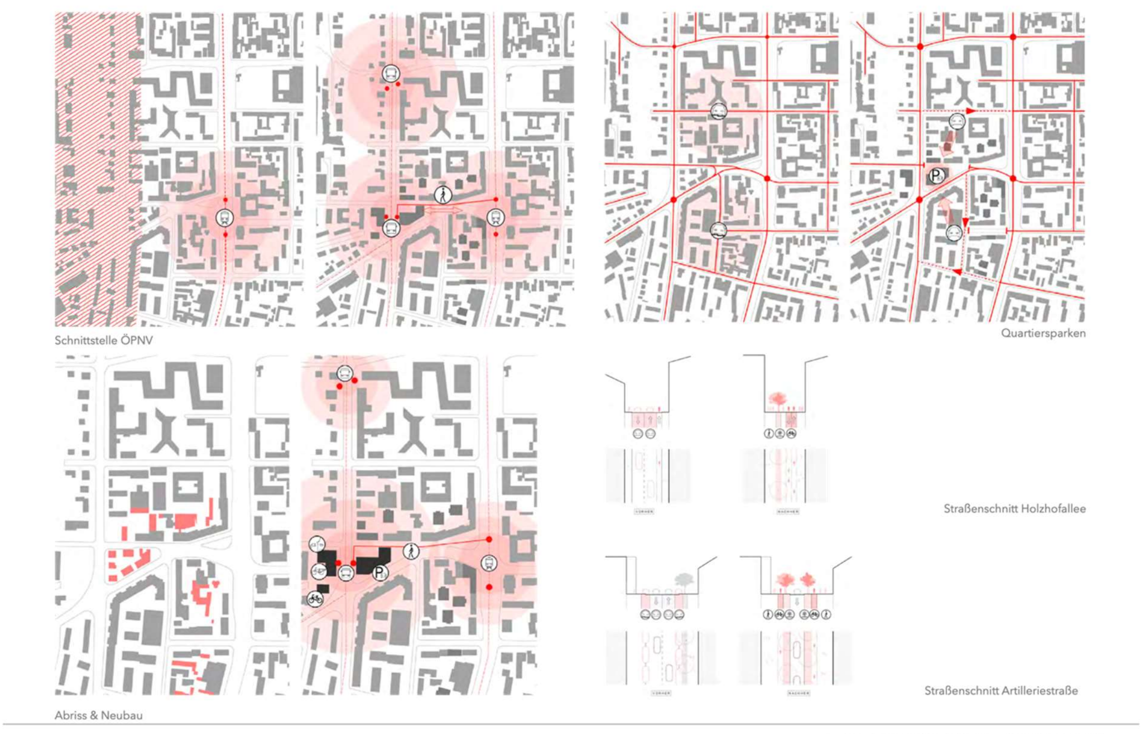


Figure 5. Aaqib Ali Nawaz and Gabriel Schumacher Gutierrez, extracts of their student design

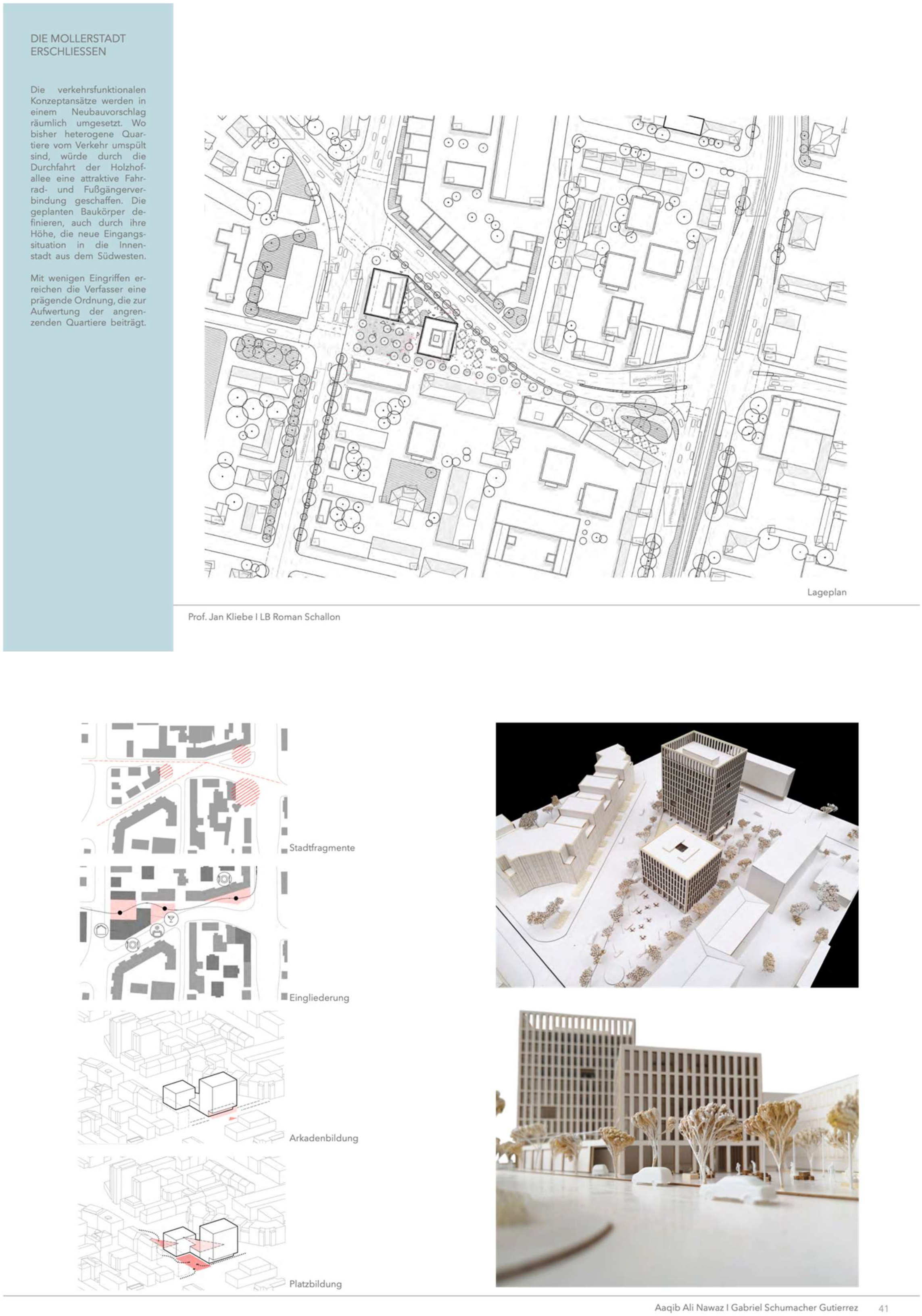


Figure 6. Aaqib Ali Nawaz and Gabriel Schumacher Gutierrez, extracts of their student design

Figure 7. Annika Enders, Nina Scheld, Franziska Grau, Katharina Haumann, extracts of their student design

Figure 8. Annika Enders, Nina Scheld, Franziska Grau, Katharina Haumann, extracts of their student design

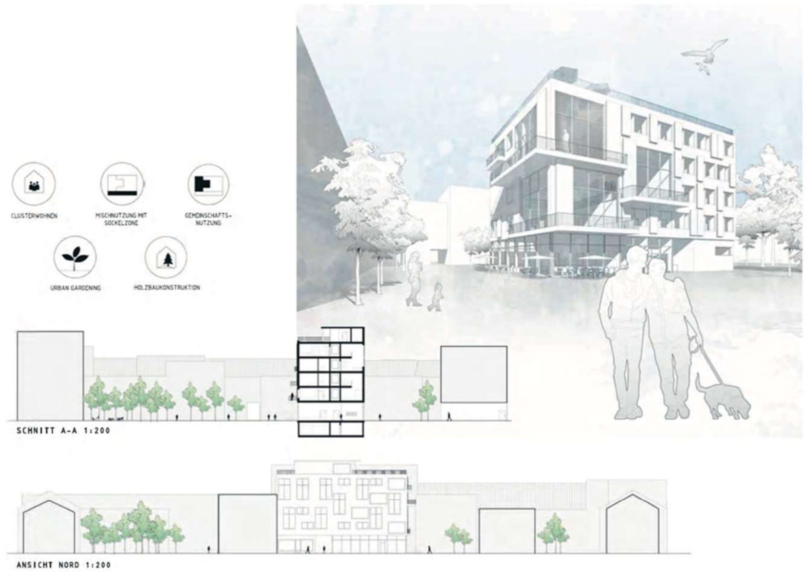
Figure 9. Theresa Mehler, Vera Schmitt Louise Wiebalck, extracts of their student design

NEUE TYPOLOGIEN WOHNEN UND NACHBARSCHAFT

Die Gruppe Mehler, Schmitt, Wiebelback bietet in ihren "Hofwelten" einen zusammenhängenden halböffentlichen Außenraum an, der zwischen Bestandsbauten und neuen Wohngebäuden mit Gemeinschaftsnutzungen im Erdgeschoss mäandert und so differenzierte Aufenthaltsbereiche schafft.

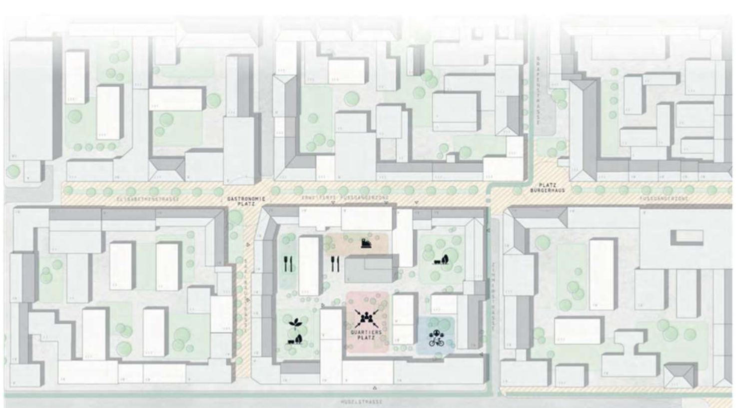
Quartiersfunktionen wie Café oder Fahrradwerkstatt werden vorgeschlagen, ebenso wie neue Wohnformen. Es wird ein Quartiershaus mit Clusterwohnungen angeordnet, in welchem sich in ihren Individualflächen minimierte Apartments um doppelgeschossige Gemeinschaftsräume organisieren. Im Erdgeschoss befindet sich das Quartierscafé, welches auch für Besucher*innen offen ist.

Das Gebäude ist als Holzbau aus einem nachwachsenden Rohstoff erstellt und erhält eine gut gedämmte Gebäudehülle.



Die Aktivierung der Innenhöfe finde ich in den Studierendenarbeiten toll. Innenhöfe sind nach deutscher Tradition privat. Um sie als öffentliche Wohnhöfe mit Aufenthaltsqualität auszubilden, kann man sich am mediterranen Raum oder auch an der Züricher Kalkbreite orientieren.

Dr. Christina West
Hochschule Darmstadt



Lageplan

Theresa Mehler I Vera Schmitt I Louise Wielback 119

Figure 10. Theresa Mehler, Vera Schmitt Louise Wiebalck, extracts of their student design

2. Evaluation

2.1. Relating to the evenings in the Schader-Stiftung

The discussants enjoyed communicating with the students, and highlighted the importance of their ideas. At the same time, they confronted them with reality. Third-year students are not experienced enough, yet, to oversee and integrate the complexity of the urban scale, the different set of rules and laws that apply, and the social and financial approaches that are at stake, while simultaneously being visionary. The discussants showed them the limits of their proposals and some of them were quite fast in accepting those limits. Questioning the status quo is necessary, however, in order to overcome impediments to sustainable change. That is the whole idea of s:ne: to overcome a practice preventing sustainable development and that is why we see a need for system innovation, which, naturally, is not easy to attain.

The discussants also related the students' design concepts to their own work, to the „Masterplan Darmstadt 2030+", and to s:ne. That was a desired effect, since the aim was to place the designs' content within a public discussion and scientific discourse. It is important that architecture and urban design are shown to be relevant for our future development as a society, as well as that of our cities.

2.2. Relating to s:ne

In relation to s:ne, the designs, as well as the evenings in the Schader-Stiftung, are limited in their potential. Methodologically, s:ne aims to follow specific steps: the formation of a stable group of stakeholders and a common understanding of problems, the formulation of transfer-questions, and the set-up of an experimental space where changes can take place. The student designs, as well as the evenings in the Schader-Stiftung, do not really fit into this methodological process in a linear way. Nonetheless, those evenings brought the themes relevant in s:ne into a broader discussion, connecting stakeholders with stakeholders, and stakeholders with researchers.

The diagrams and student designs also do not fit smoothly into the different fields of actions in „Future Oriented Urban Development". Over time, those fields developed transfer questions with their stakeholders that no longer focused on Mollerstadt. This was either because the addressed problems could not be limited to that district, like the improvement of alternative mobility, or because essential stakeholders could not be integrated into the process. This was especially true for the heterogeneous group of owners. Actually s:ne has faced the same problems the administration did in the redevelopment process. Since they did not reach the owners, measures of greening, as well as modernization, could not be realized to the desired degree.

The different fields of action intersect thematically, and also have spatial dimensions. But the students' works, especially the diagrams, are the only approaches left in which different aspects and consequences from sustainable mobility, buildings' modernization, densification, and consumption are related to the same common ground. Here, the measures aimed for, their interrelations, and the competition for space become visible.

In that sense, a new field of action in s:ne will pick up the loose ends, and draw on Mollerstadt as a common focal point. The idea is to set up a writing workshop with relevant stakeholders, resulting in a publication. That way, different views on Mollerstadt and its development, and on qualities, problems, chances, and impediments can be made available for the broader public, preparing for future innovation and transfer.

2.3. Final thoughts

Next to a general interest in sustainable urban development and transfer, the motivation as an architect to participate in s:ne has been to integrate an aesthetic and creative, revealing design's relevance and potential. Design integrates technical, social, and spatial aspects, and can be seen as a transformative power itself. Within s:ne, design has been on the sidelines thus far, so it might be interesting to set up a follow-up transfer project that focuses on a participative design process, establishing a model of future-oriented, sustainable development.

The approach toward teaching shown above, also reflects the general approach we have in our department's way of teaching, more specifically in the area of urban design. We understand ourselves as a social and intellectual part of the city, as well as the region. With the students taking up relevant questions which are highly-debated topics, and by bringing the students' designs into it, we hope to become part of the urban discourse and the participatory social project of urban development.

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[13] The team was: Michèle Bernhard from Schader-Stiftung, Birte Frommer from the Department of Civil and Environmental Engineering as well as Project Leader of the project's task „Future Oriented Urban Development" in s:ne, Astrid Schmeing as part of the Department of Architecture as well as of s:ne, Ulrike Franke, and Michael Schröder as part of the Department of Architecture

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[16] Architektur und Grünräume: The discussants were Dr. Ing. Susanne Bieker, Frauenhofer-Institut für System- und Innovationsforschung/Frauenhofer-Institute for Research in Systems and Innovation, Karlsruhe, Dr. Barbara Boczek, Planungsdezernentin/Head of Planning, Wissenschaftsstadt Darmstadt, and Martina Fendt, Landschaftsarchitektin/landscape Architect, Darmstadt

[17] Architektur und Funktionen: The discussants were Dr. Marina Hofmann, Industrie- und Handelskammer/Chamber of Commerce and Industry Darmstadt; Jochen Krehbiehl, Leiter Planungsamt/Head of Planning Office, Wissenschaftsstadt Darmstadt, and Dr. Christina West, s:ne, Hochschule Darmstadt/ University of Applied Science Darmstadt

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THE TEMPORAL CITY - THE AGENCY OF BIG DATA

Ian NAZARETH*, David SCHWARZMAN

RMIT University
124 La Trobe St, Melbourne VIC 3000, Australia;
ian.nazareth@rmit.edu.au, david.schwarzman@rmit.edu.au

Keywords

Temporal, Big Data, P2P, complexity, transformation

1 Introduction

'The future is already here — it is just not evenly distributed' _William Gibson

Cities are straightforwardly a proposition – to exercise the benefits of dense settlement and adjacency. They thrive when the advantages of proximity between people and entities are greater than the cost. They are platforms for global activity, nodes for collective movements. Market-driven cities, industrialisation, globalisation, neoliberalism and so on, set in motion a cycle of distinctive, specialised and aspirational cities.

Cities are large and complex organisms, impossible to decode. Obstinate and unyielding. They are not risk averse. They are resource and capital-intensive exploits. Their robustness paradoxically deems them passive and resistant to change. The city is now, neither symbolic nor historical. The city has no reference point. Its polyvalency is self-perpetuating.

Cities are empirical and even experimental. Seldom random, deterministic for most part. City forms that have been virtually stable for centuries are undergoing a metamorphosis. While the city might be vaguely familiar on the surface it is unrecognisable when you peer into its cellular logic.

Overall, productivity of infrastructure has declined[1] and the relative pace of transformation of the 'soft infrastructures' of the city has created a schism, prompting an evaluation of design and the agency of creative disciplines in the city.

2 The Temporal City

'The introduction of time as the fourth dimension into architecture has been obvious since anyone had a brick wall fall down…' _Cedric Price

The system and forces that shape the city and catalyse its vertiginous growth no longer require a physical address. Cities are also manifested through digital proxies. Arguably, we are urban only by or through association and/or surrogacy. The city of the mind's eye is possible anywhere.

The Temporal City is a kinetic organism that is simultaneously and synchronously enabled by the flow of data, people and logistics. It proposes a spatial operating system, a stream of inputs and outputs – I/O. Its intensity and form unravel and wane as an organic mechanism that underpins a chronologically-based urbanism. Traditional principles of the city are upturned. The temporal city is not about absolutes or repeatable spatial products - but a framework that embraces and amplifies the indeterminate, messy, contradictory, combinatory, uncertain and improbable conditions. It is opportunistic. Agility instead of stability, multipliers rather than repetition. Change, difference and time are accelerated. The complexity of its systems benefits from variability, unpredictability, imbalance and volatility.

The Temporal City focusses on the relationship between virtual applications, digital realms and physical spaces in the city, as well as the implications they have on the temporal and permanent patterns of occupation, spaces and typologies. It seeks to establish a platform through which virtual (and even real-time) data can be juxtaposed from multiple sources and spatialised.

3 APIs and Realtime

Projects undertaken as part of this research are empowered by a process of data scrapping – whereby geo-referenced information and data from web-based Application Programming Interfaces (APIs) can be extracted into design environments. Here raw information is co-referenced. The platform is thus a conduit between APIs and computer aided design application (Rhinoceros 3D) through an algorithmic visual programming language (Grasshopper).

The focus is to hybridise disparate datasets from public services and private entities who have a vested interest in the city. This convergence offers architects, planners, and other disciplines an insight into behaviours of cities and networks all captured through decentralised systems. These can record and reveal patterns and offer new ways of engaging with the city.

The architectural and urban project is typically concerned with the design of static physical objects in a time and place context. The introduction of tools such as real-time data visualization and hybridization enable the reading and mapping of spatial elements and their change over time. One example of this is mapping the patterns of car parking within Melbourne CBD. In hybridising, spatializing this dynamic against the city-imposed time restrictions for parking (Figure 1&2) we can reveal disparities between city planning and optimal usage. In eliminating inefficiencies in car parking within the CBD we can suggest this redundancy of space be assigned to a more beneficial function within the city system – public open space, green space as an evidence-based design project.

This novel workflow within the profession of architecture aims to further the core competency to include an understanding of patterns, interdependencies, and relationships within urban environments. Only through the introduction of time as a parameter (enabled by real-time or historic city data) we can begin to reveal the medium and invariants in behaviour in which the city is suspended, how it can be manipulated and how we can steer change within our cities.

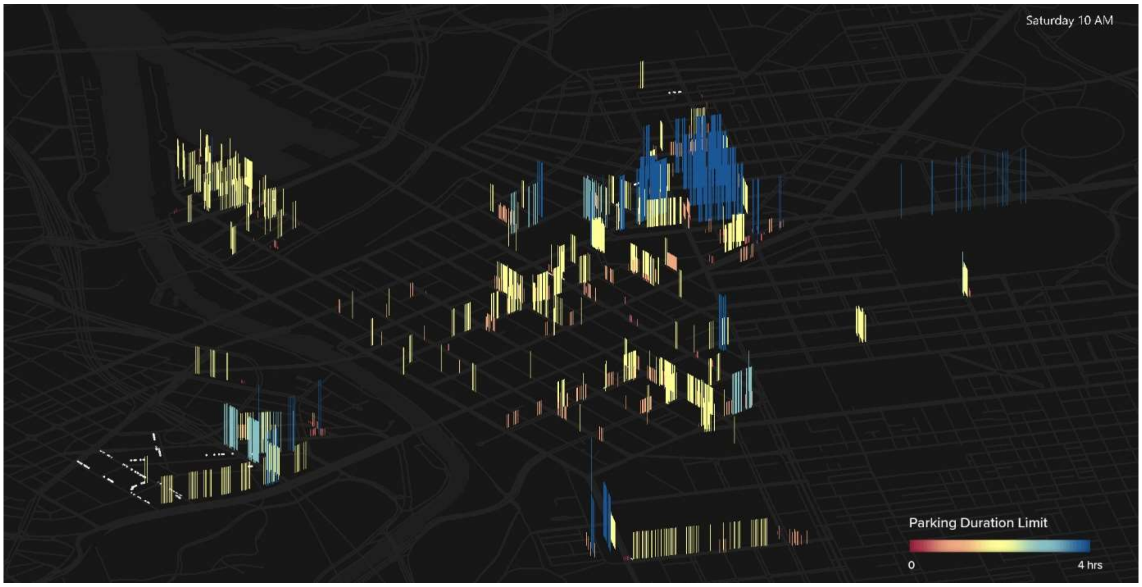

Figure 1. Visualizing carparking restrictions and their change over time in Melbourne CBD using Grasshopper and Rhinoceros 3D. Image: Kathryn Larkin, Temporal City with Ian Nazareth & David Schwarzman

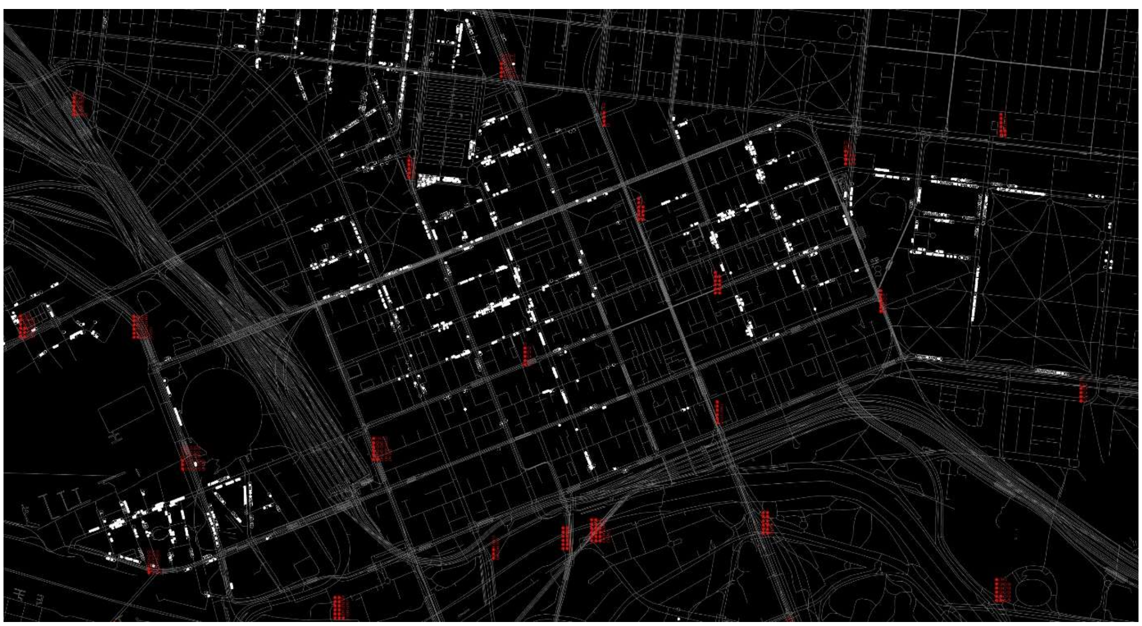

Figure 2. Visualizing real-time carparking and city bike sharing and their change over time in Melbourne CBD using Grasshopper and Rhinoceros 3D. Image: David Schwarzman & Ian Nazareth

4 Platform Technologies

'An ideal platform is like an empty diagram' _ Benjamin Bratton

'Platform Technologies' describe a group of technologies that form the base infrastructure upon which other applications, technologies or processes are developed and delivered. A platform operates as a digital/physical infrastructure that mediates in between heterogeneous groups of behaviours.[2] The city too, is a representative platform technology. It provides a core set of underlying infrastructure services for investment and speculation. Buildings and developments typically are the modular structures that that plug-in to the platform to draw upon underlying services. The analogy of platform technologies is intensified and abstracted.

The platforms of the city will not follow a deliberate plan. They are a veritable staging ground for actions and events like an open system. Coordinate systems are remade. Two-dimensional city structures unfold as three-dimensional matrices - grids become armatures. Cells explode as voxels. A hierarchy of modules or subsystems that in turn have their own subsystems. It is not an empty and neutral space exterior to its agents, but a behaviour in itself with a double purpose: on the one hand, platforms provide assistance by supplying specific tools, products and services, and on the other hand, platforms regulate activity by structuring development processes under a specific Ideological regime.[3]

Its manifestation will lead to new centres, hyper nodes, spikes rather than uniformity. The form of and networks of the city will be steered as much by 'technological infrastructures' and distributed applications, partitions, inter-node communication as by 'urban architectures', land valuation, prospecting and geography. The city will have greater levels of uncertainty and certainly more things are in play, accompanied by the systematic disassembling of traditional all-encompassing formats of early modernity, notably the nation-state and the interstate system.[4]

5 Transactional Urbanism

In Megalopolis (1961), Jean Gottmann began to describe transactional forces that stemmed from a labour pool once engaged primarily in the production of goods and tangible products, that were rapidly moving to a model of processing and managing intangibles like information and knowledge.[5] In assessing the role of cities, it became apparent that cities were still the 'principal loci'[6] for activities that were now akin to transactions. The shift into intangible domains was elaborated through The Coming of the Transactional City (1983). While the paradigm was rather nascent, Gottmann posits cities as hosting environments for transactional activities.

Access (in a broader sense) to nodes of hyper-connectivity are a vital force in globalisation. As a counterpoint to Thomas Friedman's 'flat world' dictum, which describes the levelling effects of technology on a global scale, urban theorist Richard Florida observed that from an economic, consumption and innovation standpoint the world is 'spiky'[7] – a view that is ratified by the explosive growth of cities, manufacturing hubs and nodes of service activities.

In the intervening decades, digital transformation has continued to be an imperious force driving the metamorphosis of cities and regions, where de-spatialised dynamics and variables increasingly effect how cities are described, understood and valued, fundamentally increasing pressure for deeper societal change.

'Transactional Urbanism' is a protraction of the flat, spiky, decentralised city, expressing the significance and influence of ubiquitous transactional exchanges on the form of the city. It presents the techno-social spatial domains that engender the city – an urban realm that is remote, dispersed yet kinetic and all-pervading and responds to a subtle relative pace of change. The transformational shifts are simultaneously incremental and rapid, and adjust, occupy and insert themselves within the fabric of the city. The 'sharing' or 'peer-to-peer' economy has accelerated the distribution and division of individual transactions, altering the form and order of the city.

6 Disruptive Sharing, Smart vs Collaborative

The now ubiquitous term 'sharing economy', also described as 'collaborative consumption' and the 'gig economy', is a decentralised platform for commerce and transactions, that operates from peer-to-peer (P2P).

While, the sharing economy is a product of capitalism, it signifies a new, possibly novel economic system, and the first since capitalism and socialism.[8] Economist Jeremy Rifkin places the sharing economy at the centre of the current epoch he refers to as 'The Third Industrial Revolution'. The 'cloud' (cloud computing), big data and an Internet of Things (IoT) have fuelled a 'planetary digital interconnected platform'.[9] The convergence of new communication technologies, energy regimes, renewables and mobility – i.e. an unfolding of a matrix of co-dependent 'internets', has collectively energised fundamental economic change.

These economies have prompted inventive if not radical application of logistical, commercial, spatial and legal frameworks. Their expeditious uptake has also raised serious regulatory concerns – from confrontations with labour unions, monitoring minimum wage to safeguarding users and contractors. We have barely begun to understand the sharing economy and collaborative consumption.

It is vital to locate the sharing economy adjacent to the concept of 'Smart Cities' which will also be a protagonist in the future city but rooted in a different set of assumptions and aspirations. The 'Smart City' has become symbol and symptom of political change, of aspirational governance shifting one's gaze from space to data, and from civic to corporatisation. Arguments against the smart city cite the following: that it is incompatible with an informal character of the city, that it subjects the city to corporate power and that it reproduces social and urban inequalities.[10]

The smart city as a proposition has become a hegemonic notion of urban governance, transforming and supplanting planning,[11] where the prevailing focus is infrastructure and not architecture or urban planning.[12] It is more than the movement of data. It is the exchange of capital.

Collaborative consumption is one attribute of the sharing economy, referring to events in which one or more persons consume economic goods or services in the process of engaging in joint activities with one or more others.[13] It involves not mere "consumers" but "obtainers" who may also be "providers",[14] and stakeholders sharing resources.

Surge pricing is feature associated with Uber and other ride-sharing services. In essence it's a supply-demand multiplier, that exponentially increases the rate at moments of bad weather, rush hour, and special events, for instance, may cause unusually large numbers of people to want to ride, all at the same time.[15]

The peer-to-peer economy, decentralised platforms, blockchain and decentralised ledgers have transformed the nature of transactional exchanges and unleash the potential for symbiosis, for cities within the organizational web of transnational systems. Cities and by extension their urbanism have been reluctant to renegotiate the dichotomous relation of centre and sprawl. Attempts to entertain this have been tentative and cautious. Cities are infinitely more complex than the binary that engenders them.

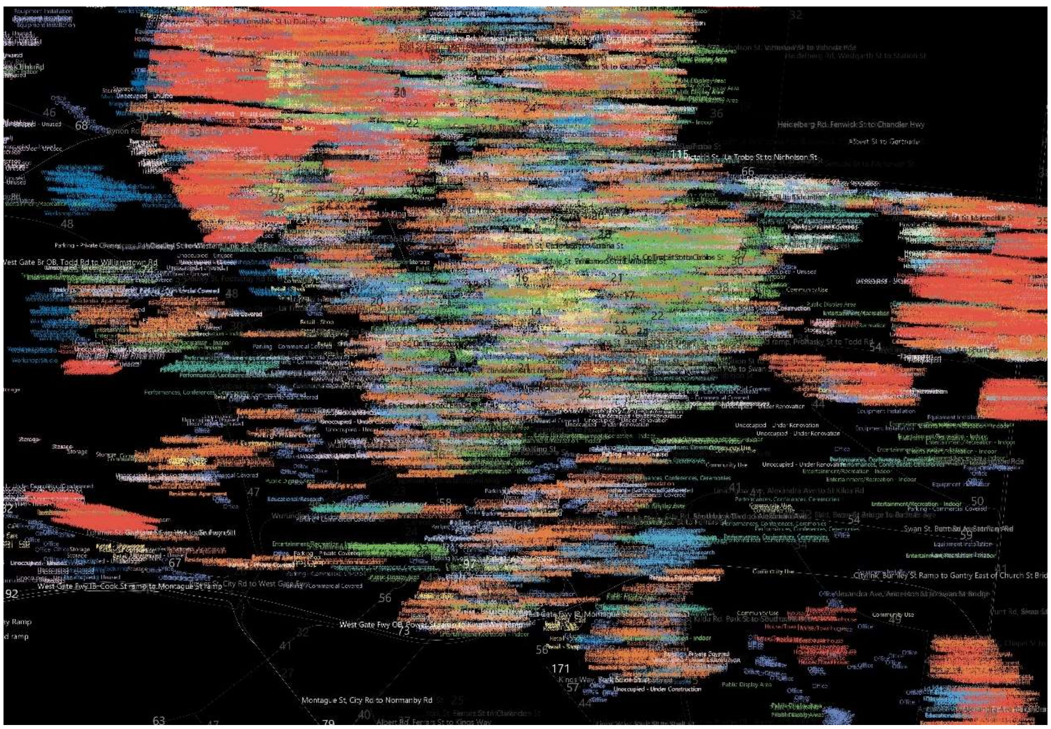

Figure 3. Mapping the functional mix of Melbourne using open-source data from the City of Melbourne. Image: David Schwarzman & Ian Nazareth

In the Functional Mix (Figure 3), the city simultaneously despatialised and dematerialised. It discloses a synchronous digital shadow and a legibility of the virtual registers of the physical city. Devoid of geometry, a surreal landscape of data emerges, described explicitly by geo-located information. The multivalent systems, densities, behaviours and inter-dependencies are perhaps indeterminate, but unravel in real-time.

The city, is a scalar field condition, permeating physical and virtual space - a medium, a substrate that hosts probability. The arena of potentiality is not created by but mediated by the city. Its fundamental constituents and elementary particles are held within a 'weak' force. Proximity and immediacy might be beneficial or symbiotic, but their variables are temporal and transient. The field is also a register and condensation of its immediate legacy.

There are physical implications to virtual agreements, these changes are already evident in the way cities operate and behave. Transactional exchanges perpetuate the idea of the city as an infrastructure and hosting environment. These services do not invent new forms or outlines but rather augments and interfere with the source code, the inputs and outputs and didacticism of the city. We are also familiar with its many mutants, variants and strains.

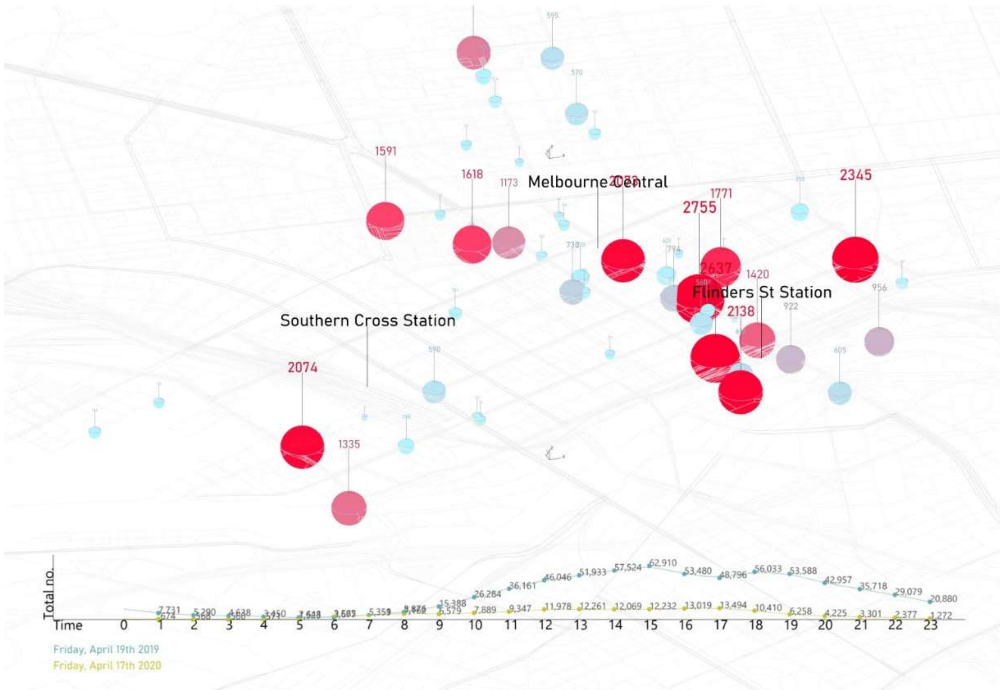

Figure 4. Mapping and graphing fluctuating pedestrian flows through Melbourne using real-time data. Image: David Schwarzman & Ian Nazareth

7 Big Data

"Billions of sensors tweeting from our pockets, the walls, and city sidewalks, reporting on minutiae of every kind: vehicle locations, room temperatures, seismic tremors, and more" _ Anthony M. Townsend

Big Data refers to complex data sets from new data sources data that contains greater variety and arriving in increasing volumes with more velocity, that traditional data processing software is inadequate. One scenario for discerning general trends in our city's usage and its social reality comes from a project which uses geolocated digital traces of mobile phone applications to map and speculate about a possible future for our cities.

Here we begin to understand an emergent city and architecture manifested through an operative, symbiotic entanglement between multiple agents simultaneously. These expansive protocols could include operative tunings in between ecological, biological, geological and algorithmic variables.[16] Information now becomes experiential with technology that promotes a haptic informational interaction with humans that is intimate and multisensorial. This extends to an imminent possibility for hyper computational processes to re-construct reality as another experience rather than as an abstraction of an experience.[17] The city is a physical experience and a discarnate experience, citizens fluctuating between hybrid realities.

The project utilises the 'Best time API' an API (like the 'Popular Times' feature on Google Maps) allowing users to read how busy any given place is (0%-100%) during any given hour of a week relative to its busiest hour. The Best Time API collects its data from anonymized smartphone GPS signals from third-party mobile applications from users who opt in. This project uses this data to describe and graph the usage of the cities various functions within a given block of Melbourne CBD. This data predicts the usage of the cities various functions and their fluctuations over 24hrs (Figure 5) giving insight into the dynamic social and economic patterns that the city enables within its static fabric. This disparity between dynamic use and the static physical substrate which enables it drives a speculation for a more adaptable architecture. An architecture which can shrink or expand, or change function to maximise efficiency of space use, a kind of optimised city-wide real-time timetabling system (Figure 6). In another example the same idea is visualized at the furniture/room scale (Figure 7) mapping out the fluctuating usage of furniture items & spaces and their associated typologies over 24 hours to highlight the temporal nature of their use in contrast to their permanent physical occupation of space.

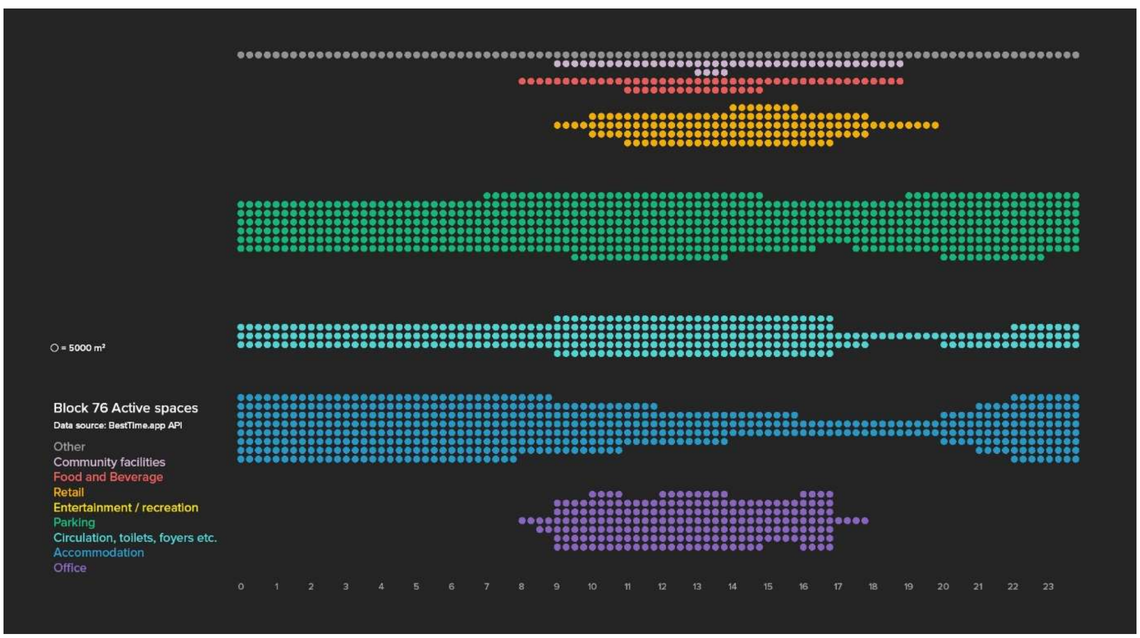

Figure 5. Graphing the usage of various functions over time of a particular block within the Melbourne CBD. Image: Kathryn Larkin, Temporal City with Ian Nazareth & David Schwarzman

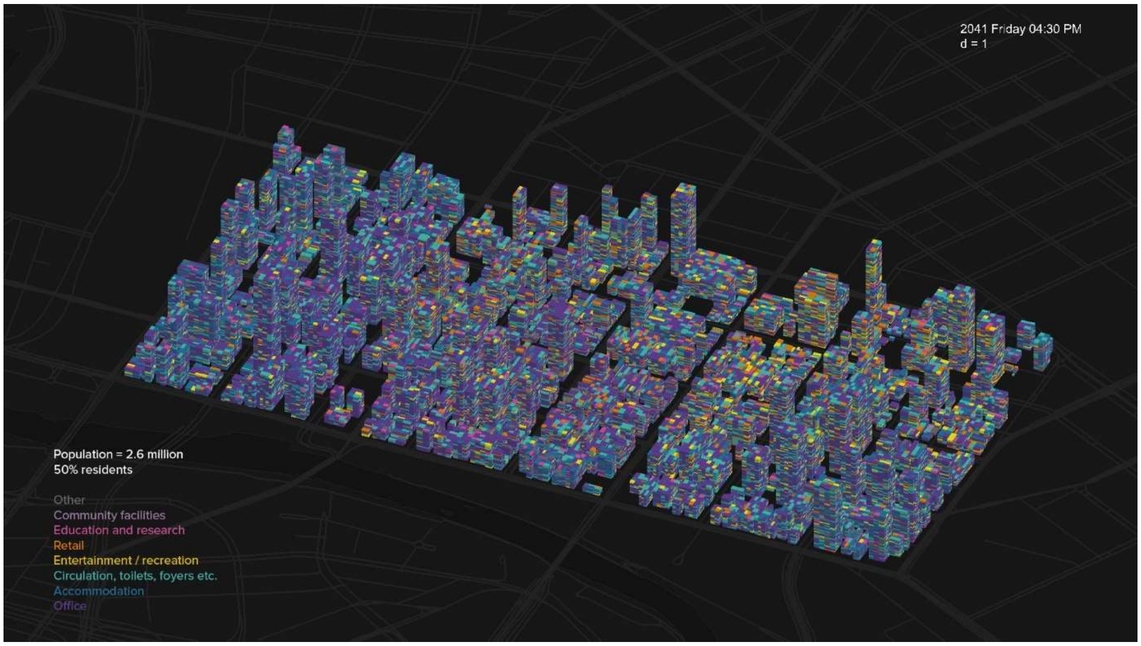

Figure 6. Graphing the usage of the various city functions and their change over time onto the existing fabric of Melbourne CBD. Image: Kathryn Larkin, Temporal City with Ian Nazareth & David Schwarzman

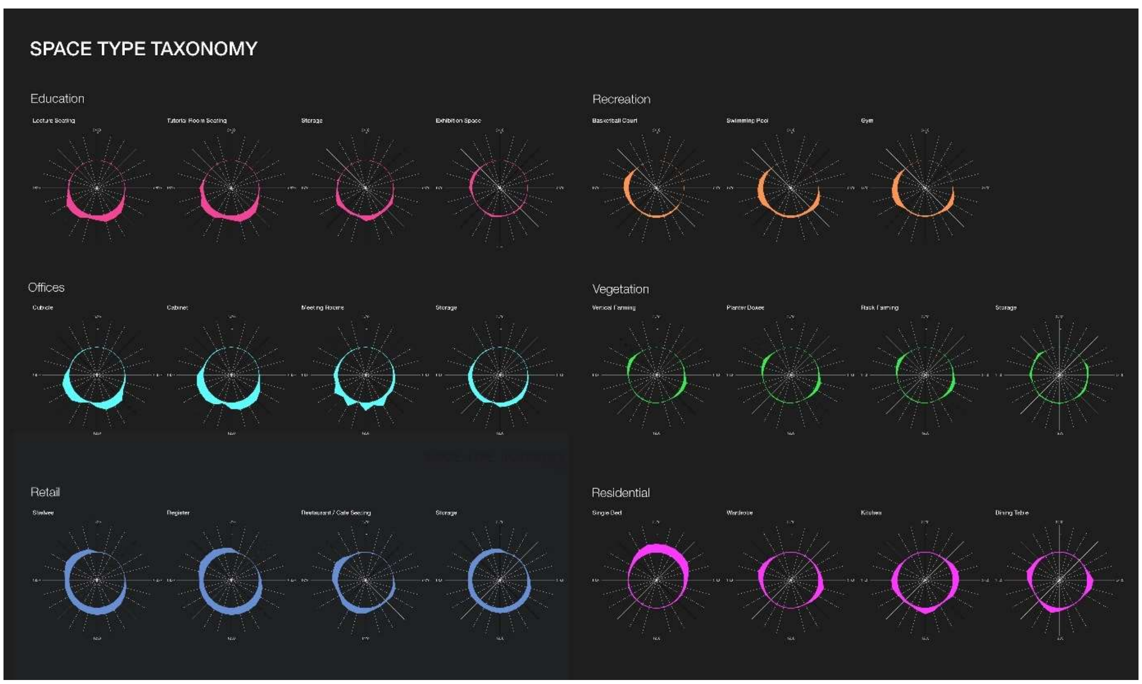

Figure 7. Graphing the usage of various space types over a 24hr period. Image: Anthony Mollica, Temporal City with Ian Nazareth & David Schwarzman

8 Conclusion

Embracing the next wave of technological prowess seems irresistible. The dystopic future of the city and society characterised by villainous corporations and helpless citizens, or one of labouring robotic character, is spurious at best. Decentralisation will accelerate multiple ubiquitous systems. All deliberations of sovereignty, governance and civil liberties will once again be revisited, re-drawing agreements and understandings - what do you give up, what is encompassed? what is excepted?

Future cities will be contingent, sited, and particular arrangements, that compel a re-evaluation of relationships with the environment and planet. Cities will encompass processes of production, distribution, consumption to disassembly and reutilisation. Food security, energy regimes, affordability, wellbeing, rewilding, etc. will all need re-contextualising. The borders between the city, states and nation will be subservient to the enterprise of the city. The organisation of the city will thereby be more strategic than opportunistic. The dynamic, kinetic city will mark a shift from closed loops to open systems.

The redistribution and decentralisation of the city into nodes and endpoints, exaggerates the idea of satellite cities. Independent satellites orbiting their own centres, urban networks creating, receiving and transmitting information, logistics, people. This new form of city cities as a strategic frontline will inherit a familiar society and culture. This is not a techno-utopia but there will be a certain alien-ness to its technology and transactions. High tech meets mundane.

One sees a city only in its most exaggerated sense. Overstated and embellished -points, lines, blocks and chains - an impression. One posits a version of the 'ecumenopolis' or the world city is more relevant. This is a city that sits in stark contrast to the current zeitgeist determined primarily by organisational and governance structures. This future city is also incompatible with a singular world notion of 'planet-city'[18] – where the world's population retreats into one hyper-dense metropolis housing the entire population of the earth. But it's certainly somewhere in between - the city as distinct archipelago rather than undifferentiated, limitless mass echoing the vestiges of earlier urban form.

The exact coordinates of the Temporal City are obscure. A moving, shapeshifting target. This city can only capture it through the alluring synthesis of a multiplication of order and centrality, that deftly weaves between centripetal tendencies and centrifugal propensities[19]. The Temporal City is immediate.

Where then does that leave the future of the city, or settlement? A reasonable degree of nodal compression, some disassembling and re-assembling. The city as a technology - settlements and commerce that might be infinite in spatial and temporal dimensions.

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INTERACTIVE PERFORMANCE: PRINCIPLES AND PEDAGOGY

Olga Mesa, Nathan Fash
Roger Williams University School of Architecture, Art, Historic Preservation
1 Old Ferry Road, Bristol, Rhode Island, 02809, USA
omesa@rwu.edu, nfash@rwu.edu

Abstract

The skin of buildings can be seen as a mediator between interior and exterior environments which are in a state of constant flux. On building facades, whether automated or human-controlled, the demand for transformation is crucial in order to accommodate and respond to multiple inputs, making them suitable to the changing conditions inherent in various time spans. As such, there is a mutual interdependence between dynamic facades and the environment.

In this paper, we outline a lens through which we expand the possibilities that arise from that relationship while referencing the process and outcome developed in a graduate-level design studio co-taught by the authors. Applied research has enabled computational technologies to map our environment, predict climatic patterns, target energy loads, and apply smart systems to design responsive, adaptable, and interactive structures. This has led to a common methodology that prioritizes designing building skins to attain optimal performance. And yet, an efficiency approach alone leaves behind a whole set of human and cultural considerations.

Within the arc of our studio, we applied a more rounded approach to the sustainable design of dynamic facades by considering both quantitative functional characteristics as well as the communicative and interactive potentials that are context driven. We developed a comprehensive understanding of environmental and social factors -- urban and rural sites, biology, culture, materials, and technology -- the connections between them, and their transformations over time, be it on a seasonal, diurnal, momentary, or geological span. We analyzed adaptable strategies from built and living skins, studied the programmatic and spatial implications beyond the skin and applied both low and high-tech building technology principles aligned with context. As a result, building skins were designed not as barriers but as dynamic elements of exchange within a greater ecology, to respond and contribute more meaningfully to the design of the built environment.

Under this approach, as building skins perform, they reveal how inhabitants relate to their context, both enabling them to gain a deeper understanding of their own environment, and of the multifaceted exchange that is active at the interface that is the building skin.

Keywords

Dynamic Skins, Interactive Architecture, Sustainable Performance, Design Pedagogy

1 Introduction and Background

Skins are membranes which mediate the exchange between the inside and the outside of an organism. The role of the skin in that exchange varies dynamically in response to internal and external stimuli. It can be, for instance, a heat exchanger through sweating, a mechanism of defense or protection through camouflaging or skin tanning, an energy harvester through photosynthetic processes, or a means of visual communication through expression. The morphology of skins in the natural world is correlated to their performance, which makes them inspiring and useful analogues for thinking about the function of skins in buildings. Yet the skins in the built environment are, more often than not, static. Collections of hermetic glass towers are abundant in urban centers. However, recent examples exist that transcend the static nature of the status quo, like the Al Bahr towers, which deploy a kinetic folding skin that mitigates solar heat gain and improves interior light quality [1].

Dynamic transformation can be attained not only by employing geometric principles and moving mechanisms, but also by harnessing the inherent properties of the very materials with which we construct. For instance, in the case of the retrofitted Hanhwa Headquarters facade, the characteristics of the solar cells in the photovoltaics make it possible for the facade to harvest solar energy [2]. Or in the case of the Prosolve 370e building, the façade acts as a filtering device to reduce pollution in Mexico City by using a titanium dioxide coating to break down nitric and nitrogen oxides when exposed to sunlight [3]. Recent research has studied the absorptive characteristics of clay for use in evaporative cooling of spaces in hot arid climates [4]. And although changeability--like the tendency of materials to weather, thermally expand and contract, and their potential for movement--is often resisted in the production of buildings for pragmatic reasons, this capacity for transformation presents great potential for responding to changing conditions if channeled productively. For instance, whereas the distortion of wood can be seen as a failure, the HygroSkin Pavilion uses the properties of thin wood veneers to open or close the pores of a skin in response to moisture content, potentially promoting air flow [5].

Whether through mechanical or material means, or by using low-tech or high-tech systems, the capacity of facades to transform is critical when aiming to adapt to a constantly changing environment. Adjusting based on specific loads allows building envelopes to perform in a targeted way, minimizing energy consumption and carbon footprint. Moreover, technological and computational advances have helped optimize skins in response to either environmental or human inputs. The development of more reliable construction methods, research on materials systems, along with more accurate weather predictions and simulations, sensing mechanisms, and behavioral tracking, have recently generated adaptable, intelligent, and responsive facades and promising building skin prototypes. For instance, the Media-ICT building in Barcelona limits solar heat gain by employing an ETFE facade that activates inner layers pneumatically when embedded light sensors are exposed to sunlight [6]. Or the thermo bimetals of the Armored Corset prototype feature a self-ventilating skin that uses the differential thermal expansion coefficients of metals to open or close a cladding system when exposed to targeted temperatures [7]. Meanwhile, the automated facade for the HouseZero prototype utilizes sensors, weather data, computation, and motorized openings to successfully regulate outside air informed by the immediate climatic conditions of the site. Additionally, it incorporates augmented reality technology, accessible to the inhabitants, allowing them to visualize airflow [8].

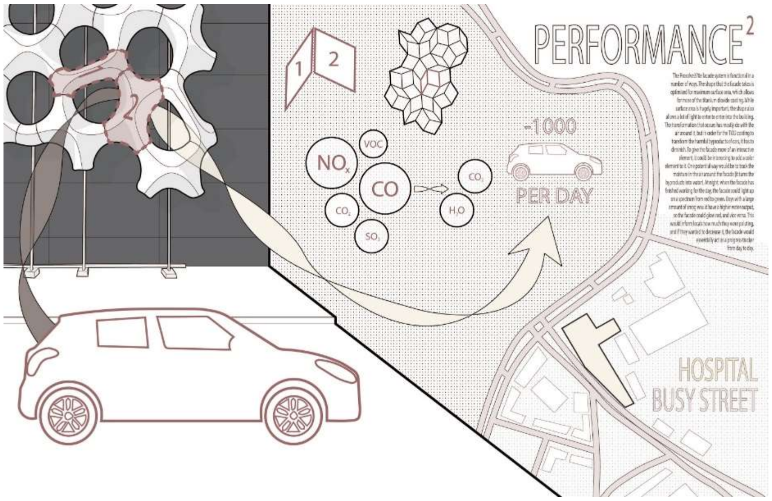
While technology-driven strategies hold great promise for achieving more sustainable possibilities with architectural design, it is important to highlight the strong likelihood that, in an effort to deliver indoor human comfort through automated or otherwise imperceptible means, designers can create an experience that is characterized by a detachment between humans and their surrounding environment. Thus, while we can recognize the benefits of and the need for energy efficiency driven envelopes and systems, we must simultaneously set our sights on the latent opportunities within the design of building skins to engage people, offering experiences that promote learning, appreciation, and caring for the environment and a better understanding of our role within it. This agency and empowerment through knowledge and behavior can take innumerable forms but remains largely unexplored in practice.

In this research we explore the mutual interdependence between dynamic facades and the environment. How can building skins act as elements of exchange within a greater ecology, and help humans understand themselves within it? Can the skin itself host new forms of habitat beyond that which the natural world already provides, and propose new ways of inhabitation? What are the extents of the interface that happens at the building skin? What are the performative, programmatic and experiential implications when addressing differences in height and the width of the spaces on either side of the skin? What opportunities arise for building skins when we account for human consciousness, engagement, and other human factors beyond comfort as part of our approach to sustainable design? These questions informed the development of a graduate-level studio co-taught by the authors. The studio structure and some examples of the investigations are featured below.

2 Studio Methodology

Prompts were developed to study how the performative capacities of building skin design are intrinsically related to their human and environmental context. In the development of their skins, students analyzed the context they were designing within, articulated the type of transformation enacted by the skins, the stimuli that triggered change, and the different time spans in play.

Sampling from a wide range of disciplines including Art, Architecture, and Biology, a collection of dynamic skins were documented. These precedents varied in their technological advancement, efficiency, and ability to express narrative [9]. For each, students identified the following parameters: design scope, context, stimuli, materials and technology, formal order and type of transformation relative to the function of the skins. Students worked from a variety of possible functions, considering the skin as a host of habitat, as a mechanism of defense, as a means of creating privacy, as a device for solar harvesting or solar control, as a self-repairing membrane, as a heat and humidity exchanger, or as a vehicle for communication. They also ascertained how notions of performance were evident and where both functional and phenomenological aspects worked in tandem (Figure 1a).



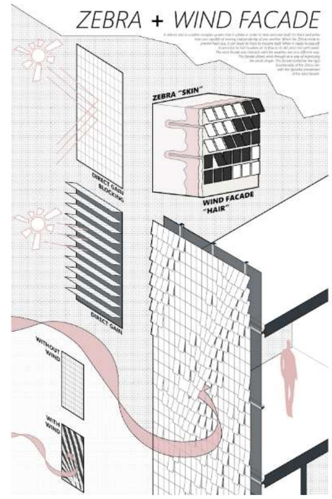


Figure 1a. Analysis of Prosolve 370e facade (left). Figure 1b. Zebra and Wind Veil Chimera (right), by Sean Flannery and John Dye.

Subsequently, students combined two skin precedents, one biological, and the other architectural, into the design of hybrid skins with the goal of expanding the kind of transformations enacted by them (Figure 1b). For this exercise, they reexamined how each of the original skins performs and the context and circumstances in which each existed. In joining them, they identified emergent opportunities as well as limitations.

Students examined four different contexts: Nuk, Greenland; Kyoto, Japan; Napo Province, Ecuador; and Marrakesh, Morocco. Each presented a range of climatic conditions and cultural identities which were recorded through an in-depth analysis of environmental, historical, and cultural aspects. Additionally, students analyzed examples of skins from both the natural and built environment to study the way in which these adapt to the specific contexts mentioned above.

Having documented the ways in which environmental and cultural contexts enable interactions between the inside and outside of natural and built skins, students adapted their hybrid designs to the specific sites and their environment. Students considered the morphological characteristics of the site, density of construction, programmatic uses, solar orientation, predominant materials used, socio-cultural factors, and natural landscape features.

Students identified technologies related to the performance that they were seeking, explored the implications of employing either high-tech or low-tech approaches, or a combination of these, to make the aspirations for their skin a viable facade proposal. They considered the skin in at least three sectional conditions: ground, mid, and top, paying close attention to the performative opportunities brought by these differences in height. On a smaller scale, they defined the type of mechanisms that their proposal would use to achieve transformations, the materials to be used, and how their properties would allow a dynamic exchange (Figure 2).

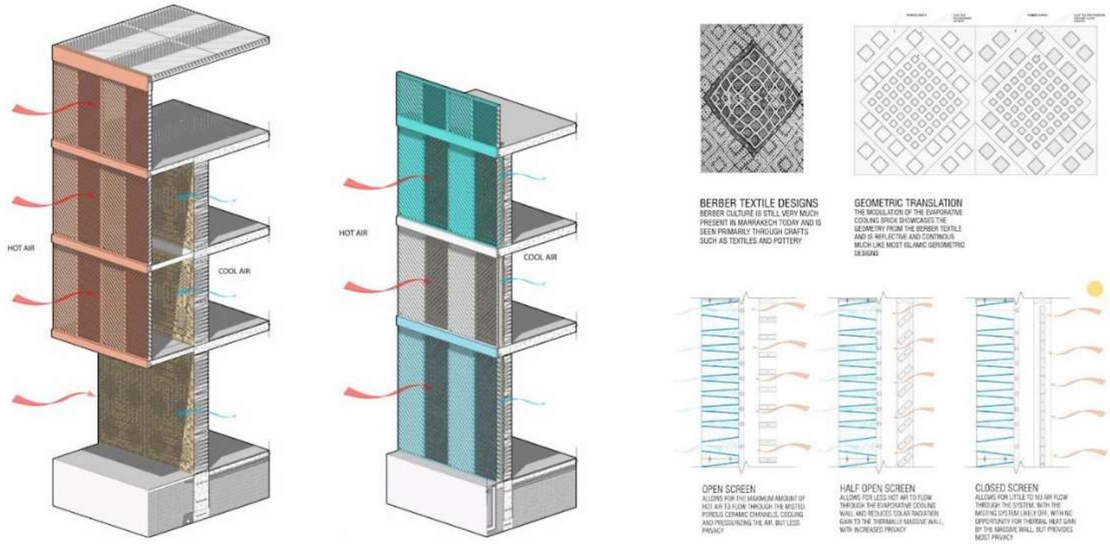


Figure 2. Berber textile-inspired ceramic porous wall, by Michael Montano and Rachel Kelly.

The skin was articulated at various scales in response to both environmental and cultural inputs. One of the main considerations in the development of their proposals was to consider the spatial and programmatic implications regarding both the difference in height and the spaces on either side of the building skin. For example, the adjacencies to a street or to the sky brought spatial opportunities, limitations, and programmatic activities that became intertwined with the skin, making it dynamic. Thus, the program emerged informed by human needs, desires, rituals, and other contextual social factors that originated with the exchange enacted by the skin in a particular site and its interrelated environmental circumstances (Figure 3).

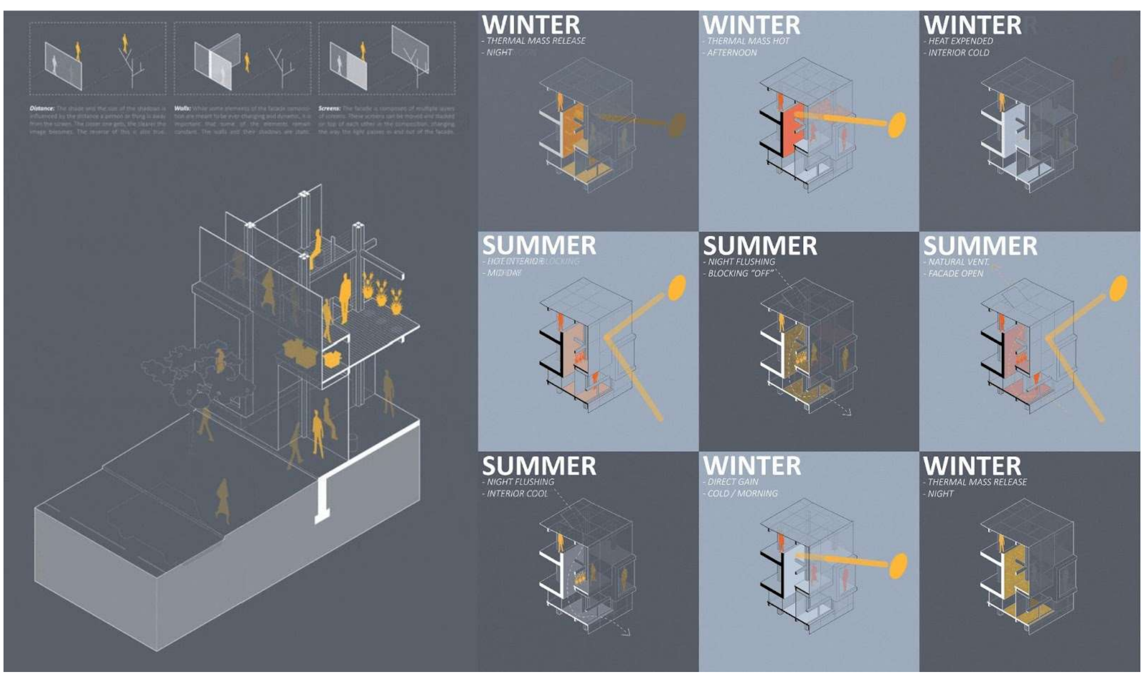


Figure 3. Programmatic activities in relation to diurnal and seasonal cycles beyond the skin, by Sean Flannery and John Dye.

The multi-faceted qualities of skins were tested through drawing animated wall sections that explored the types of transformations over time. Using animations and simulations, students examined the inputs that cause the skin to react dynamically, in response to environmental, human, or digital factors on both sides of the skin. They specified the extent to which users participate in the transformation and their level of control over it, and they defined the span of transformation (instant, hourly, diurnal, seasonal, annual), exploring the spatial and experiential implications (Figure 3).

Through the prompts outlined above, students developed projects that had their own drivers and constraints. Two student projects are presented here.

3 Learning Through Habitat

This project explores the idea of designing a school informed not only by anthropocentric parameters, but by the symbiotic relationships between humans and species, and in so doing, fostering an understanding and an awareness of the environment. The proposal features a school located in the rainforest of the Napo Province near the city of Tena, Ecuador that aims to serve the children of the Napo community by allowing them to learn about the flora and fauna of the area both within the “classroom” and while experiencing first-hand the environment from which they are learning. The approach takes advantage of the abundant educational opportunities offered by the natural world, in a context where culture values the sharing of knowledge through experience across generations.

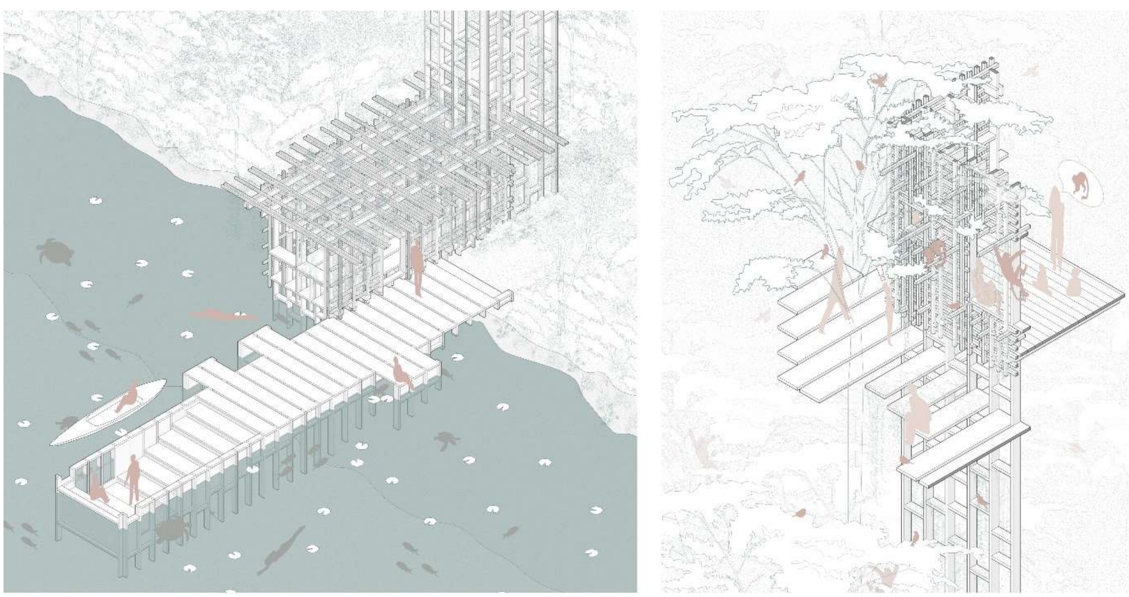


Figure 4. *Learning Through Habitat* ground, mid and top condition of the skin, by Karolina Domagala, Katie Whitin and Sean Flannery.

A series of pavilions located at specific heights are designed to host various animal and plant species while providing circulation for humans and sheltered areas for resting and learning. Using building materials found in the rainforest, the skins of the enclosures transform to respond to environmental and human opportunities brought by the elevational changes found in the Ecuadorian rainforest. For instance, the ground pavilions situated at the riverbank enable amphibians, salamanders and fish to nest in their thickened walls, while providing an anchor to tie down the canoes used by the indigenous community. In the middle section, vertical elements create an armature for bromeliads and orchids to grow and thus nurture the plentiful frogs and butterflies. This frame also supports a series of stairs that allow people to enjoy their surroundings and learn while traveling from one pavilion to another through the didactic journey that the architecture offers. The facades of the upper pavilions have a collection of horizontal rods for woolly and capuchin monkeys to play, and for macaws to perch while allowing inhabitants to experience expansive views of the treetops. The skins accommodate niches of various sizes and depths. Some pockets provide a place for plants to grow and animals to feed and take refuge, while others connect the interior with the exterior allowing children to inhabit the facade. Through the building skin, a dialogue is established with the different species which it invites. The use of low-tech strategies takes advantage of the precipitation in the area by directing rainwater to feed animals and irrigate the plants from the top down. The design of this project's skin exemplifies the potential of blurring the lines between the needs of plant and animal species and human needs and interests.

4 Embedded Community: Global Climate Change Awareness

The idea that we can design for change over time can be engaged at a variety of time intervals. Extending our understanding of time to a geological scale -- considering change over millions of years -- we can recognize that we are living in a period of rapid change in global climate brought on by human activities. These changes are shifting patterns of behavior in humans and other species worldwide, and we can expect that this will continue. Projecting forward we can then see a future in which areas of the world that experience extreme cold today will gradually become more appealing places for human habitation. Taking this long time span perspective as a point of departure, this project imagines an environmental research campus, sited in Nuuk, Greenland, which deploys scientific research coupled with growing environmental tourism as a means to build awareness of, and engagement, with climate change. The role of the skin extends beyond simply that of heat retention and daylight regulation and instead becomes a means of communication through its visible presence. Sited advantageously on a peninsula, it is visible to all incoming marine traffic, standing forth as an emergent beacon or icon.

As a model for environmental consciousness, the performance of the building skin is seen as an opportunity for demonstration. A variety of strategies engage with the challenges presented by cold temperatures and limited daylight. Active systems for harvesting and distributing heat and electricity are coupled with well insulated exterior envelope strategies. Translucent fiberglass sandwich panels provide daylight while retaining high-performing thermal insulation. Retaining walls and radiant floors make use of local stone as structure and finish material, providing a low embodied energy resource for construction. Meanwhile, spanning floors and roofs are imagined as cross laminated timber, as a means to capture carbon in the structural surfaces of the buildings. In addition to contemporary technological approaches, the project takes inspiration from vernacular turf houses, utilizing the natural topography to embed some buildings underground, while allowing other portions to emerge from the landscape. This low-tech approach enables less of the interior volume of the buildings to be exposed to the cold air, thus enhancing the thermal efficiency of the exterior skin.

Figure 5. *Embedded Community* site plan, section diagrams, and site sections, by Daniel Cusmano and Cameron Germond.

Figure 6. *Embedded Community* Thermal flows and wayfinding strategies, by Daniel Cusmano and Cameron Germond.

The roofs of freestanding structures play host to solar photovoltaic and solar thermal technologies, providing electricity and heat to support interior activities within the campus. Closed loop ground source heat pumps exchange heat with the warm underground, while interior radiant floors and vertical screens provide an efficient and targeted means of achieving human comfort.

Phospholuminescent panels are deployed to provide ambient illumination and wayfinding associated with public spaces, while also offering a potential physiological offset to the effects of light scarcity that are typical during winter months in Nuuk. Meanwhile the sloping surfaces of roof planes of embedded structures allow opportunities for recreational activities -- providing seating for a soccer field, or a slope for winter sports. The many manifestations of building skin thus become participants in the social fabric of the place.

5 Conclusions

Contemporary building skin design often centers its efforts on achieving human comfort and productivity within buildings, and although we are witnessing innovative developments that continue to improve their efficiency and efficacy, it is important to expand the range of factors that design responds to as we strive for a more comprehensive notion of sustainability. Beyond energy use and the optimization of building systems, we must address environmental conditions, socio-cultural dimensions, temporal considerations, phenomenological opportunities, and other contextual influences as a means to achieve well-being for both humans and other species in support of a healthy ecology.

Our perspective considers building skins as a dynamic interface between interior and exterior spaces, capable of responding to the constant flux of environmental and human factors, and as a zone in which these forces coalesce. We conceptualize building skins and their performance as the result of a mediation between environment, human (physical and socio-cultural) needs, and those of other species through different time spans. Furthermore, the way the skin responds to different scales -- global, regional, urban, block, building, and human -- and to different height conditions -- ground, middle, and top -- becomes richer when skins are dynamic elements that perform in relation to time.

The design of our graduate level studio and the student work demonstrate many design potentials for building skins when considered from this vantage and that building skins constitute a valid starting point for the development of spatial concepts. As the area of the exchange enacted at the facade is expanded, new formal, spatial, and programmatic opportunities emerge within that threshold and beyond the skin. The interface between inside and outside spaces can be a territory to host habitat and a zone for didactic engagement and experiential exchange among humans and other species that have been invited to participate. In doing so, building skins become active elements in redefining the extents of the natural world and challenging how we relate to it. They offer circumstances in which human behavior can be shaped through a dialogue that is not exclusively anthropocentric. The design of the skins can thus help impart a deeper understanding of the environment, inspire ownership, user participation, and stewardship in both the life of the building skin and beyond.

Acknowledgments

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FORM FINDING FOR THE POLAR STATION CZ*ECO NELSON

Martin Kaftan
Department of Experimental Design, Faculty of Architecture, TU Brno Poříčí 5,
63900 Brno, Czech Republic;
kaftan@vutbr.cz

Abstract

Over the years, polar architecture has undergone changes ranging from cruel shelters of whale fishermen to advanced science stations. In order to conquer such a harsh environment, these buildings test our abilities and demonstrate technological advancement. The paper presents research-driven design of a new Czech polar station. The design of this station is the result of collaboration among architects, engineers and polar scientists with the goal to develop a suitable building for the Antarctic climate that offers a state of the arts solution in terms of form optimization and comfort while being affordable. The construction system is tailored to restrictive logistics and complicated site conditions without the possibility of using heavy machinery. Furthermore, it implements robotic fabrication and invents structural logic that is able to form even non-standard architecture.

Keywords

extreme architecture, form optimization, energy concept, digital fabrication

1 Antarctica's specifics

Antarctica is a continent stretching around the Earth's south pole. Its area is approximately 14 million km2 (compared to 10.18 million km2 in Europe) [1]. It is separated from the nearest continent (South America) by the Drake Passage.

Antarctica is the coldest continent on Earth, with 99.97% of its territory covered in ice. In the continental areas, the climate is also extremely dry, with average annual rainfall below 50 mm, with most of it being wind-blown snow. The situation on the Antarctic Peninsula is different; unlike the mainland it is very humid, and the annual rainfall is 500 to 1000 mm. Temperatures are much milder here. In the coastal areas, the winds are very strong gusting winds (up to 300 km/h), with wind speeds decreasing inland.

Transportation in Antarctica is made very difficult by the extreme conditions, especially the severe frosts, winds and the ubiquitous ice. The only seaport in Antarctica is at the McMurdo Polar Station. In other areas it is necessary to anchor further offshore and supplies or passengers are transported to their destination by small boats or helicopter.

Politically, it belongs to no one; relations between the states in the Antarctic region are regulated by the Antarctic Treaty. The most important points of the treaty are peaceful scientific cooperation, the prohibition of military and the suspension of all claims to sovereignty over any part of the continent. It currently consists of a total of 48 countries, 29 of which have advisory (voting) rights in any joint decisions.

The Antarctic Treaty System has a strong commitment to protecting Antarctica's environment. The design process must comply with a number of regulations and rules that are more stringent than for usual construction outside the continent.

These regulations relate, for example, to environmental impact, use of materials, and waste management. Any new construction must first be approved by the Conference of Antarctic States Treaty, which is held annually in one of the 29 voting countries (the Czech Republic has had voting rights since April 1st, 2014).

1.1 Architecture in Antarctica

Due to its location and extreme conditions in Antarctica, building is quite complicated and requires proper preparation. All materials, equipment and supplies must be imported (usually by boat). Since the early wooden huts, the dwellings were primarily made from prefabricated parts to minimize the time spent on construction. The first buildings had no insulation and were not suitable for long-term occupation. Many stations were established during the International Geophysical Year (IGY) of 1957- 8 (49 stations)[2]. Their design was purely based on functioning engineering that would satisfy program requirements and cost.

What has changed since the early explorations is the technology available for building such stations and the design principles that are used to deal with the difficulties of erecting a human shelter in such a hostile environment. The newly built stations are progressing beyond simple dwellings for scientists and becoming science projects themselves, testing architectural capabilities [fig. 1]. They focus on sustainability and psychological impact on their inhabitants and can be seen in many ways as pioneers of future space habitats [3]. This justifies the high cost of many of these new stations.

Figure 1. a) Port Lockroy base - 1944,b) Princess Elizabeth - 2009, c) Halley VI - 2013

2 Czech Antarctic stations

Antarctic stations are generally founded from dedicated funds of the country it belongs to. This is nevertheless not the case of Czech Republic, which maintains two stations in Antarctica.

2.1 Johann Gregor Mendel station

This is the main Antarctic base of the Czech Republic. Operating since 2007, it was built in the course of two years between 2005-2006 on the James Ross Island [fig. 2]. It belongs to the Masaryk University, which funded its creation and maintains it. Therefore, the station was built on a very low budget. The main building of 305 sq.m. is composed of the so-called K-Kontrol construction system [4]. It is a sandwich wall panel structure made of two oriented strand boards (OSB) with an inner insulation layer of polystyrene foam. This construction system influenced the building's shape and simple one-story disposition. The system is protected against saltwater and abrasive storms from the outside by a façade made of 6mm waterproofed plywood fasted on a lath grid.

The station is located on a coastal plateau where thawing water does not represent direct risk to the foundations of the main building, but in order to sustain the building's stability, it is based on a grate made of railway oak sleepers fixed to the ground.

For the storage and maintenance are accommodated by shipping containers. Part of the electric energy is created by photovoltaic panels and stored in batteries. The station was originally also equipped with wind turbines, however, they did not sustain the gusty, direction changing strong winds, which is a problematic issue in Antarctica in general.

The station is inhabited only during the summer by a team with a maximum of 15 persons. The main areas of conducted research are geology, paleontology and biology.

Figure 2. J.G.Mendel station. a) construction from K-Kontrol system, b) final station

2.2 Eco Nelson

The station was founded by the Czech explorer Jaroslav Pavlíček in December of 1988. It consists of four small wooden huts and was established as a practical study in sustainable living, minimal environmental impact and survival skills. For thirty years it functioned as the only private station in all of Antarctica before the founder donated it to the Czech Antarctic Foundation (CAF) in October of 2017. The operator of the station, Masaryk University in Brno (or the Czech Antarctic Research Program, which is based at the university), is responsible for running the station. The University leased the Eco-Nelson station in 2018 from CAF for 99 years, with a plan to carry out scientific activities.

It is located at the very northern tip of the Nelson Island, a few dozen meters from the shore, which consists of a sandy and rocky beach. In the first season of the southern summer, after the change of operator, a general cleaning was carried out in cooperation with the Masaryk University and the CAF. During this phase, more than 6 tons of material was removed, and mandatory safety equipment was added to classify the base as a refugium. The buildings that make up the station allow only temporary use, with polar explorers sleeping in their own tents when they visit [fig. 3].

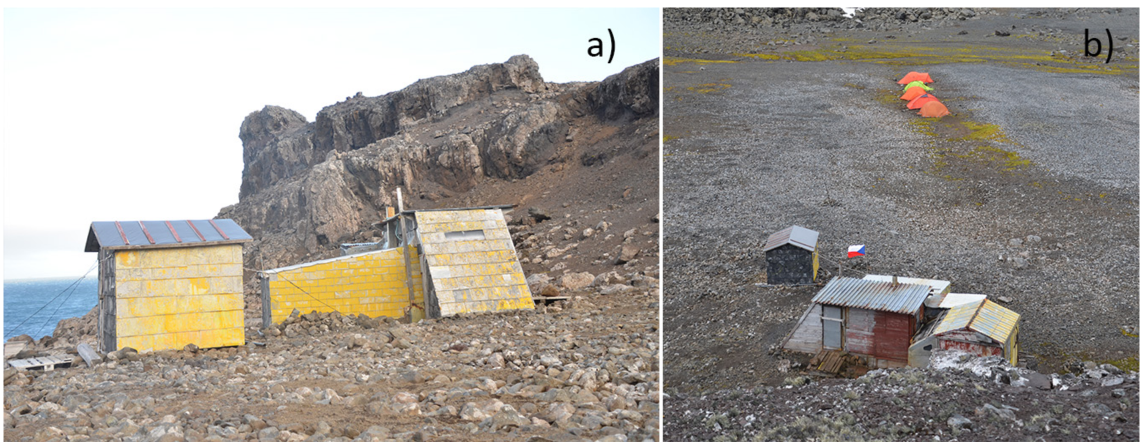

Figure 3. a) Eco Nelson, b) current state with scientists staying in tents

3 Renewing Eco Nelson to CZ*ECO Nelson station

There had been several attempts to replace the inhabitable stations with a new one, however, none of them went beyond preliminary design studies. In 2020 the Department of Experimental Design at the Faculty of Architecture, Brno University of Technology started to collaborate with the Czech Antarctic Research Program on defining the form of a new Czech station at Nelson Island. The task was to maximize the architectural qualities while maintaining a low budget. The design process since its beginning, brought together specialists both from academic and private sectors, however, most of the design process is driven by the enthusiastic work of architectural students. In 2020 it was approved by the national authorities that the new station will be named CZ*ECO Nelson.

The new station needs to meet several requirements:

- maximum built-up area of 150 m2
- living capacity of 6-9 persons
- maximum building height of 6m above ground
- each building component must be able to be lifted by max. two persons (< 60kg)
- construction system for a minimum of hand tools, no heavy machinery

- suitable foundation system due to the specific conditions of the subsoil
- orientation and shape of the buildings according to the prevailing wind direction to minimize winter snow accumulation on their windward and leeward sides
- the use of a natural water source
- drainage of rainwater from the station area so that it does not run into the sub-basement and freeze the following winter
- designing a sufficient ventilation system for the buildings to prevent the growth of mold and bacteria inside the enclosed spaces
- sustainable energy concept and waste management

3.1 Site conditions

Nelson Island is located about 700 km from Cape Horn (South America) and 110 km from Antarctica's mainland. It is part of the South Shetland Islands and has an area of approximately 200 km2 [fig. 4]. It is made up of mostly volcanic rock, 90% of which is hidden under the ice. There are lakes and streams that draw water from glaciers, drifts and snowfields. The shape of the coastline is varied, from sandy beaches to pebbles, small boulders and steep cliffs.

In terms of accessibility, the island can be reached either by boat, which can take around 14 days from the southern tip of South America, or by plane to the neighboring King George Island and taking a boat from there. Expeditions take place between December and March.

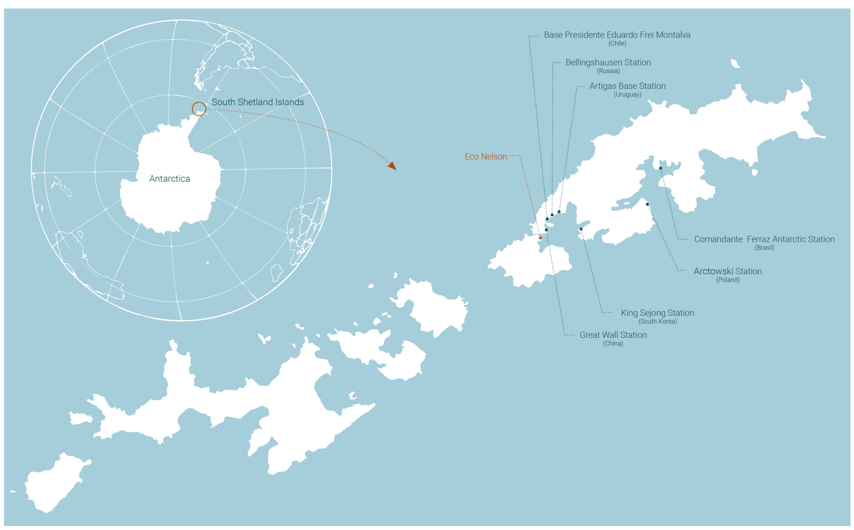

Figure 4. Location of the site on Nelson Island

4 FORM FINDING

The shape of the station and its aerodynamics were carefully considered to reduce wind loading and control snow accumulation. The sum of the floor areas of the original station is 150 m2, which was distributed between two new spaces; the main building and the storage room. The design process was inspired by the aerodynamic shapes of a water droplet in the early stages of design. The buildings were shaped and oriented in order for the roof to have optimal angles n each side for receiving maximum solar irradiation. The overall outer shell's angles and pitch were further optimized in terms of wind flow in a simulated wind tunel, so there is a minimized windward pressure and leeward suction. For the formfinding iterative process using a parametric model of the form, weather data obtained from the closest polar stations was used as an input [fig.5].

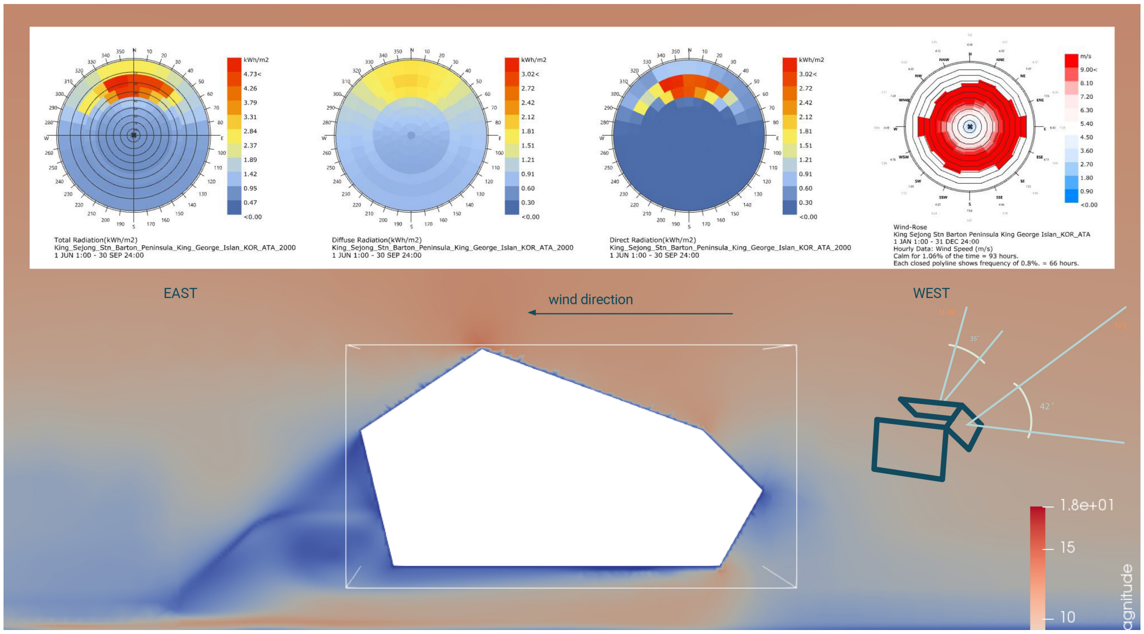

Figure 5. Graphs of obtained weather data (King Sejong station) and wind simulation

The resulting form was further rationalized into a suitable form in terms implementing a floor layout and construction. The main building is a living/working habitat for up to 9 scientists [fig. 6]. The layout was worked on with the experienced polar scientists, in order for the occupants to have a suitable environment for their research, but also gaining certain psychologically positive qualities.

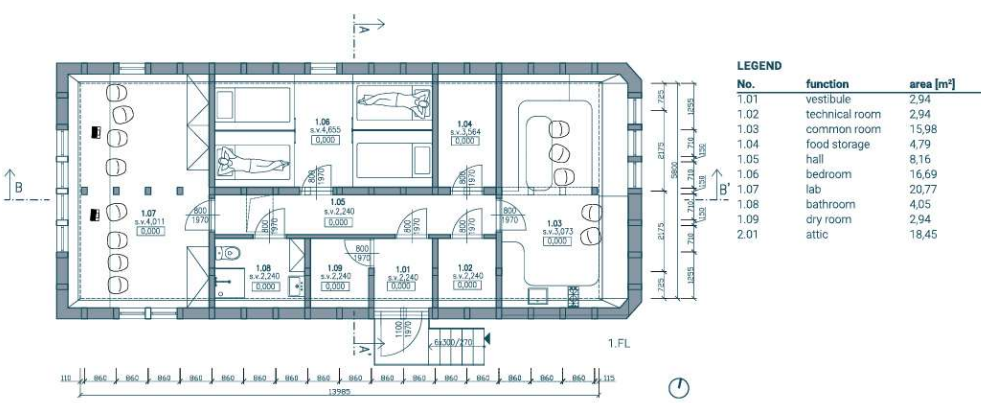

Figure 6. first floor plan of the main building

5 CONSTRUCTION SYSTEM

In the given climatic conditions, it is not possible to build using conventional construction methods. The ability to construct a building without wet processes is essential. Ideal inspiration is found in timber buildings. Antarctica's architecture has been using wood since the erection of its first huts. With the absence of bacteria that causes wood to decay, it lasts for many years and instead, rather fortifies itself. However, timber materials have also underwent significant development. In the case of the station J.G.Mendel a utilitarian structural system was used. This enabled low building cost, but it has limited structural capabilities, thus the building's form was kept as basic as possible. On the other hand, the structure of the Princess Elizabeth Station is 80% made of wood [5]. It was prefabricated from cross laminated timber (CLT) panels. The disadvantage is the heavy weight of such a construction and high costs.

5.1 Open-source architecture

In 20th century the housing crisis has received a growing interest from academia and industry. As a response open construction systems have emerged as a promising solution to achieve social, environmental and economic sustainability. They aim to enable non-professionals to build their own house without neglecting the architectural and construction quality. One of the most famous figures of the self-built movement is the European architect Walter Segal (b. 1907 – d. 1985). Segal developed a method which simplified the design and timber frame construction of buildings so that residents could build homes for themselves at a low cost [6].

The proliferation in timber materials goes hand in hand with rapidly developing digital design and fabrication. In 2011 an open-source architecture project called WikiHouse emerged. The project grew out of the realization that the current housing model is outdated and has led to poor quality housing. Like Segal's Method, WikiHouse uses standard sizes of commonly used materials to make the system cost-effective. For example, the primary structure is composed of OSB or plywood panels that fit together like a large 3D jigsaw puzzle. The prefabricated parts can be transported easily. The system has a high level of construction precision as the parts are produced by Computer Numerical Control (CNC) mills. The whole system can be constructed on site using simple tools.

5.2 CZ*ECO construction system

The original WikiHouse system, however, does not allow large form flexibility. Therefore, it was modified in order to suit the needs of form finding design. The modular system was changed, so even non-orthogonal boxes and frames could be formed [fig.7]. As this is not a trivial task to do manually, several digital tools were created to semi-automatize the process; the computational process defines the best subdivision of the previously sun/wind optimized form and divides it into construction segments in terms of structural stability and fabrication.

The construction system consists of load-bearing frames and stiffening boxes created from 18mm spruce plywood. The frames will be assembled on site from individual pre-prepared elements. The stiffening boxes are inserted between the frames and assembled before being transported from the location of its fabrication. The framework needs a 5 axis CNC milling machine and will be fabricated either in Czech Republic or in Chile (saving transportation cost). All structural elements will be filled with blown thermal insulation.

The buildings will be enclosed in a waterproofing membrane and coated aluminum sheets. The entire structure will be elevated above ground. Foundation sleepers or gabion foundations will be used to base the structure on a layer of permafrost and gravel. In case of using gabions, the steel cages will be filled on site by the rocks and the water would freeze inside, making it statically stable. However, for using rocks, a local material, permission is required from the Antarctic Treaty Committee. Being complicated in terms of fabrication, the on-site assembly is kept within the WikiHouse simplicity.

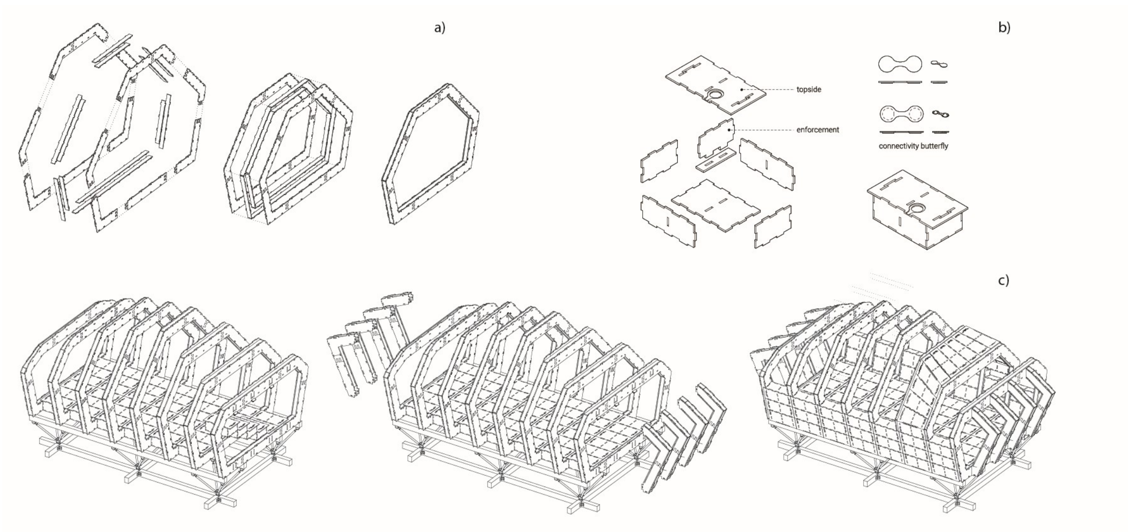

Figure 7. a) load bearing frame, b) boxes, c) assembly logic

6 Energy concept

The main power supply is a CHP System powered by vegetable oil. The produced heat will be used to heat the building, to preheat the fresh air, dehumidify the rooms and to produce the domestic hot water. The CHP System with heat storage is located in the storage room and is provided with an additional air heat exchanger to prevent overheating.

There will be a heat pipe to the station which supports a 1000l heat storage. The domestic hot water will be produced with a freshwater module using the direct flow principle. The heating system in the rooms will be normal convectors. To supply the person with fresh air without enormous thermal loss, there will be a mechanical ventilation air handling unit (AHU) with heat recovery. The system supports the station with 250 m3/h fresh air, additionally there is the possibility for a circulation air flow of 250 m3/h for dehumidification [fig.9].

The east and west sides of the roofs are filled with integrated photovoltaic panels. The excessive electricity by PVs will be stored in batteries. Over the summer months where the station is occupied (December to March) the electricity produced by PVs should be sufficient for 88% of the building's energy demand.

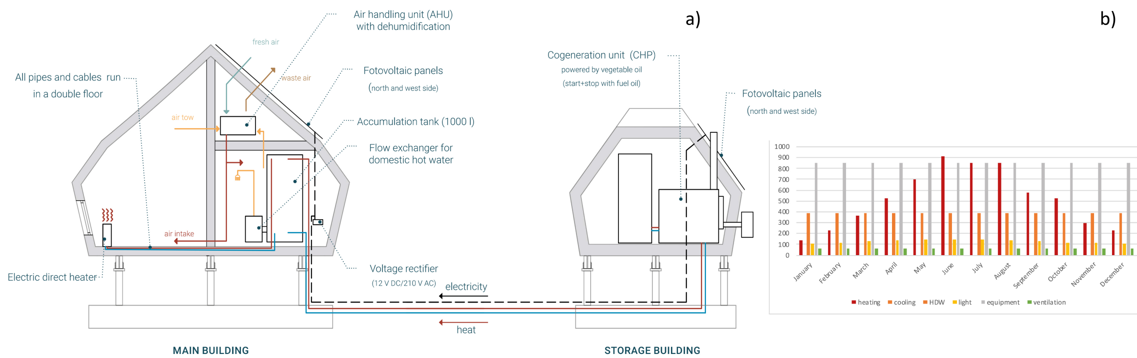

Figure 9. a) energy concept diagram, b) energy demand prediction

7 Conclusion

The timber construction for prototype of the technical building will be produced at the robotic lab of Brno University of Technology the building will be erected. The building will be tested in terms of structural integrity, fabrication logic and resilience against the harsh climate.

Simultaneously, by the 2021 design plans will be finished for submission to the Antarctic Treaty Committee to receive the approval to build. It is estimated that the station will be assembled on site in 2023-2024 [fig. 10].

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The energy concept was developed in collaboration with Sebastian Sautter.

Figure 10. Visualization of the new CZ*ECO Nelson station

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CHALLENGING THE REUSE:
STUDENT INTERPRETATIONS ON BUILDING ADAPTATIONS

Anna EFSTATHIOU

University of Nicosia
31 Michael Giorgalla srt., CY-2409, Engomi, Nicosia, Cyprus; efstathiou.a@unic.ac.cy

Abstract

This paper focuses on an analysis of spatial reconsiderations proposed by a number of design projects. It explores how immaterial characteristics of contemporary society are interpreted by Interior Architecture students to provide materiality in spatial design. During the educational process students are introduced to contemporary social, cultural and environmental issues and are asked to respond to them by designing and adapting uses, building structures and living norms. They analyse and interpret external stimuli and synthesize their proposals trying to capture and satisfy the present momentum.

Changing needs, changing economies, nomad users, and an ever advancing domestic technology create the context where young designers are requested to create. Flexible, adjustable, innovative and ephemeral structures characterize the outcomes of the educational framework, expressing to a great extent a general social attitude. The subjective interpretations become designed answers to given thematics and project briefs. An attempt to capture the waves of change and momentum is apparent. The main characteristics that occur are discussed in the present study. They can be defined by key issues such as “Adaptability”, “Sustainability”, “Interactivity” and “Social Engagement”.

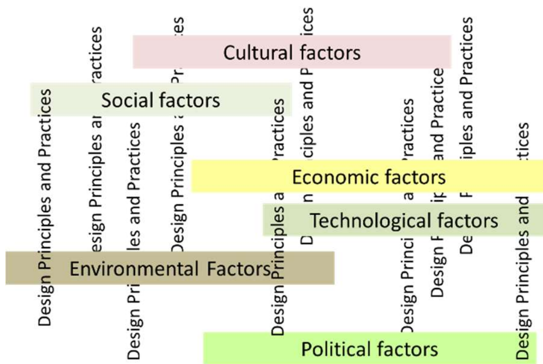
Adaptive reuse and a tendency towards flexible interiors rather than new buildings become major parameters in young designers’ decisions due to a global unstable economic and social context. Priorities such as the fragility of the environment, the control over energy consumption and the cost effectiveness result towards sustainable, multipurpose and malleable design proposals. Furthermore, technological innovation seems to be a significant supportive contributor.

Keywords

Adaptability, Flexibility, Interactivity, Reuse, Spatial Transformation

1 Introduction

This paper explores how immaterial characteristics of contemporary society are interpreted by Interior Design students to provide materiality in spatial design. Key Issues in Society and in Design Education together with a global design reference system weave the students' approaches together with the challenges they confront. The whole design production can be seen metaphorically as a creative loom where basic "warp threads" of design principles and practices are interwoven with the ever changing additions of "weft threads" consisting of technological evolutions and sociocultural turbulence. (fig. 1)



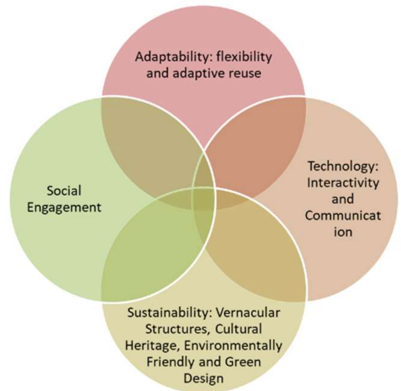


Figure 1. Design principles and practices are interwoven with the ever changing of technological evolutions and sociocultural turbulence to create contemporary interpretations in Design.

Figure 2: Contemporary Design Interpretations capture momentum through a complex combination of issues.

The Interior Design educational framework, provides the collection and facilitates the categorization of a number of examples that are studied in the present paper. The student interpretations are considered as designed answers to contemporary framework through given thematics and project briefs. The attempt to capture the waves of change and momentum is apparent. The main characteristics that occur and are discussed in the present study can be defined by the following key issues (fig.2):

- Adaptability: flexibility and adaptive reuse
- Sustainability: rediscovering nature, vernacular structures and appreciating the value of environment and green design
- Technology: interactivity and communication
- Social engagement

These issues tend to appear in complex combinations in the students' responses and a fruitful method of introducing young designers to the multitasking of their future is to lead them to collaborate with a variety of backgrounds in order to understand as many as possible different approaches. Additionally, Interior Design and Interior Architecture education has the responsibility to show to the future designers their social role. Therefore, the self-centred design is of no use in our demanding and difficult times. Adaptability becomes a major parameter in young designers' decisions. An unstable economic and social context characterized by shortage in states', municipalities' and private clientele's financial support, creates the need for seeking multipurpose, cost effective and malleable design proposals. As a result, adaptive reuse and concentration to the creation of flexible interiors rather than new buildings can be detected.

This tendency serves very effectively another parameter related to contemporary values, which is that of sustainability and green design. Adaptive reuse and sustainability share the same ideological background. The recent continuous and multifaceted crisis became for the students the driving force towards projects related to adaptability and green design. At the same time these tendencies are reinforced by a conscious or subconscious turn to the local past and are characterized by cultural heritage sensitivity. Young designers turn back to the basics, rediscover the advantages of a past close to nature and to traditional design and appreciate their value[1]. They care about wasting and overconsumption not as a result of an imposed ideology or an Avant-guard tendency, but as a reaction to the everyday problems. They understand the respect to the environment shown by their ancestors just a few decades ago, or by people from third world countries.

2 Student Interpretations on Building Adaptations

Due to financial issues in Greece, Cyprus, and Middle East, that consists most of the student's background, a large number of buildings that were either in the middle of the construction process or became abandoned by their previous users for a variety of reasons (either because they were difficult to maintain or related to bankrupted enterprises), provided to young designers ground to propose solutions and think of ways to contribute to their society. Additionally, the huge refugee and homeless waves in the Mediterranean countries gave rise to a more humane approach by designers who eventually show an increased preference to use their skills for a more socially engaged approach. Students are nowadays in between these necessities and values, but at the same time they are part of a global attractive and challenging network were information and technology are providing innumerous opportunities to innovate. A new tendency is then seen that of a new type of reconciliation between the essential/natural with the technological/smart. A rephrasing of Papanek Victor's "Design for the Real World"[2] could be "Technology for the Real world" expressing very clearly the significance to technology and innovation not just for the sake of it, but for a purpose. The student project works that are following support to a great extent this approach.

2.1 Existing Buildings, Urban Gardens and Social Media Applications

A large number of students realise a lack of a challenging urban green environment that will balance the depressing and demanding contemporary way of leaving. The unused urban fabric provides the ground for stimulating spatial solutions that deal with nature as a therapeutic provider of the basics' and a highly sociable agent.

A deteriorating building structure of the 50's in a low income residential area in Thessaloniki, Greece, is proposed to be transformed to an urban oasis. The existing abandoned and deteriorating concrete structure and the concept of aeroponics system are joined in one effective structure. Technology in the form of game design, similar to the "Farmville" or "Garden World" facebook applications, makes the project attractive and fun to all ages and target groups. School children of the neighbouring elementary school is proposed to encompass it in their everyday schedule and locals will get to know and support each other through a real and not just virtual network. The abandoned building becomes a provider of basic ingredients where the locals can cultivate their food. The designed system connects those who want to offer with those who need it. School children will be able to realise in practice the significance of nature. It can become the ultimate of a sociable adaptive reuse project, where space designers, game designers and agronomists exchange their knowledge (fig. 3).

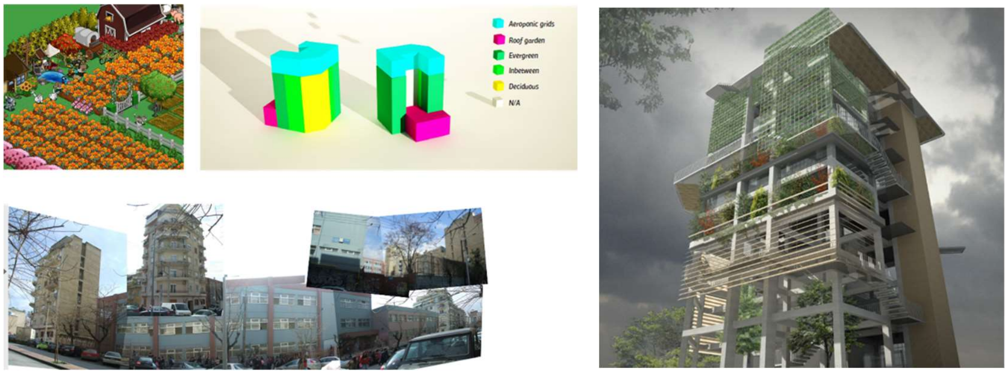


Figure 3: "Urban Nature". A deteriorating building in a low income residential area is transformed into a public urban farm. AAS – UCLAN, student name Marilena Dyranis – Maounis. Supervisor Anna Efstathiou.

2.2 Existing Buildings, Urban Gardens and Social Interaction

Interior Design students of the University of Nicosia were given as a project an unused parking building in the heart of Ayia Napa, the most touristic town in Cyprus. The task was to be brought back to life with the joint forces of the Municipality, the Art and Design Programmes of the University of Nicosia and the ResArtis Organisation. The Municipality is to offer the building and will benefit from a roof garden area for public gathering and open air exhibition park, the University will financially support the construction and will host in site part of its Art and Design lessons and summer courses, while the Res Artis Organisation, by using it will develop its network by offering at the same time cultural life to the otherwise lacking of cultural experience touristic establishments. Struggling between regulations and permissions and an existing depressing building shell, the students managed to propose a number of applicable solutions and apply the collaboration scheme. Flexibility became a very important design element and the interrelation of public and private spaces occurred as the outcome of a multipurpose sociable process (fig.4).

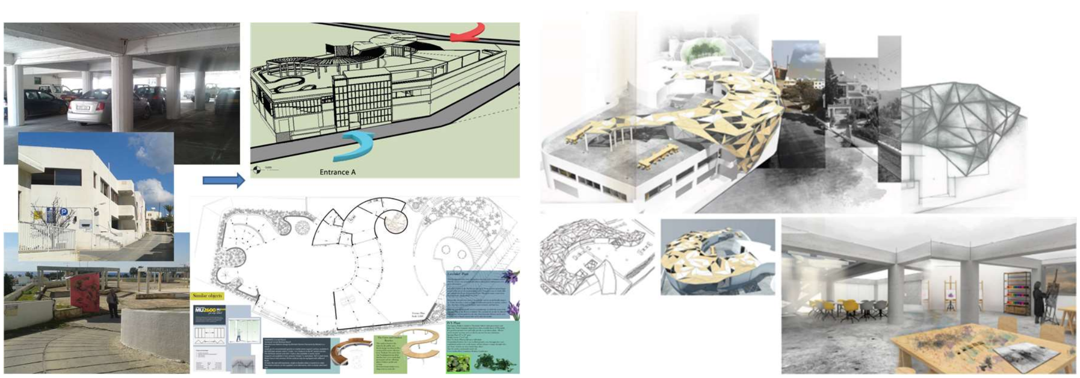


Figure 4: Public garden and open air exhibition on the roof of an adapted former parking building in Ayia Napa, Cyprus. Students' names: Reza Hajramezan, Marwa Avram. Supervisor Anna Efstathiou.

Similarly, unused, abandoned buildings are the remaining witnesses of the industrial past of the 19th century evolution. Industrial heritage complexes provide challenging shells for design solutions that respect the historical background and at the same time save valuable energy, material and labour cost. The University campus in Nicosia is amid a number of industrial complexes remaining of the previous cultural identity of the region. They become excellent case studies for the designers in education to analyse, reconsider, propose and reuse. The new uses and identity of the location as a University campus neighbourhood requires new uses such as food courts, wellness places and student/teenagers activity centres. Students' projects explore these alternative solutions (fig. 5)

Figure 5: Variations on the adaptation of a former industrial building in Nicosia, Cyprus. Students' names: George Xenofontos, Lourd Alarja, Andria Theodoulou. Supervisor Anna Efstathiou, Eleonore Zippelius.

2.3 Existing Urban Building Block Shells and Vernacular Courtyards

Reuse though is not only limited to industrial heritage. Residential buildings offer ground for reconsideration of ways of living and traditional ways of dealing with social as well as climatic issues. As it is pointed out (Efstathiou, Shehade 2018) "Social value relates to the fulfilment of a community function that may also shape some aspects of community behaviour. Residential courtyards denote a social life that distinguishes the common from the private, the personal family life from the public one. This social and cultural dimension is enhanced even more in the case of communal courtyards, shared by many neighbours, which created a communal, sharing microcosm. Each of these courtyards constituted a point of reference for accessing complexes of houses, but also a special bond which brought together many neighbours and created a very special sense of belonging and connecting to the other. Thus, this architectural feature was at the core of creating a community identity to its inhabitants. The function of this courtyard as a landmark or a symbol of home enhancing a sense of belonging, adds a very special identity value to the cultural significance of these courtyards."[3]

A most common building block in the suburbs of Larnaca, and a similar one in Nicosia, Cyprus, were proposed to be transformed to a multi dwelling unit of small but humane residences, where the forgotten vernacular Cypriot courtyard is retreated as an innovative solution to alternate the compromising, selfish, inwards looking urban apartment. The small scale developments gain from the collaboration between the new structural frame and the old typology. The main advantages of both the old and the new are combined to form a viable and challenging way of urban residence (fig.6).

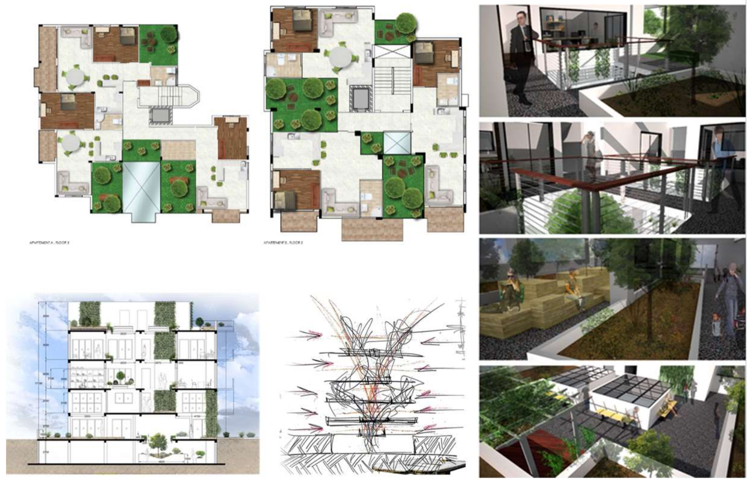


Figure 6: A building block is transformed into a multi-dwelling unit based on the vernacular courtyard typology, Larnaca, Cyprus. UNIC Student name: Maria Georgiou, Sophie Savvidou. Supervisor Anna Efstathiou.

2.4 Existing Buildings and Social Engagement

Young people in the south regions of Europe are among the mostly harmed target groups due to the continuous economic, social and pandemic crises. Unemployment is very high for ages between 20- 35 and highly qualified young professionals of that age range migrate creating a substantial brain drain phenomenon. The rest of the young people either quit from any creative and productive attempt or try to solve alone, beyond state or governmental contribution, their own problems. Social engagement attitudes and collective proposals seem to thrive, affecting a lot the form of design proposals.

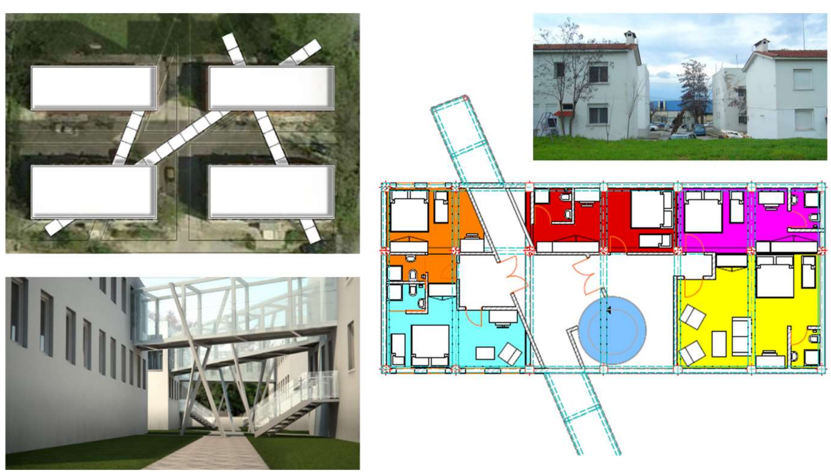


Figure 8: “Flexible Housing” residential project for student parent families. AAS-UCLAN Student name: Despoina Siamanti. Supervisor Anna Efstathiou.

The potentiality of the first of the presented projects (fig. 8) is deeply in favour of a solution to a major social problem, that of support to the one parent families and specifically those who are in the middle of their studies. Four old existing buildings, near the Aristotle University and the University of Macedonia area in the city centre of Thessaloniki, become the basis of a self-sustained community of young people studying in the University. The proximity to the University and the small scale of the complex become ideal for the purpose. The student proposes a highly flexible arrangement of individual flats that can be easily interconnected or separated from each other with a number of common spaces for parallel use. Those common spaces and the way the units are connected to each other provide a highly effective interior where the mutual support of the inhabitants is enhanced by the spatial design.

In another case the student used an existing abandoned warehouse building in the industrial area of Nicosia to host low income families and create a “Co-housing Community”. The existing skin provided the grid for a free arrangement of boxed container-like apartments. One of the main objectives was the creation of interior common spaces with direct contact. The proposed design supports and enhances the communication between users and introduces a small scale environment within a bigger shell. It considers the given grid and reintroduces a second parallel one, which signifies a second layer of functions and a successful, but not limiting, coexistence between the old and new (fig. 9).

Figure 9: “Co-housing Community” residential project for low income families. UNIC Student name: Diana Kochegarova. Supervisor Eleonore Zippelius.

Another student proposal (fig. 10) deals with the radically increasing numbers of homeless and refugees that are part of most of the European countries.

Figure 10: Homeless Shelter. UNIC Student name: Victoria Todorova. Supervisor Anna Efstathiou.

Thematics like this appear increasingly in the student proposals, as design students see their role affecting and being affected by social issues. Stations, day or night shelters and support centres, refugee camps and crises structures are designed to provide solutions to a major socioeconomic problem. Emergency architecture becomes a multifaceted task in contemporary studio thematics for Interior Architects and Designers. The project presented here combines the adaptive reuse of an abandoned building. Ecofriendly, reused and upcycled construction material and sustainable interior design are explored extensively. The use of innovative materials becomes not only an improvement to cost and sustainability but also to effectiveness (fig.10).

2.5 Existing Buildings, New Technologies, Social media

A series of abandoned former industrial buildings that became present squats are proposed to be used to host young professionals offering equipped common spaces related to the professions of the users in order to support the most vulnerable and most productive social groups. The building presented here is proposed to host graduates of the wide creative sector. The common spaces include library, printing and copying equipment, conference and meeting rooms, workshops and lab spaces. A reception area and pre-constructed building services are also provided (fig. 11).

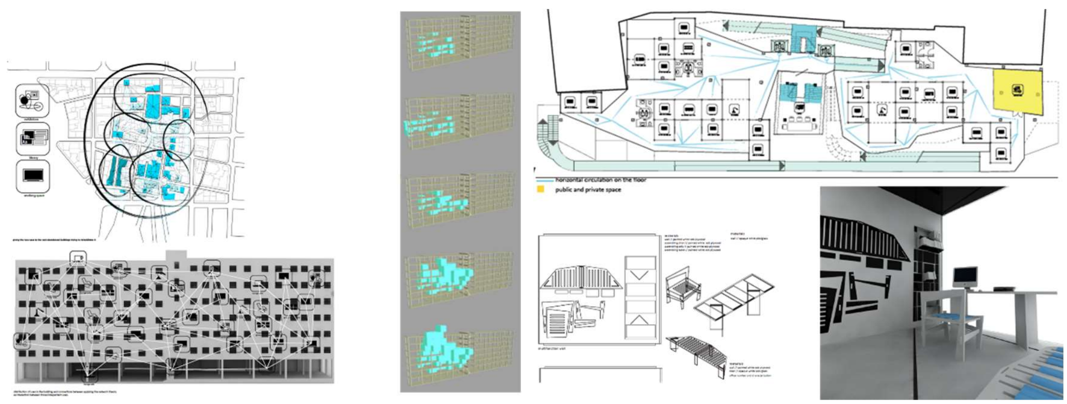


Figure 11: The "9 m2 para – spread" project is a network of small spaces to be provided to young professionals in the city of Thessaloniki. AAS-UCLAN Student name: George Gkiatas. Supervisor Anna Efstathiou.

The specific building is connected to a network of abandoned buildings and young professionals can access and apply for an office there through a mobile application. An algorithm calculates the empty slots in the buildings and addresses, through an application, potential users to specific spaces with relevance to neighbouring users. According to their preferences for proximity to other professionals or new inputs, the hosted people can easily change their placement in the building by directly informing the system. The continuous movement, the input and output to the building is presented in this virtual recording. The façade of the building interacts also to the recorded needs for interior light and to the exterior lighting circumstances creating a sustainable skin. Technology acts here as a valuable and communicative tool that supports communication and interaction.[4]

2.6 Urban Structures, Social Engagement, New Technologies, Social Media, Ecology

An urban structure is designed as an eco-friendly shelter, an information kiosk and donating centre, as well as a meeting place. The building materials used are created from waste agricultural produce. The project introduces also a fund raising method for maintenance and further research. Social interaction is directly implied by design (fig. 12).

Figure 12: “Re- project”: Utilizing plant residues and by-products of primary agricultural production. Student name: Olympia Theodoridou. Supervisor Anna Efstathiou.

2.8 Adaptable Interior Spaces and Interactivity

Flexible Interiors and multipurpose spaces provide the notion of “furoshikibility” , a term used in the 90’s my Michael Mönninger[5]. The wrapping material called “furoshiki” used traditionally in Japan for any wrapping purpose from becoming a wallet or a shopping bag, expresses the Japanese approach to multipurpose design, which introduces a variety of interesting approaches in interior design. Technology and Interactivity often support those solutions.

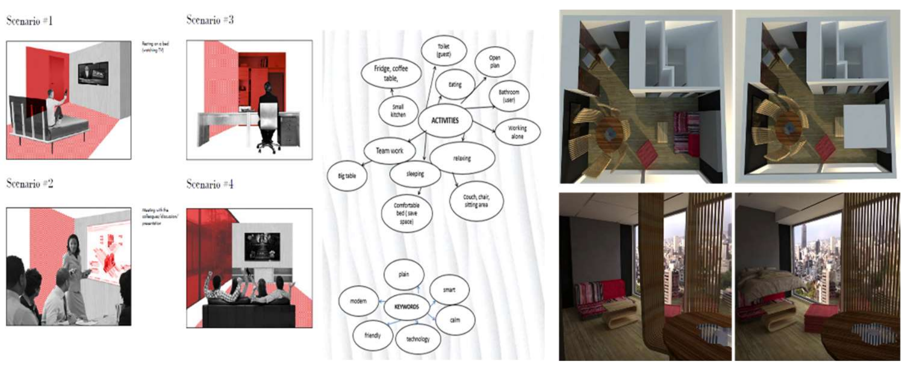


Figure 13: a. Scenarios of activities of mobile workers. UNIC Student name: D. Kochegarova. b. Transformation of a conventional hotel room to a more flexible temporal one that can host living, sleeping and working. UNIC Student names: A. Goineau, A. Theodoulou, V. Christophi. Supervisor Anna Efstathiou.

The mobile workers that characterize contemporary working norms demand a highly adaptable space for their short but regular visits to other cities or countries. Together with the demand for technological support and web connection, adaptability is of great significance. The examples that are presented here propose the transformation of a conventional hotel typology to a more flexible one that can host the specific demands (fig. 13).

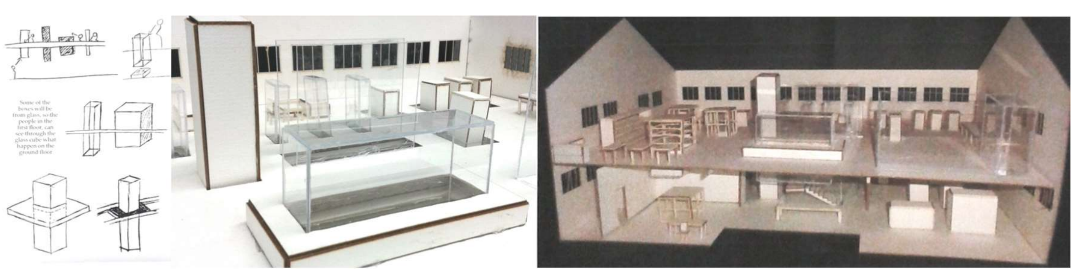


Figure 14: The glass cases of the exhibition space are moving according to the visitor's demand up and down through the ceiling seen from both floors. Student name: Athina Hadjinikolaou. Supervisor Anna Efstathiou.

Interactivity presupposes flexibility and is extensively used by design students, who want to provide a subjective narration to their target users. The abandoned building of a former printing industry is reused as a typography museum. The glass cases of the exhibition space, imitating the movement of the typographic machines, are moving according to the visitor's demand, up and down through the ceiling, seen from both floors. They imitate the printing motion and they offer to the previously deteriorating space, movement and life (fig. 14).

3 Epilogue: Design Education; Signifier of Society and Leader in Development

Design is always inseparable to the forces of a given society and its time. Design Education has to prepare future designers to be able to decode the requirements, the meanings and the intangible characteristics of their time and plan for a better future. Their creations will characterize an era, will signify its values and will facilitate people's lives. Therefore, educators should open all channels of information and awareness.

In our times Spatial Design and Interior Architecture students are required to be ready to respond to the continuous changes with adaptability and flexibility, to the increased needs of the less privileged social groups with inventiveness and openness of mind and to the fragility of the environment with respect and thoughtfulness. Technological innovation is here to support, to expand boundaries and connect them in a global network of active contributors.

Acknowledgements

For the present paper I would like to thank my students for the collaboration, the development of the teaching reference material, and the elaboration of feedbacks.

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A NOVEL HABITATION DESIGN METHODOLOGY FOR EXTREME ENVIRONMENTS OF EARTH

Gokhan DEDE

Politecnico di Milano
Piazza Leonardo Da Vinci, 32, 20133 & Milan, Italy; gokhan.dede@polimi.it

Abstract

The research paper explores a methodological approach for designing a habitation concept that does not need human assistance to be designed and built under extreme conditions when people cannot protect comfort conditions and cannot send project resources to the construction site.

The methodological approach considers climate change on a global or local scale environment because some environments are 'extreme' for the survival of their natural ecosystems; instances include enormously common unfavorable climatic events such as extreme colds, severe droughts, or storms. Another point is also important to realize that global climate change is causing particular, extreme ecosystems to become common.

Note. For more information on climate change and its consequences with future projections, see Intergovernmental Panel on Climate Change (IPCC, 2018)[1].

The work develops on contemporary research about comprehensive design approaches related to Earth's future and the current uninhabitable ecological locations. This research study uses annual weather data of extreme locations for human survival to develop a conceptual design of innovative habitation form and then simulate it with possible in-situ materials from literature review to analyze habitation's structural and environmental behavior under extreme temperature differences between interior and exterior atmosphere. Using in-situ material is essential to construct autonomously designed habitation by using additive construction technologies. In this regard, research phases including layout configuration, form-finding, a structural and environmental analysis aim to explore a habitation concept implemented with generative design tools as a decision-maker in extreme conditions.

Within this research project, due to the numerous extreme challenges of the design of habitation in extreme conditions by using conventional approaches, a performance-driven design methodology is done to provide a rational and sustainable design methodology to tackle extreme environmental barriers of the future.

Keywords

Extreme conditions; Habitation; Performance-driven design; Autonomous methodology

1 Introduction: The Need for A Novel Design Methodology

Researchers indicated in the IPCC report [1] that extreme conditions will appear in unexpected places due to global warming and environmental challenges. While extreme environments have already occurred on Earth, extreme climate scenarios will arise in other locations due to climate change.

Since the 1960s, space organizations have been attempting to discover other planets to teach about planetary science, comprehend the nature of climate change, and predict Earth's evolution. As a result of these researches, Wordsworth [2], [3], and Forget [4] state that Mars underwent a significant alteration at some point during its history. The dusty, dried husk we see today became a planet that once was something like the Earth.

For decades, organizations such as NASA [5] have been researching self-sufficient human dwellings to colonize the most extreme environments and deal with the obstacles of living in extreme terrestrial environments such as the Moon and Mars. These research projects conducted by institutes and space organizations can serve as a starting point for developing a habitation concept for any extreme environment to develop a design methodology.

The research project explores a methodological approach for designing a habitation that does not need human assistance to be designed and built under extreme conditions when people cannot protect comfort conditions and send project resources to the construction site. Exploring a design and construction methodology to develop an inhabitable space with a habitation definition is necessary for further developments of humanity to adapt to the most extreme environments like current and future extreme locations on Earth.

Extreme conditions that vary in every location or habitation's functional needs may alter depending on desired functionality for specific objectives. As a result, the research framework's subproblem identifies habitation requirements in terms of functionality, structure, and environment at the early design stage. It transforms them into design input of the required habitation to design a performance-based habitation concept to provide sustainability of design methodology under different extreme conditions.

The primary goal of the research project is to show a scientific design process that uses design criteria as input data to identify the most suitable output as an optimized design choice to enable autonomous advancement in extreme environments. The second goal is to enable the use of construction techniques such as robotic and additive construction.

Due to the numerous extreme challenges of design and construction of habitation in extreme conditions by utilizing traditional techniques, a performance-driven design methodology will be developed to conclude the research project to illustrate a systematic and controlled design methodology to overcome extreme environments.

2 Performance-driven Habitation Design In Extreme Environments

Shi and Yang [6] show that the performance-driven design theory effectively increases design rationality and efficiency, which stimulates its architectural design application. They highlight that performance-driven architectural design focuses on optimizing the design proposal's performance, taking into account the context, climate conditions, and functional needs, ensuring comfort, and putting in place the appropriate design strategies for the digital design platform. Before showing a performance-driven design process, each design need should be specified to be used as input for parametric CAD (Computer-aided Design) tools. To build a habitation for extreme environments, three fields of knowledge must begin and end the computer simulation cycle. Architectural design requirements, structural design requirements, and environmental conditions to create a proposal are covered.

After specification of design criteria from the literature review, a performance-driven methodology will be implemented to provide a reasonable and sustainable design cycle to define a generative habitation concept by following five phases which are;

- a literature review of habitation design requirements for the extreme environment;
- generation of diagrammatic configurations of design requirements with space syntax methodology and layout generation process;
- form-finding simulations for diagrammatic space syntax layout;
- structural analysis for habitation shell performance;
- the environmental performance evaluation of the proposed habitation concept.

2.1 Design parameters as input of the digital workflow: phase 1

Analyzing past space habitat missions and their design concepts is the starting point for establishing design criteria. Space habitats illustrate an optimal habitation concept where it has enough volume and surface internal size, which ensures that the crew can carry out mission work in a secure, productive, and effective way, including work, sleeping, feeding, servicing, housing, and other activities necessary for safe and successful missions.

In 2009, the Paragon Space Development Corporation's team of space engineers [7] carried out expert analysis of historical data and existing requirements for estimating crew volumes for the general nominal, contingency, and emergency operating scenarios using the 95th percentile male crew member of the American crew. The results of this study displayed in Table 1 will be specified as architectural needs for the design and analysis phases.

Table 1: Summary of volume allowances for functional areas per crew member [7].

Functions	**m^3 per crew**	**m^2 per crew**
Command / Control Area	1.06	0.7
Paylaod / Science Area	2.36	1.16
Kitchen/ Galley / Wardroom	1.06	0.7
Private Hygiene	2..36	1.16
Sleeping Quarters	0.85	0.56

The system's material choices, mechanical load, and thermal loads will determine the structural design requirements. Furthermore, using reference studies, particular structural requirements for the most extreme environments, such as the surface of Mars, are examined to execute design suggestions for specific extreme conditions.

Structural analysis of generated habitation in extraterrestrial circumstances must consider the significant loading variables impacting the structural framework of the habitat zone. The gravity, air pressure, internal air pressure, and temperature fluctuation are as indicated in Table 2 and Table 3. For three examples of thermal conditions, higher, lowest, and average outdoor habitat temperatures due to the changes in daylight, the thermal load calculations have been performed. Data in tables are taken from the study of Park et al. [8] on the design of structural Martian habitat analysis.

Table 2: Environmental loads at the Mars surface and the inside of the habitation [8].

Loading Case	**Mars Surface**	**Inside of the habitat**
Gravity Acceleration	3.721 m/s^2 (146.496 in/s^2)	
Air Pressure	0.6 kPa (6.0 mbar; 0.087 psi)	52.67 kPa (526 mbar; 7.639 psi)

Table 3: Temperature differences between Mars surface and the interior of habitat [8].

Loading Case	**Mars Surface**	**Interior Temperature**	**Temperature Difference (Δ)**
High Temperature (Viking 1 lander site)	-31°C (242K; -24°F)		56°C (56K; 101°F)
Low Temperature (Viking 1 lander site)	-89°C (184K; -128°F)		114°C (114K; 205°F)
Highest Temperature (Equator)	20°C (293K; 68°F)	25°C (298K; 77°F)	5°C (5K; 9°F)
Lowest Temperature (South pole)	-153°C (120K; -243°F)		178°C (178K; 320°F)
Average Temperature	-63°C (210K; -82°F)		88°C (88K; 158°F)

Table 4: Properties of Martian Concrete.

Normal modulus [GPa]	10
Densification ratio [–]	1
Tensile strength [–] [MPa]	3.7
Yielding compressive Stress [MPa]	300
Shear Strength Ratio [–]	4
Tensile characteristic length [mm]	55
Softening exponent [–]	0.2
Initial hardening modulus ratio [–]	0.12
Transitional strain ratio [–]	4
Initial friction [–]	0.1

The last structural load factor that influences the simulation is the construction materials selected for the solution. This research project does not involve developing new material for extreme conditions, but it is a crucial step to develop an approach that can be adopted rapidly to understand the behavior of any material under extreme conditions. The fundamental difficulty with the material is that the main research topic is based on extreme environments, and the existing opportunities to offer material from construction sites are seen as the only choice to use for building material. From this point of view, the mechanical characteristics of a newly produced in-situ material will be determined to perform the simulation, although the simulation procedure can be implemented in any local material. In the case of Mars, because the planet has previously been characterized as a "sulfur-rich planet," Wan, Wendner, and Cusatis [9] created Martian concrete, a novel material for on-site construction made primarily of synthetic Martian soil and molten sulfur. Table 4 displays its mechanical properties.

2.2 Generative layout design with the space syntax: phase 2

In this study phase, the architectural criteria of space habitation specified in the previous research phase are applied to develop the best-integrated plan configuration using Syntactic, a generative space-syntax tool created by Pirouz Nourian and Samaneh Rezvani at TU Delft [10]. This plugin integrates Space Syntax theory into parametric design processes with diagrammed input data configurations defined by Paragon Space Development Corporation for this research study [7]. Four syntactic steps can be computed, which are integration, connectivity, depth, and control value. The interior layout follows the functional needs for habitation, such as working, hygiene, exercise, preparing, and eating food.

The previously established architectural requirements are entered into the generative design interface via .csv (comma-separated values) files in the initial stage of generating a connection diagram. After inserting input data, points for each functional area are randomly determined, and connecting lines between the areas are drawn that must be linked to other specified areas following functional requirements. The result disc graph drawing and its analyses are shown in Figure 1. In addition, the space-syntax analysis of layout configuration is shown in the tables of analyses in Figure 1. Integration analysis defines the integration value of space as a result of the input data to indicate the degree to which space is public or private. According to this measurement, the higher the value, the more private space, and the lower the value, the more communal space. The degree to which a vertex in a network is superior to other points is calculated using control analysis. The choice analysis evaluates the degree of choice, determining how frequently space is on the shortest path between other spaces. Lastly, entropy analysis illustrates how space in a system is related. The greater the value, the more difficult it is to move from one location to another.

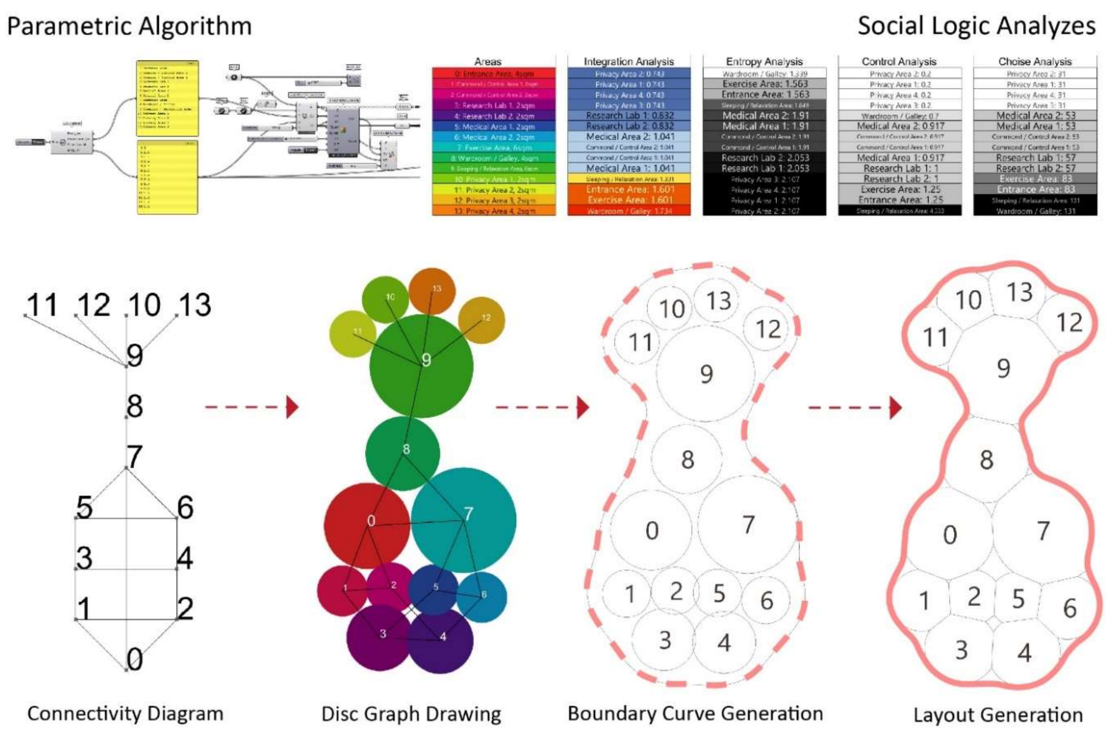


Figure 1. Bubble diagrams for generation and analyses of habitation layout

For generated diagrams, the next step is to mimic a boundary curve. The boundary curve must be automatically computed when the configuration of a conceptual diagram is renewed with a revised requirement input. The bubble diagram algorithm in Figure 1 generates center points for each circle, and radius values for each circle are calculated in Grasshopper using math equations derived from each region's areal data. The center points and radius values are then used as input data for Grasshopper's Metaball tool, which generates a metaball geometry from merged circle definitions. The radius settings have been tuned to produce the bubble diagram-like boundary curves. An isocurve with index zero was chosen to establish a boundary, and then the bubble diagram's circles were calculated angular geometries using a method to fit bubble diagrams within the produced boundary.

2.3 Shell Form generation with volumetric design tools: phase 3

The design of a floor-plan is an essential element in architectural form design that takes place between the design phase and the development phase to produce architectural form morphology as an input parameter, according to Sumini and Mueller [11]. The formula for the development of the inflatable habitat for exploration was provided by Sumini and Müller [11], as seen in Figure 2. The methodology created uses a 3-dimensional optimum layout diagram with areas that reflect the corresponding volume of each functional space. According to this process, the optimized diagram defines an external metabal envelope around the spheres by packaging them. The proposed form-finding simulation approach does not necessitate manual iteration, and the resultant geometry was used for structural calculations utilizing a structural simulation program called Karamba2.

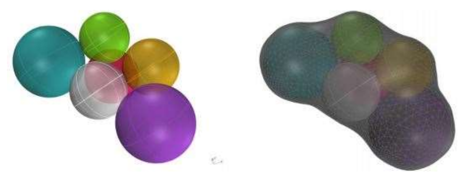


Figure 2. Form generation illustration [11].

This research study follows Sumini and Mueller's methodology, but instead of employing spherical volumes to build a metaball envelope, it considers using the resulting space-syntax diagram. When the space-syntax diagram is changed, the resulting envelope will be updated and will wrap the floor plan diagrams.

Figure 3 illustrates the space-syntax-based volumetric shape generating process. The center points of the functional regions are utilized as input data to characterize the volumes that correspond to them, and the overall volume is determined. The isocurves surrounding this volume are then approximated at regular intervals to construct a cocoon-like envelope that can be used as a shell against extreme conditions. The resulting isocurves are used to build the volumetric envelope.

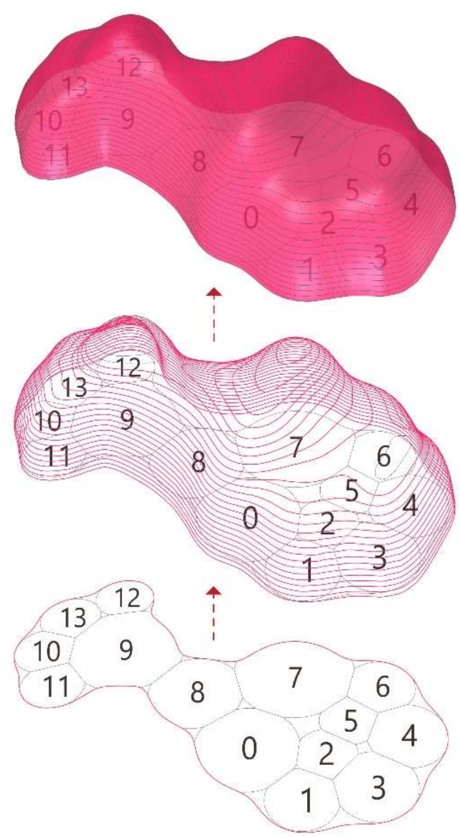


Figure 3. The illustration of habitation form generation process.

2.4 Structural simulations for Extreme conditions: phase 4

During this phase, numerical finite element modeling (FEM) was used to synchronize structural requirements with habitation design as a shell structure using a Karamba Structural Analysis Tool in the Grasshopper interface. The developed habitation form was analyzed as a shell structure since the system must be built with solid in-situ material, and the behavior of the structure must demonstrate stiffness like a shell under extreme environmental conditions.

The Support (Karamba) component defines the support conditions with six degrees of freedom (dofs), three rotational, and three translational. Because all supports are considered fixed, six dofs are indicated as fixed. The vertices as support points, a series of points on the edges of the form on the XY plane, are achieved with the MeshToShell component (Karamba).

The shell structure's self-weight is integrated with an algorithm of gravity, atmospheric pressure, internal air pressure, and the temperature load to model the structural behavior of the habitation shell under specified extreme conditions. The load of gravity is 3,721 m/s^2 and 0.6 kN/m^2. The air pressure inside is 52.67 kN/m^{2,} and the load of the temperature at the lowest, average, and greatest temperature on the Martian surface is computed independently. It is estimated that the internal temperature of the house was 25°C. For the analysis of habitat proposals, the defined data have been used: main forces, moments, shifting forces, maximum movement, and material use.

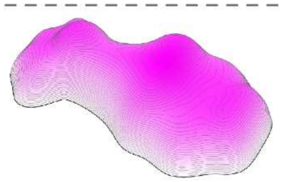
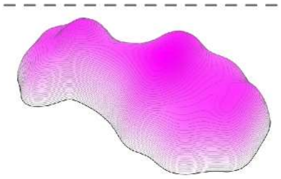
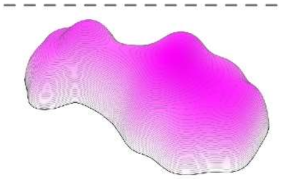
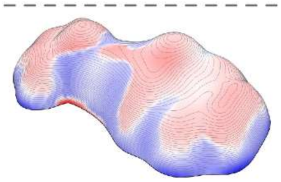
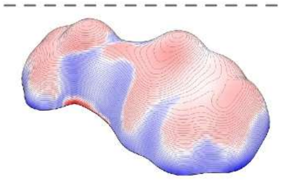
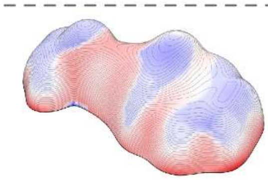
Interior Temperature: +25 °C	Exterior Temperature: -153 °C	Exterior Temperature: -63 °C	Exterior Temperature: +20 °C
Displacement Simulation (cm) +			
Utilization Simulation (%) − +			
Min & Max Principal Forces (kN)	-53.26 to +7696.70 (kN)	-53.26 to +3171.28 (kN)	-447.79 to +292.94 (kN)
Min & Max Principal Moment (kNm)	-300.39 to +1121.86 (kNm)	-125.88 to +453.55 (kNm)	-50.32 to +110.74 (kNm)
Min & Max Shear Force in X (kN/m)	-16681.86 to +25309.53 (kN/m)	-6869.52 to +10455.28 (kN/m)	-3243.62 to +2179.62 (kN/m)
Min & Max Shear Force in Y (kN/m)	-104579.09 to +102916.47 (kN/m)	-42993.33 to +42363.42 (kN/m)	-13479.94 to +13802.41 (kN/m)
Maximum Displacement (cm)	0.988558 (cm)	0.406 (cm)	0.129 (cm)
Material Utilization (%)	-12.4% to +14.3%	-5.2% to +5.7%	-2.2% to +1.9%

Figure 4. Structural simulation result comparison for habitation design

The maximum displacement values for the generated habitation typology shown in Figure 4 for a horizontal circulation orientation are 0.99 cm, 0.40 cm, and 0.13 cm at -153°C, -63°C, and

+20°C, respectively. Maximum principal forces increase by 143 percent, maximum principal moments increase by 147 percent, and maximum shear force values in the x and y directions rise by 142 percent and 143 percent when the temperature is reduced from -63°C to -153°C, but the model behaves differently when the temperature is increased to +20°C. As the exterior temperature parameter is raised from -63°C to +20°C, the maximum principal forces decrease by 91 percent, the maximum principal moment values decrease by 76 percent, and the maximum shear force values x and y directions decrease by 79 percent and 67 percent, respectively. The material utilization value for horizontal habitat design is between -12.4% and +14.3% at -153°C, between -5.2% and +5.7% at -63°C and between -2.2% and +1.9% at +20°C.

The resulting habitation shell design proved stable under dead and environmental loads. On the other hand, material utilization will vary depending on the material standards in place, and its attributes can be adjusted to fit specific requirements. Integrating structural outputs into future research stages will result in a complete procedure for autonomously designing advancement and optimizing it for varied functional purposes and environmental settings.

2.5 The Environmental Evaluations As A Decision-Maker On-Site: Phase 5

As stated, in extreme environmental conditions, a decision-making process is required for design and construction. The study will use weather data for one specific area to examine the level of radiation on the habitation surface to optimize site orientation for the annual maximum level of radiation.

NASA has been conducting research investigations in the most extreme corners of the Earth to understand better the environmental effects on specialized vehicles, technologies, and human comfort requirements. Devon Island, the Atacama Desert, and Death Valley are three of NASA's most extraordinary study locations. Except for January, Devon Island is the largest island with no human habitation and has a similar sunlight duration and radiation intensity to Mars. NASA conducted extensive tests on the island before deploying Mars exploratory vehicles. The island is located on Canada's northwestern coast, near Cornwallis Island.

Before running an environmental simulation, a particular meteorological data file called .epw must be retrieved from the EnergyPlus database. This file format contains a specific location, daily and annual meteorological data such as temperature, radiation, humidity, and wind. However, this information is only available in the database for the specific site having human settlements. As a result, the .epw file is missing from the weather data files for Devon Island, the Atacama Desert, and Death Valley. The meteorological characteristics and geography of the Atacama Desert and Death Valley may change if a different location is chosen, even if it is adjacent to them. On the other side, Cornwallis is separated by a river and has similar weather characteristics from Devon Island. Cornwallis Island has a file of weather data that can be utilized to simulate the environment as it is neighboring Devon Island.

In order to demonstrate the radiation orienting process shown in Figure 5, radiation analyzes have been performed on generated habitation design. The gathered annual temperature data showed that the maximum temperature of Cornwallis Island is +12.8°C, and the lowest temperature is –43.10°C. From February to December, the overall radiation level is 841,53 kWh/m², a low level compared with the average radiation on Earth.

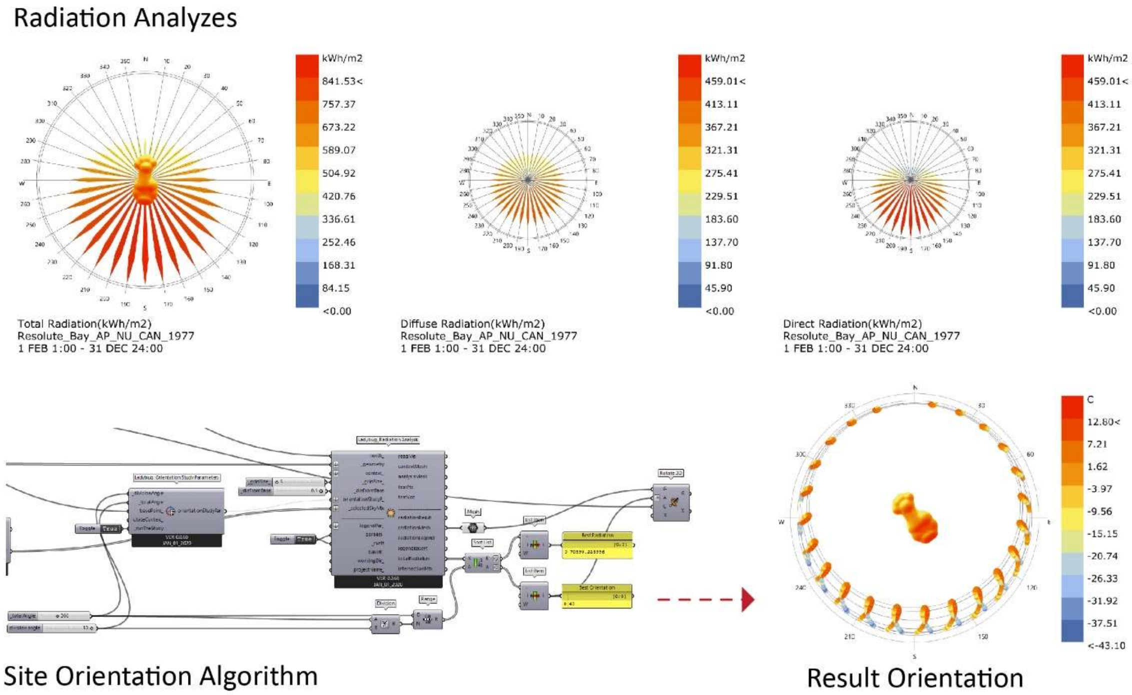


Figure 5. Structural simulation result comparison for habitation design

Following the completion of the radiation study, one of Ladybug's component tools, an optimization tool for orientation, is used to identify the optimal orientation degree. The overall orientation angle is defined as 360 degrees to include radiation from all directions, and a target angle of 10 degrees is defined to rotate the habitation according to this value to repeat its radiation level in each sequence of defined target angles. According to the output data, the habitation has been rotated 40 degrees to get the highest overall radiation. The use of radiation analysis-based site orientation parameters enables a decision-maker process in terms of site orientation without human assistance.

3 Conclusion and Future Work

This study explains the different phases of designing habitation solutions for the most extreme conditions to develop an autonomous process utilizing performance-driven design methodologies. Internal layout creation, form-finding investigations, and structural simulations with Mars load conditions have recently been done to establish an autonomous technique that does not require human assistance in extreme environments.

Layout configurations are formulated utilizing bubble diagrams generated by space-syntax generating tools to determine the best defined spatial relationships. When the layout configuration changes due to a change in connectivity definitions, a self-generated habitation envelope method is created using parametric design tools to reconstruct itself. As a result of this method, habitation forms for various design options could be developed. Because in-situ materials must be used, habitation envelopes are converted into a Finite Element Model as a shell structure for analysis and tested under unique load circumstances. A decision-making system, which allows the structure to be optimized based on its surroundings after showing that the proposed shell designs can resist extreme load situations, should be described as environmental analysis. In order to define the environmental positioning technique, the radiation study was performed, and site orientation in terms of sunlight was fully automated.

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ESTABLISHING THE ACCESSIBILITY OF PEOPLE WITH DISABILITIES IN THE TRADITIONAL SETTLEMENTS:

THE CASE STUDY OF SYMI

Niovi Tomou, Alcestis Rodi

Department of Architecture, University of Patras
Ploutonos 14, 17562, P. Faliro, Greece; niovi.tom@gmail.com

Abstract

This paper aims to reconsider the relationship among the identity of rural historic settlements, the accessibility of people with disabilities and the flexibility of public spaces. Disability remains at the forefront of the social and political agenda worldwide. However, in rural areas, due to existing preservation legislations, the necessary infrastructures for people with disabilities are yet to be introduced. Especially in Greece, the geomorphologic characteristics and the historic identity of mountain and island settlements, impede the establishment of such infrastructures. The largest percentage of island settlements is found in the Aegean Sea, which are the main touristic destinations of the country. Consequently, there is an imperative need to adapt these settlements to the contemporary disability policies ceasing the exclusion from public space of both residents and tourists with disabilities. Besides the expected benefits, an alternative resource of tourism revenues will be developed.

The island of Symi, in the Dodecanese, is an example of social exclusion for people with disabilities. In the past, many inhabitants were diagnosed with the diver's disease due to the intense sponge fishing commerce. It is important to acknowledge that, nowadays, the existing barriers of the built environment are causing the exclusion of people with mental and physical impairments.

In this framework, this research analyses *in situ* Symi's urban fabric and comments, based on the international requirements for accessibility, whether the settlement can become accessible to people with disabilities, without losing its architectural identity. Furthermore, it introduces new design guidelines in order to transform the historic public space and adapt it to the accessibility standards.

Through the case study of Symi, this research aims to highlight the imperative need and the means to regenerate sloppy, unwelcoming rural areas, in order to become accessible destinations for people with disabilities. Despite the peculiar topography and the identity of an historic settlement, after certain modifications in the urban morphology, rural areas can reach the values of universal design.

Keywords

rural regeneration; traditional settlements; accessibility; people with disabilities; public space.

1. Introduction

Nowadays, accessibility and inclusiveness for people with disabilities, are increasingly becoming a fundamental prerequisite for sustainable development. Although in the last fifteen years, there is a significant progress on accessibility in the urban centers, there are many unresolved problems in rural areas.

Residents of rural areas with disabilities face greater challenges than those of urban areas. This also applies to Greece. Most rural areas lack the appropriate, spatial infrastructure thus excluding people with disabilities from the public space.

Disability is an integral part of human life, as most of the human beings may, at some point, find themselves temporarily or permanently physically incapable[1]. In Greece, people with disabilities are estimated at 24% of the total population[2]. At the same time, the average life expectancy rate increased to 81 years, while the number of births decreased[3]. By 2050 it is estimated that the elderly will be 40.8% of the population. Moreover, the lack of the necessary standards for accessibility in the islands does not only concern people with disabilities, but the evolving aging population as well.

At the same time, the Aegean islands are an important part of the Greek cultural heritage and a constant value of the domestic tourism industry. Tourists with disabilities find it difficult to visit them, due to the absence of an equal and inclusive tourism. Adopting and adapting in the contemporary disability policies, would significantly contribute to developing an alternative resource of tourism revenues, both on the islands and in the whole country.

This research aims at the improvement of accessibility and mobility that will benefit not only the people with disabilities but the residents and tourists as well. Daily life in the islands, especially during winter, can be difficult, cut off from the rest urban centers. The case study of Symi, as a territorial and socioeconomic marginalized rural territory, will contribute to the further understanding of the built area of the rest Aegean islands, since most of them present common elements in the development and form of their residential fabric. For centuries, Aegean islands' architecture and settlement fabric have been fully adapted to the natural environment and local topography based on the principles of sustainable design. In a similar way, we strongly argue that their residents should transform traditional settlements based on the ones of Universal Design.

2. Methodology

This research aims to develop design guidelines in order to create an inclusive and accessible to all environment in the Aegean settlements. The Island of Symi is selected as a case study, a traditional settlement in the Dodecanese. The selection criteria were the island's high percentage of people with disabilities due to the sponge divers disease and the personal experience of the island. The research identifies, analyzes and evaluates the settlement's built environment in terms of accessibility. Through an *in situ* observation, after recording all the existent architectural barriers that make it inaccessible, the paper suggest ways to remove or overcome them, based on the international design standards.

A setback to our research was the lack of basic data, such as detailed, accurate and reliable mapping. Since 2003, there has been no recent version of the settlement's site plans. Therefore, large areas of the settlement were drawn from scratch . In order to confirm the measurements and recordings, I visited the island more than three times in a year. An equally useful tool was Wheel-map application, an online world map for finding and marking spaces accessible to wheelchair users. This application helped me to understand the type of roads that were defined as accessible or inaccessible, but also to exclude specific routes from the beginning, as they could not be modified into accessible ones.

The research is conducted in three sections. The first section presents an historical overview of the concept of disability in order to understand shifts in accessibility and inclusiveness. The second section focuses on the Aegean's settlements morphology, and ways of spatial regeneration. In the third, the contemporary built fabric of Symi is analyzed and evaluated based on . international accessibility standards so as to develop design guidelines that promote accessibility.

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3. Interpreting "disability "

Historically, people with disabilities always have been at the forefront of societies, with different cultures giving more or less weight to the acceptance of disability and its proper treatment [4]. Its complex, dynamic and multidimensional character makes it difficult to give a clear definition. It is a constantly evolving concept, defined by two correlated variables, time and place. These variables affect the way in which each person experiences disability, as well as the way they deal with the social environment.

In Greek the most common word for describing disability is "anapiria", the lack of physical capacity or integrity of a member of the body[6]. At the same time, "anapiros" is used for each person with disability. The etymology of this term was first introduced in the 5th century BC by Aristophanes and derives from the expression "*ana ton piro*", movement with aid[7]. This definition reflects the initially prevailing notion that disability defined the characteristic of the individual, the problem, or otherwise damage of the human body, which society required to be corrected. In the aftermath of World War II, the way of addressing the phenomenon of disability changed. The catalyst for the social exclusion was the ratification of the UN Convention of Persons with Disabilities (UNCRPD) and optional Protocol in 2006. Recognizing the complexity of the phenomenon of disability, the Convention became a cornerstone in its interpretation and perception. Thus, from an initially cold medical model, a new social model of disability was formed. According to this model, disability was perceived as "*an evolving concept that results from the interaction between persons with impairments and attitudinal and environmental barriers that hinders their full and effective participation in society on an equal basis with others* [8]."

Nowadays, taking into consideration the fact that an impairment alone would not lead to disability, if there were completely inclusive and comprehensible environments[9], another model of disability is introduced. This Interactional model views disability as a compromise between the medical and the social models, "*arising from the negative interaction between health conditions and contextual factors – environmental and personal factors* [10]."

Despite the diversity among people with disabilities, all of them still remain to the same degree excluded from their natural environments. Realizing the magnitude of the impact of the daily constraints they meet and their social exclusion, the conceptualization of the international requirements for accessibility has been one more milestone in the reassurance of an accessible environment.

4. The need for accessibility in the Aegean settlements

A total inclusion and participation in society for people with disabilities hasn't yet been achieved in contemporary societies. A large percent, higher than30%, still faces obstacles, both physical and social, in their daily lives. Especially in the rural areas, people face greater hardships due to he lack of appropriate equipment and infrastructure.

In Greece, most of the mountainous and island settlements are found located in unwelcoming? terrain. Moreover, priority is mainly provided to improve the living conditions in Greek cities where the 2/3 of the country's population is residing in urban areas. Thus, people with disabilities in rural areas are more likely to experience social exclusion due to social sigma, discrimination, lack of the necessary technological infrastructures and policy provisions.

The mountainous and rocky topography, in combination with the distinct architecture found in the Cyclades, the Dodecanese or the islands of the North Aegean Sea, compose a unique cultural unity. Despite the fact that the islands economy is based on tourism, they are difficult to be accessed by people with disabilities. The sloppy topography, the narrow cobblestone streets, the absence of spacious public spaces, create physical barriers for people with disabilities.

Taking into consideration the contribution of these historic settlements in the country's evolution and financial growth, while recognizing the importance of an equal right in tourism for people with disabilities, there is an impeding need to regenerate and reform them. At the same time, except for people with disabilities, we must provide as well for the aging population, as a result of the increase life expectancy. Specifically, in Greece life expectancy is estimated at 81 years, representing so far, a percentage over 21.3% of the Greek population. Consequently, there is an intense need to improve the infrastructures of those traditional settlements in order to facilitate the living conditions, not only for the visitors but also for the permanent residents.

4.1. The Aegean settlements' morphology

A distinctive trait of the Aegean that proves its special character, is the coexistence of various "microcosms" in one region [11]. Primary concern of the inhabitants was to adapt to the prevailing conditions of each place. Without any intense intervention in the natural surface, they successfully adapted the construction of the houses on it. The houses, until today, are developed organically, following the landscape's slopes, each one of them supporting the other. All the island cores, known as "Chores" seem to be rooted in the rocks. The inhabitants always made sure that these areas were protected from the strong winds. At the same time, the insecure living conditions from the successive pirate and foreign invasions, from the Middle Ages to the 19th century, created the need of a defensive architecture. Several "Chores" are either built on the top of the mountains, or 'hidden' in natural fortifications.

In many cases, the remains of the first citadels are still preserved as tourist destinations, carrying the name “Castle”. On the inside, these citadels were densely built up, with narrow and often labyrinthine roads, for extra protection. Usually, the stairs of the houses were placed on the narrow alleys, reducing their narrow width even more. Concurrently, the desire to save space and consequently the construction materials, contributed as well in the suffocating layout of the dwellings. With the arrival of the 19th century and the acceleration of urbanization, the settlements’ architectural character changed. The houses spread beyond the boundaries of the old castles, without a predetermined plan. Many settlements expanded their boundaries, reaching the sea level, making them more accessible.

However, their urban sprawl made the residential fabric more complex, as it caused several unforeseen problems. Steep ascents or steps with uneven ridges and narrow widths, made it difficult to move and transfer the goods for the households. The islanders were forced to use daily these sloppy arteries, carrying the merchandises either on the shoulders or on donkeys. Thus, they improvised small ways and tricks to face this unfavorable landscape. Such a solution was to add large landings in the public steps as a resting area in their ascent or descent. In addition, they learned to step sideways at the landings for preventing the protrusion of the sole in slipping. Another way to deal with the sloppy geomorphology was to create ramp ladders that followed its declination with landings bigger than 0.60m. It is worth mentioning that they never crossed the ascents vertically. In order to reduce the physical effort and retain their endurance until the end of the slope, they were climbing the stairs following a zig-zag path.

Unfortunately, these methods were not always successful. Strong evidence of exclusion and isolation of residents due to the hilly topography, are the cases of Symi and Kalymnos, where many sponge divers were struck by the disease of the divers. According to personal testimonies form locals, the bed-ridden divers were carried on the shoulders of their friends or relatives, sitting in chairs, or lying on stretchers (Figure 1). People with congenital motor or mental impairments, due to social stigma they remained at home and were not participating in the island’s everyday life, being able to go out on the island.

It is generally striking that despite people's interest in adapting to the place, there was a lack of provisions when body functions were limited, not only due to disability but also due to aging. To this day, the problem unfortunately remains unsolved.

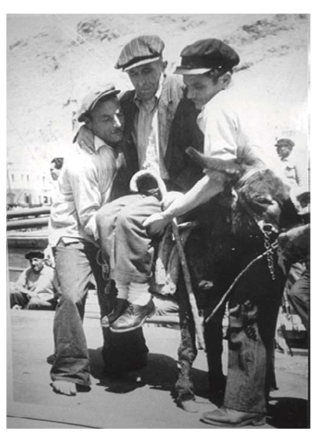

Figure 1. A diver paralyzed by the bends

4.2.Local architectural elements as obstacles

Strolling in “Chora” is an important part of experiencing the islands. Walks in the old citadels, climbing to the highest points for panoramic views and exploring the labyrinth of cobbled streets are common tourist activities.

However, such an experience of the public space and its surroundings is not available to the disabled individuals . Due to obstacles, they are excluded from many facets of the island’s built environment. It is important to understand that disability is defined as the interaction of people with disabilities with barriers that hinder their full participation in society, coming from their environment. This fact states that the existing configuration of the public spaces in the islands cause the disability of the individuals, as the lack on the necessary elements for an inclusive built space.

Examples of these limitations are architectural and urban design elements, that shape local identity and aesthetics. Stairs are considered an unavoidable, long lasting solution to the hilly and rocky landscape of the islands and an integral part of their building fabrics. What once played a major role in the social life of the islanders, as a place of gathering and decision-making, is now hampering social participation. Typo-morphological elements such as roofs, outdoor stairs, yards, terraces and pergolas, may became barriers to accessibility. The organic development of the settlement with the labyrinthine streets and paths, created complex routes that very often lead to dead- ends or very narrow streets. Of course, these open spaces create an unfriendly environment for people with disabilities, without any proper signage and information. Moreover, parts of public space are illegally occupied by residents’ for everyday activities. Additional disadvantage is the overall absence of sidewalks. Wherever these can be found are too narrow to use and their pavings make it difficult for wheelchair users or visually impaired people to move.

To this day, the number of hotel accommodation with the appropriate infrastructure for tourists with disabilities is small and expensive. This presupposes a high income and assisted/non-independent mobility . Besides the few barrier-free units, there is no support and upgraded infrastructure with assistive technology. People with visual, auditory, or speech impairments are less likely to be informed as they lack the necessary information points, such as Braille or other audiovisual media.

5. The case of Symi

In order to create a barrier-free built environment that socially includes individuals with impairments, we need to identify the architectural barriers in-situ and acknowledge the specific characteristics of the existing public space that promote or constrain accessibility. To this end, Symi is selected as a case study for our research. Symi, a small island of the Dodecanese complex, is the eighth largest island, northwest of Rhodes. Its inhabitants managed to adapt to the dryness and isolation of the place, excelling mainly in shipping, shipbuilding and sponge fishing. Today, the island's economy is based exclusively/mainly? on the tourism industry.

The wild, barren and mountainous morphology of the soil shaped the impressive aesthetics of the place. From the beginning, the inhabitants adapted to its rocky and sloping rugged topography, taking advantage of its steep slopes, building its houses in a set of different levels.

The high-altitude distance from the sea level, the inclined rocky surface and the need to connect the acropolis with the port of the settlement, created the need for stepping passages. The densely structured settlement features neoclassical mansions with the color shades of ocher or terra cotta. The residential fabric of Symi followed the same rhythms as the rest of the Aegean islands, as mentioned above. From the ancient times the regular pirate attacks pushed Symians to establish the Acropolis at the top of Mount Vigla. Inside the Castle, Symians built their houses in which they escaped for protection during the raids. At the same time, many of them preserved a second home outside the citadel. As a result, the settlement spread both from the back of the Acropolis and towards the sea level, the port.

The settlement acquired an amphitheater layout around the natural port and was structured in two zones, Yialos and Chorio, or else Ano Chora. The Chorio gathered the largest part of the population, while Yialos became the commercial and recreational center of the settlement. Today, the most common and easiest way to get around the island is by car or motorbike. Many people consciously avoid using the stairs, except when they have no alternative.

The oldest and main artery that connected the Chorio with Yialos is "Strata Kali", a path made of 500 stone steps and a width of 6 meters. To this day, this route maintains the same prestige, despite the creation of the main road and the individual connections with other stairs. Main touristic attractions in Strata Kali, are the imposing, massive neoclassical mansions -*archontika*- with symmetrical glazed windows on either side. These houses belonged to wealthy merchants and captains, who due to their long business trips, brought to the island the echo of the artistic movements of the West. The physical fatigue caused by the daily movement through the stairs brought the need of the wide stairs for rest and rest. Despite its beauty, Kali Strata has two important peculiarities that now make it difficult for the visitors. At their starting point, in the part of Yialos, the stairs are narrow, while as they approach the Upper town they widen. So far, no handrail supports have ever been attached to the neoclassical facades for the passer-by.

Through the years, the number of stairs has increased significantly in proportion to the houses, dominating the place. The houses continue to be built on the rocks with their stairs being an integral part of the daily movement. The neighborhoods of Symi, mainly in the districts of Chorio and Mouragio, are distinguished for their labyrinthine, cobbled narrow allays. It is important to emphasize that from an age onwards the inhabitants of the island, finding it difficult to climb the innumerable steps of the settlement, are limited to their homes exiting only at their yards or the neighborhood. How is possible, a society that managed to

Figure 2. Yialos - Mapping the pedestrian streets.

adapt to the difficulties of the place and vice versa to adapt the place to its needs, failed to create the necessary conditions for the unimpeded movement of its members?

5.1 Creating a database of the barriers

In order to understand Symi's physical barriers, a street map was created. More specifically, we focused on three types: (A) the pedestrian streets, (B) the seafront pavements and (C) the public stairs. For these types, both permanent and temporary spatial interventions were examined.

(A) The Pedestrian Streets

The most important pedestrian streets are located in the center of Yialos, the social and commercial center of the island (Figure 2). Restaurants, cafes, grocery stores and shops of touristic interest are accessible only through these routes.

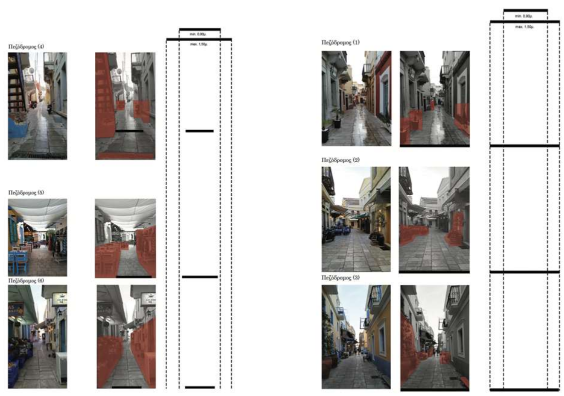

Figure 3. Barriers in the pedestrian streets.

The average width of these alleys ranges from 1.5m. up to 3m. However, considering elements such as shop furniture or counters, the width of the streets decreases to a minimum of 0.70m. and a maximum of 1.80m. In the cases (1), (2) and (3), there are obstacles due to commercial activities such as flowerpots, product stands, restaurant tables as well as parked bicycles or motorbikes. In all three cases, however, despite the reduction of the width of the road, a pedestrian can move in an area of more than 1.20 m. This means that people with mobility impairments can move easily on these roads according to international design standards. On the contrary, in cases (4), (5) and (6) their movement is difficult or even impossible. This is because elements such as the outside stairs of the houses, counters and tavern tables give a margin of 0.70m. It is also worth noting that while the paving surface may be considered as suitable, there are no special markings and guide strips for the visually impaired visitors.

(B) The seafront pavements

Symi's main road connects Yialos with other areas of the island. The main road follows the coastline. In zones (A) and (C) the sidewalks are completely absent (Figure 4). The pedestrian has to move only through the main road. Undoubtedly, the intermittent shape of the pavement in the coastal part of Yialos makes the traffic of all pedestrians difficult. In zone (A), the road width varies from a minimum dimension of 3m. to a maximum of 6m. Many times, in this part of the road, the movement of vehicles is two-way, resulting in frequent congestion of vehicles. At the same time, the lack of protection from the sea, both for vehicles and pedestrians, makes the situation more dangerous. In addition, there are no special markings and guide strips. In zone (C), where again the are no sidewalks, the road width reaches in maximum 2.50 m.

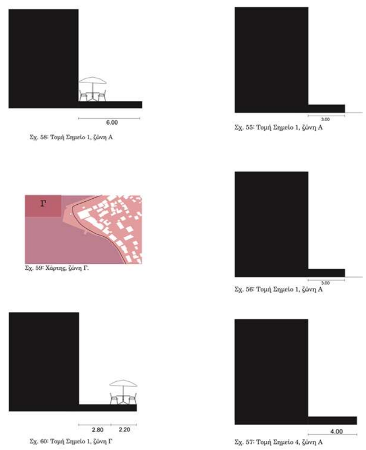

Figure 4. The typology of zones A and C.

In the contrary, sidewalks exist only in zone (B) (Figure 5). However, the course of all pedestrians can be characterized as inappropriate, due to the width, the countless obstacles, the successive changes in their height as well as their sudden interruptions. Their width, although it reaches 1.50 m., gives the margin of movement to only one pedestrian at a time. The bollards of the sailboats, the threes and the benches reduce their width greatly, restricting the free movement of passers-by. In many places, equipment of the sailboats (eg boards, cables, ropes) impede the movement thus making the environment dangerous. In several places the sidewalks show successive changes in height from street level. The minimum height is 0.10m. and the maximum of 0.50m. An important obstacle in these elevations is the configuration of stairs for the ascent to the sidewalk, with the complete absence of ramps. In addition, there is no protection either from the sea or roadside.

Figure 5. The typology of zone B.

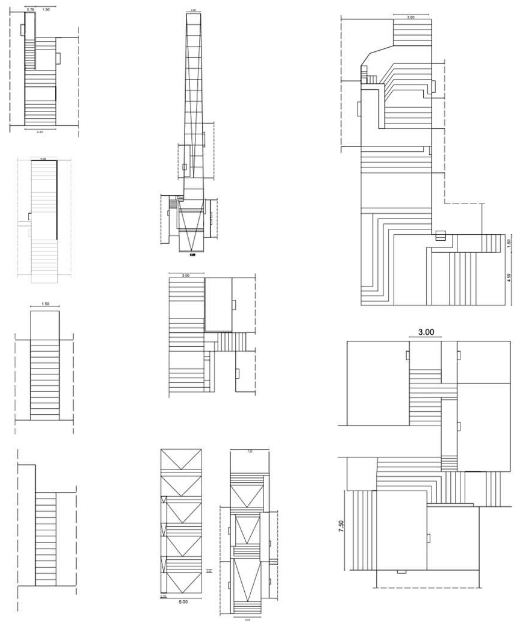

Figure 6. The typology of public stairs.

(C) The public stairs

After an exhaustive personal observation, different typologies of neighborhoods' streets with stairs were recorded (Figure 6). The widths of the stairs in the settlement of Symi range from 6m. up to 1.20m. In its older parts they have slippery stoned surfaces with curved ends, while in the more recent ones have a concrete surface with square ends.

Apart from their difference in width and materiality, several steps also differ in the inclination. In the part of Chorio and Mouragio the steps are continuous and steep, without wide landings and with ridges that exceed the 0.20m. A special feature of the stairs of Symi, mainly in the part of Kali Strata, is the intersection of stairs of different directions, which either lead to the thresholds of the mansions, or branch into other alleys and stairs. However, there are places also, where the stairs have a ribbed shape, making the climb more relaxing.

Common elements in all types of stairs are the lack of the necessary configurations for the people with disabilities. There are no paved warning signs found at the beginning and end of the stairs. Quite narrow and stairs lead to dead ends or steep gradients without any warning or direction sign. In addition to the slope of the ground, the surfaces of the stairs are slippery without non-slip strips on their footprints. At the same time, there is a lack of handrails.

For a better depiction of the landscaped stairs and the search for possible suitable routes, I designed a topology of plans from the most common types of stairs on the island.

5.2 Towards a universal design of the settlement of Symi

As a first impression, the pedestrian streets (1), (2) and (3) can be recognized as accessible simply because they leave room for circulation. This would be wrong as this margin only applies to people with mobility impairments, and not to people with disabilities as a whole. The routes (4), (5) and (6) leave no room for traffic. In both cases, there are obstacles due to human intervention, which limit the space of movement and lack of the necessary markings and specially designed pavings for people with visual impairments. Therefore, the current situation of the pedestrian streets makes them inaccessible. However, this does not necessarily mean that it is not a problem to be solved. Instead, a proposed solution for cases (1), (2) and (3), is to remove existing barriers and adapt the floor surface to the needs of all the people with disabilities, such as installing the necessary guide strips (Figure 7).

Figure 7. Plan of the inaccessible and accessible pedestrian streets.

Concerning the typology of the seaside pavements, we can conclude that they are equally inaccessible, as they do not meet the requirements of international design regulations for people with disabilities. In zones (A) and (C) the sidewalks are absent, so that pedestrians have to walk across/along? the road parallel to the vehicles. It also lacks any kind of protection from the water, while at the same time the movement becomes more difficult due to the restaurant tables. At the same time, in zone (B) some of the sidewalks comply with the regulations and some accessibility standards, such as the fencing of the planting in a continuous line or the placement of stops for rest every 100m. However, even in this case, successive leveling from the ground, lack of protection from vehicles, slippery surfaces and continuous port obstacles, create a 'disabling' public space. Therefore, the above obstacles and shortcomings make the whole coastal front inaccessible, not only for the disabled, but for all pedestrians.

In zones (A) and (C) emerged type 1, where the sidewalk is on the same level with the road, while from zone (B) type 2, where the sidewalk rises from the street level (Figure 8). Through this categorization came the conclusion that all three zones can be easily modified to make them accessible in the future. A common element in both cases is the need to differentiate the movement of pedestrians from vehicles, providing the necessary tour space (minimum 0.90m.) and the required markings for all disabled. For both the types above, our research proposes an extension of the coastline street for the pedestrians towards the sea, separating circulation lanes for vehicles, bikes, pedestrians and port activities.

Figure 8. Types 1 and 2 for the seafront pavements.

The stairs of the settlement of Symi are also considered inaccessible for individuals with disabilities. The slippery construction material (e.g. stone), the absence of the necessary anti-slip lines, the guide strips, the handrails make the stairs a deterrent for use by people with disabilities. However, another conclusion of the recording of the structures of the settlement was a typology for the stairs (Figure 9). In particular, during the recording of the stairs in floor plans I noticed that certain types of stairs were either a specific type by themselves, or the result of a combination of other types.

The composition of the above typology contributes to the understanding which parts of the settlement with steps, will either become accessible or not. Categories 1 and 3 cannot be used by wheelchair users. Instead, Category 2 might be used with the installment of appropriate equipment, such as some form of ramps or mechanical climbing platform. However, all three types must have the necessary configurations based on international design standards. Certainly, the necessary markings, floor warning and non-slip surfaces, as well as handrails will need to be installed. It is important to understand that these reforms are important not only for the disabled, but also for the inhabitants.

Concluding, the existing structure of the residential fabric of Symi, due to elements of human

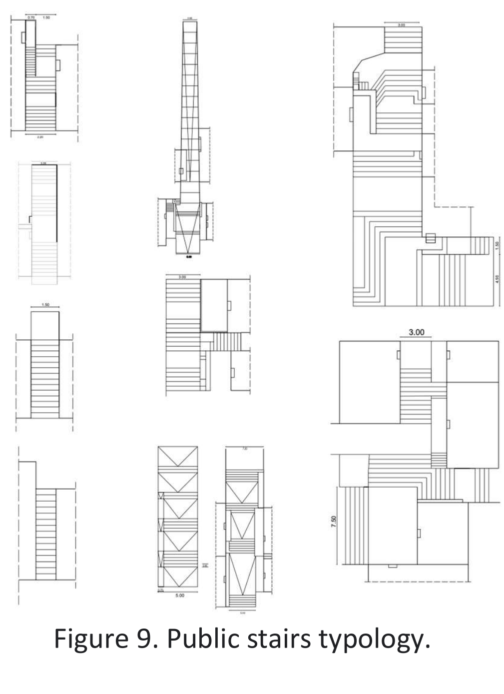

Figure 9. Public stairs typology.

activity make the settlement inaccessible. Through this detailed analysis of Symi's public spaces, it was proved that with the necessary transformations of the above barriers, the accessibility of people with disabilities can be ensured. The natural topography of the place is not the factor hindering accessibility. The way of settlement's development, the adaptation of the inhabitants to its territorial adversities, as well as the provision of their needs until today, strengthens the possibility of its adaptation to the needs of the people with disabilities. Therefore, the settlement of Symi may in the future approach the values of universal design.

6. Conclusions

This research aims to transform traditional settlements into inclusive and accessible environments. Similarities of the Aegean islands in topography, history and culture created specific morphology (e.g. citadels, narrow and labyrinthine alleys, stone stairs and the organization of the daily life in the center of Chora with sidewalks?) that is not barrier-free. Symi, an organically developed Agean settlement, has been always re-adapted to the need of its residents and vice versa. For centuries, Symi has proven its flexible, adaptable, and provisional qualities, therefore its resilience. In order to continue to be so, it must meet current need and requirements, such as, among others, accessibility standards. Spatial components of public space are major determinants that either enable or restrict the mobility of people with temporary or permanent disabilities; and, as demonstrated by this research, there is an imperative need that these spatial components are introduced in the traditional settlements so as to transform them into just and inclusive environments.

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THE MAKING OF BEDS

Piergianna MAZZOCCA

University of Texas at Austin
310 Inner Campus Drive, Austin, TX 78712, USA;
piergianna.mazzocca@austin.utexas.edu

Abstract

Few contemporary scholars and practitioners would regard beds as the site for design innovation, let alone viewing the bed as a revolutionary technology that has the impact of changing the way we have thought and conceived of the spaces they occupy. The study of beds allows exploring a form that synthesizes the relationship between architecture and health, and the power relationships they can codify and continue to replicate by remaining unquestioned. Using the bed to illustrate the power of disciplinary technologies in everyday life helps to amplify the mechanisms by which architecture resists them. This paper contends and explores the influence of the bed in conceptualizations of technology by tracing a genealogy of the bed from the clinical spaces of healthcare environments into the contested realm of the domestic. Following Anthony Gidden's theory of structuration and Wanda Orlikowsky's views on technology, the paper thus follows the various dualities of everyday technologies. In the structuration model of technology, design and use come together. This means that technology is envisioned as a medium of human action, as it variously facilitates and constrains human behavior (including design, development, and application) and human choice. This reading of the bed as a disciplinary technology opens an in-between space that demands architectural interrogation.

Keywords

Beds, technology, duality.

1 INTRODUCTION

In the world of things real and perceived, beds hardly stand out the most. Though as many may argue, it is in beds where both things commonly collide. The real ones are related to experience—the set of activities concerned with our physical presence in the world, and the perceived ones are related to abstraction—the set of rules that define and reproduce our knowledge of that same world. We could claim that because our lives begin and end in a bed, the history of habitation is cast onto them. Intimacy and familiarity are enacted every day in the automated process of making and unmaking our beds.

Seeing beds as markers of experience highlights how we have historically constructed how lives should be lived. Seen as an abstraction, beds represent how distinctions between our private and our public existences are structured and constituted. On one hand, as standardized objects, beds shape the understanding of our bodies as flesh and bone through considerations regarding hygiene and health. They are ruled by efficiency and codification to normalize differences and to meet a convention. And on the other hand, beds condition the constitution of the body politic through the medicalization of the population at large. As standardized objects—born from hygienic, social, or industrial demands—they also normalize aspirations and expectations. And by doing so, they institutionalize those same expectations. Upon deeper scrutiny, beds are the sites where goodness in the form of care is registered, but also where the power structures of society are embodied. In the end, we all sleep in the beds that we have made.

Set between these ways of seeing, the object that is the most familiar to us is transformed into the most unfamiliar. As a technology that, after becoming a part of daily life, has often been taken for granted, we tend to forget that beds speak of the creation and mediation with other objects. Never does a bed speak only about itself. Indeed, as technological objects designed to serve a specific purpose, beds not only regulate and codify their use but also our very experiences of self are changed as our interactions with beds have evolved.

This paper proposes an alternative theoretical conceptualization of beds as technology through the analysis of the dualities they have accrued over time. As introduced at the beginning, this duality refers to the objective abstraction ascribed to beds—as utilitarian, regulated objects—and to people's experience and appropriation of their meaning—referencing the many interpretations they have accumulated throughout their use. This analysis will be explained under Wanda Orlikowski's adaptation of Anthony Giddens' theory of structuration as it allows us to embrace the various dualities ingrained in everyday technologies.

2 STRUCTURATION AND THE DUALITY OF TECHNOLOGY

Theories of structure and agency have long been at the center of the social sciences. The theories that privilege structure—referred to as the objectivist view—sustain that an individual's behavior is inherently defined by their socialization with that structure. It explains how someone might, for example, conform to a society's expectations of gender or class, or about religion or familial expectations. The use of structure here can be applied to, depending on the context and the scale of the application, to different social constructs such as class, institutions, communities, and professional settings. In opposition, advocates of agency theory—also referred to as a subjectivist view— take into consideration each individual's ability to exercise their own will and to make their own decisions. For this theory, social structures are regarded as the result of an individual's action in supporting or suspending those same social structures, dismissing the possibility of regarding them as disproportionate forces [1].

Giddens' *Theory of Structuration* presents an alternative that incorporates both dimensions. For Giddens, as well as for others in the social sciences, the long-lasting opposition between objective and subjective dimensions of social reality had to be challenged. In his theory, an individual's autonomy is determined by structure, and structures are sustained and modified through the exercise of agency. Thus, social behavior cannot be sufficiently demonstrated by the structure or agency theories alone. Instead, structuration theory acknowledges that people engage with the rules produced by social structures and, by behaving in a compliant way, are these structures reinforced.

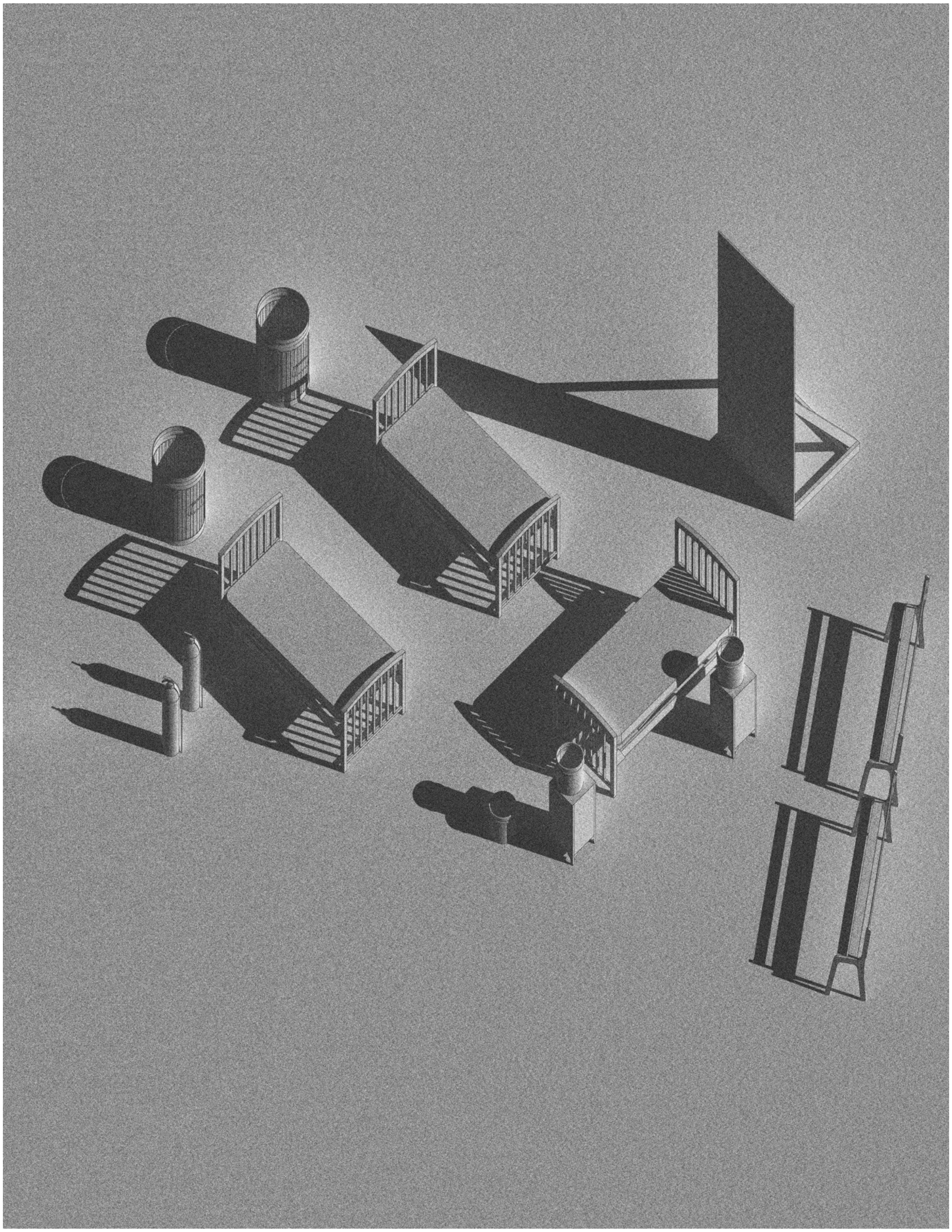

Figure 1. Mazzocca, Piergianna, *Plan view of Untitled, a photograph by Larry Sultan and Mike Mandel from 1977*, Raster Image, 2020, Austin.

Accordingly, structuration is defined as a social process that requires the mutual interaction between human players and the structural traits of organizations. The role of human actors in reaffirming structural properties is crucial in the formulation of this theory, for it recognizes that actors are both knowledgeable and reflexive of how their regular actions can establish patterns that later become standardized practices inside their organizations. Over an extended period, the habitual use of these practices will become institutionalized, establishing the structural properties of organizations. In short, structural or institutionalized properties (simply put, structures) are brought on by humans through their continuous interactions (or through their agency) even though their use ends up reinforcing the institutionalized properties. This formulation is known as the duality of structure and demonstrates how Giddens was able to subdue the dualism between objective, structural features of organizations, and subjective, deliberate action of human agents [2].

While Giddens did not address the role of technology in his structuration theory, Wanda Orlikowsky—a Professor of Information Technologies and Organization Studies at MIT—has used the structuration paradigm to reconceptualize the notion of technology and technologies' relationships with organizations. By expanding the understanding of technologies by adopting the framework of structuration, Orlikowski claims that technology can be examined as one type of structural property of organizations advancing and/or using technology. For her, "technology embodies and hence is an instantiation of some of the rules and resources constituting the structure of an organization."[3] Thus technology is produced and transformed by human action while, at the same time, it assumes structural properties. This characteristic of technology is what Orlikowski calls the duality of technology, which has come to describe the false dichotomy representing views of technology as either an objective force or as a socially constructed product.

In Orlikowski's approach, technology is underscored by its socio-historical context and by its dual nature as objective reality and as a socially constructed product, constituting a deviation from seeing technology as something immutably objective. In her view, "technology is physically constructed by actors working in a given social context, and technology is socially constructed by actors through the different meanings they attach to it and the various features they emphasize and use."[4] In this sense, both agency and structure are not autonomous. Instead, they are reciprocally necessary for analyzing and understanding how technologies are apprehended, how they sustain meaning, and how they are instituted.

As technologies are fully acquired and employed, they are inclined to reification and institutionalization. As Orlikowski claims: "It is the ongoing action of human agents in habitually drawing on a technology that objectifies and institutionalizes it."[5] This process occurs when a technology loses its association with the human agents that constructed it and assigned its meaning, appearing objective as it has been imbued into the structural properties of the organization.

Moreover, Orlikowski observes, even though agency refers to capability and not intentionality, human actions may have intended and unintended outcomes. While individual action may have an intentional effect on very confined conditions, it may also cause unexpected ones. This can be observed in the indirect effects that an individual using a technology can have in the institutional environment where it operates [6]. Indeed, this condition might explain how the thoughtless use of a given technology may cause the normalization necessary for its institutionalization. If people change the way they may use a particular technology—either by physically transforming it or by altering its meaning—then a technology's inconspicuousness or assumed normality may be challenged.

To explain technology through social and physical relationships, the 'structurational model of technology' recognizes how these processes continuously construct technology throughout its use and during a technology's existence. This relationship between humans and technology is defined by what Orlikowski calls 'interpretative flexibility,' referring to the degrees of engagement of different users in constituting the technology. The interpretative flexibility attribute allows acknowledging the limits in the design, use, and interpretation of technology and it manifests in two ways. The first one establishes that a technology is limited by its material characteristics. While the second, establishes the limit by observing the constraints imposed by the institutional context that grants the technology its different structures of signification, endorsement, and control. These limits are also restricted to the knowledge and power affecting diverse actors in the use and design of technologies. On this point, it is important to note that technology is, for Orlikowski, the product of human action [7]. Additionally, once created, a technology is ineffective unless humans manipulate and give it meaning. Otherwise, a technology would not be of much consequence to human matters. It is only through constant appropriation that a technology can influence everyday life.

Particularly relevant for this analysis is to understand how technology interacts with individuals during the design process and while in use. During the design process, people can build into the technology several instructive contents that shed light on the type of activities enabled by it, specific abilities that help accomplish its supposed purpose, and, finally, the norms and rules that define the proper way in which the activities enabled by the technology can be accomplished. During use, people appropriate the technology by assigning shared meanings to it and determine the appropriation of the instructive contents, the activities enabled, and the norms and rules that were originally designed into the technology itself. Both types of interaction have a great impact on how the activities enabled by the technology are handled. From this perspective, one unintended consequence of standardization—as a principle applied during the design of a technology or as a technology in and of itself—is how it becomes an instrument for regulating human interactions. As a form of normalization, it rationalizes how consumers and producers interact across space and time.

Normalization, in the way in which Michel Foucault used the term, involved the creation of an idealized norm of conduct—for example, the way a bed is made as defined in minute detail in nursing manuals—and then rewarding or punishing individuals for either conforming to or deviating from this rule [8]. For Foucault, normalization was one of many tactics for exerting maximum social control with the minimum expenditure of force. This kind of power is called disciplinary power. Emerging across the 19th century, disciplinary power came to be used extensively in military barracks, hospitals, asylums, schools, factories, offices, etc., becoming a crucial aspect of social structure in modern societies. Thus, the term disciplinary technology has been used to mean a device used to regulate, organize, and expand the power of bodies; while, at the same time, disciplining bodies to operate together and to become productive inside a collectivity.

A discussion on beds exemplifies the power of disciplinary technologies, while at the same time, the opposition to be reduced by them. As disciplinary technologies, beds separate—by mechanisms of inclusion and exclusion—and communicate—by what they make visible and by what remains hidden. This claim is framed both by Foucault's definition of disciplinary technologies and by Orlikowski's duality of technology. Such a framework affords a way of investigating not only the movement of technology through space and time but also across the boundaries of the hospital and the home.

3 BEDS

Beds, when read as technology, reveal and transform social practices. Yet, by reifying normalized norms, they conceal how they reveal and transform. The effects of this dual nature can be seen in the spaces that beds occupy and the social practices that unfold in and around them. To illustrate this point it is necessary to understand the evolution of the bed as the modern technology used for sanitation reform and its spatial regimentation, as a technology employed in both medical and nursing practices, and as the technology capable of disclosing a moralizing agenda inside the home. Such an evolution renders visible the duality of technology posited by Orlikowski and will be described in three distinct ways. The first is related to the development of beds as a medicalizing technology during its development phase; the second to the bed and its institutionalized use both in hospitals and in domestic spaces; and the third relates to the ongoing interactions with the bed by the nursing practice.

3.1 Beds as a Medicalizing Technology

Beginning in the 18th century, the politics of health emerged at the intersection of a new economy of assistance and management of the social body [9]. And since this epoch, everyday spaces and objects became constant agents of medicalization. If medicine was integrated into the economic and political management of society, so too did the objects that mediated this experience with the population at large. Beds provided the clinical space in which medicine could be practiced and where medical knowledge was imparted.

Late eighteenth and early nineteenth-century theories of miasmatic transmission of disease provided the basis to deploy the hygienic and sanitary urban reforms seen in many American and European cities. This idea rapidly spread the more general notion that every repulsive emanation, odor, and smell could, eventually, kill. Places where large amounts of bodies accumulated, dead or alive, were perceived as dangerous. At the time, beds inside hospitals could be shared by more than four patients, depending on the need to assist during epidemics. This promiscuous association of bodies where the sick sometimes shared a bed with the healthy started to be considered dangerous.

Accounts from the epoch described how beds were impregnated with foul substances where soiled linen was left behind [10]. In the same way, as cemeteries began to be seen with suspicion and as unsanitary—especially when they were found awfully near a populated area—so too did hospitals. The association between dirt and reeking smells with places and bodies started to draw the attention of many reformers. At the time, cleanliness was to be addressed by opposing “the shortcomings of the people, urban stenches and promiscuous mixing.” [11] Therefore, beds were commonly criticized for allowing the adjacency of bodies lying side by side and because it was beneath heated covers where the worst emanations came from.

The proposed solutions were manifold. First, beds became individualized, restricting their use to one patient at a time. Bed covers and sheets started to be regularly changed and replaced with clean linen. The patient’s clothes were also changed and replaced more often. Secondly, bodies were further categorized and separated by gender and health status. Wards for the sick and incurable became separated from the poor and beggars. And, finally, the distance between the populated areas and the location of hospitals started to increase. The location of beds was seen as a matter of spatial ordering. The medicalization of the bed, as a technology used to break from the unhealthy habits of the past, also became a technology to order and oversee space in its totality. A bed is no longer the place where a body lies but instead, it acts upon the body.

3.2 Beds Institutionalized Use (both in hospitals and in domestic spaces)

Even before the sanatoria movement, lying in bed was considered a crucial part of medical treatment, advancing the belief that beds were therapeutic. This action materialized time—as in the length of stay of patients (days became bed-days)—and by so doing, it conditioned the space around it—as in how patients could be moved, how they were cared for, and on how healthcare staff moved around beds. In this sense, “beds have provided the critical therapeutic space in which the [...] science of medicine could be practiced…” [12] Consequently, patients were required to spend long periods of rest in their beds; formal medical interventions would only enhance the inherent therapeutic effect already present in the bed.

During the middle of the twentieth century, a crisis in confidence in the hospital and its beds arose. The general claim about hospitals and beds’ safety and their therapeutic mission was challenged by the newly found evidence that long hospital stays were detrimental to the patients' recovery—leading to a rapid decline in bed numbers. Addressing such problems, new hospitals stressed restricted bed usage and favored ambulatory services and the further retreat to the home. Despite their decline in physical presence, beds are still at the core of medical management and distribution of resources, allowing for clinical observation by both medical, nursing, and health professionals. They are recognized as the quintessential space of the patient, providing every individual patient with “a recognized place in the institution of the hospital, an address in the form of a ward name and a bed number.” [13] Within this interchangeability, in which beds embody the patient’s body, we could say that hospitals were built to serve beds and not patients.

The changes operating in beds inside hospitals paralleled the ones inside domestic spaces. The rationalization of domestic beds happens through a slow but potent process of reinterpretation through which the earlier meaning of the technology and its purpose remains hidden or lost. In a continuous progression of reinterpretations and re-appropriations, beds are understood inside the home through the intersecting discourses of domesticity, health, gender, and sexuality.

Whatever the nature of the premises behind the housing initiatives of the nineteenth century—Catholicism in England, Fourierism in France, and Protestantism in the United States—domesticity aimed at new moralizing objectives well into the 20th-century. As "if the domestic sanitation movement of the late nineteenth century had opened up the middle-class bedroom to expert public and self-scrutiny through a more detailed and prescriptive focus on furniture designs, styles and materials than ever before, later commentary maintained and intensified that scrutiny, shifting its terms from those of domestic and individual hygiene to conjugal health and well-being." [14] Explanations for this can be found in the fact that modernist discourses have denigrated the needs for comfort and consolation [15]. Or in the revolts against domesticity and the sciences of the home, pointing at the separation between masculine and feminine spheres [16]. Or in the little attention given to the places of daily existence, a landscape that is not privileged by its difference or strangeness [17]. Inside the contested realm of the domestic, beds embodied conventions, concordance, and style. Its ethos is constituted by the contented comforts and rituals of middle-class family life.

3.3 Ongoing Interactions with Beds (by practicing nurses)

Beds have also provided the clinical space in which nursing could be practiced. For example, bed-making epitomizes techniques such as quality management, performance management, procedures manuals, and sanitizing rituals. In a hospital, clinic, or other care environment, beds must sometimes be made while occupied by a patient. Specialized techniques are taught to healthcare staff to enable beds to be made efficiently with due care for the patient. All of these are forms of disciplinary techniques that not only respond to functional needs but ones that act like reinforcements of power structures within hospitals and clinics. Nursing literature, from Nightingale onwards, stress the importance of beds and bedding, providing evidence of how important the location, functionality, and appearance of the bed have been to nursing practice.

Hospital corners, a bed-making technique developed by war nurses in the mid 19th century, overlap folds and tuck sheets neatly and securely under the mattress at the corners, leaving its characteristic 45-degree angle. Nurses registered the logics of efficiency into the surface of the bed. In the end, a disciplining of the body by the medical gaze excerpts its power even in the corners of a hospital bed. In this sense, beds can be seen as a “discursively contested location for nurses.” [18] Even if now beds solely act as the physical location of the hospitalized patient, they used to act as indicators of the quality and hygiene of nursing care. Neat and perfectly made beds became idealized forms. To observe hospital corners today is to observe the parameters of the ideal woman institutionalized within nursing practice and the standards ascribed to the sites of female labor. Though nursing is now less gendered and the discrete sites for cure and care are less reliant on human labor, the conventions attributed to women ever since continue to scrutinize the female body as if cleanliness, tidiness, and nurture were a practice of theirs only.

It is important to note that the gendered relationship of beds and women relates to broader conversations regarding technology and women where on the one hand, technologies of significance to women are not viewed as technologies, and, on the other hand, technological advancements are taken for granted once they become part of daily life. Margarete Sandelowski has explored how imperative the understanding of the techno-medicine relationship becomes to analyze the complex role technologies such as the bed had played in the development of nursing practice, specifically, and of gender dynamics as a consequence of technological deployment more generally. The following excerpt serves to exemplify what she observes about technologies' role in everyday life: “Any one technology leads a “double life.” On one hand, a technology is limited by virtue of its thingness; that is, there are hard limits to what a technology can mean, to what it can do, and for what it can be used. On the other hand, a technology is limitless by virtue of everything we can read into it, design it to be, use it for, and construe it as against.” [19] This passage perfectly illustrates what Orlikowski meant by the interpretative flexibility of technology for it emphasizes how there is flexibility in how people have designed, interpreted, and used beds as technology.

4 CONCLUSION

As an actual engagement with the world fulfilled by making and using objects, technology is a way of knowing that is different from knowing the world straight through the senses. Carlo Ginzburg, in his essay entitled Clues: Roots of a Scientific Paradigm, traces the “new social and epistemological autonomy found in medicine” [20] and the privilege the social sciences gave to them, placing the study of clues and minutiae (traces, vestiges, unconscious traits and responses, etc.) as the means to achieve a better understanding of the world. In Ginzburg's words: "These are essentially mute forms of knowledge in the sense that their precepts do not lend themselves to being either formalized or spoken. In knowledge of this type imponderable elements come into play: instinct, insight, intuition." [21] The continuation of the epistemological model described by Ginzburg allows for the recognition of forms of knowledge that have for too long been ignored and refused: that of women, children, laymen, etc.

The structurational model of technology, as it applies to the history of beds, allows an interdisciplinary approach to the history and theory of technology as liberation and not as a construction intended to limit the understanding of the world and its forms. These observations could lead to considerations that not only account as historical commentary or theoretical analysis only but that present ways of thinking that lead to real experimentation. For architecture, this would mean a more engaged reading of how the present has come to be and in what ways we could make things differently. Thinking about what it means to make the bed, not only as a habitual practice but also as a techno-social construction, allows recognizing a form of resistance in its unmaking. Since human agency is always needed to use technology, humans always possess the opportunity to choose to act otherwise.

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ELECTRIC AIRCRAFT TECHNOLOGY REFLECTION UPON THE FUTURE AIRPORT DEVELOPMENT – THROUGH THE ASPECTS OF REDEFINING ARCHITECTURAL DESIGN PARAMETERS; ADAPTABILITY AND REUSE

Samantha Pavić

University of Split, Faculty of Civil Engineering, Architecture and Geodesy
Matice Hrvatske 15, 2100 Split, Croatia, svp2123@columbia.edu, spavic@gradst.hr

Abstract

The paper introduces and investigates changes in an architectural design concerning the technological-transportation development of electric aircraft. The technological ingenuity of the electrical aircraft reflects upon architecture and triggers advanced architectural design; within the idea of defining design parameters and case-study model implementation for future transportation designs, including built airports, vertiports, and sustainable transportation hubs. The focus of the paper is on the electrical aircraft, and (re)definition of the design parameters of the airport, which derives from the research Le Corbusier conducted in 1935 while introducing the "*symbol of the new age*" – the aircraft (in this case, electric one) [2]. The technological advancement of electric aviation is crucial in developing design techniques for planning new transportation nodes, including implementation within the cities; various site-specific parameters and conditions. Hence, the adaptation of the built airports (in-use and abandoned ones) and executing new innovative systems that will have electrical premises while focusing on the aircraft's engine and become sustainably efficient in aspects of architecture.

The 'take-off path" of the paper continues with the analysis of the current aviation startups. Although all electric-aviation-based startups share the same advanced engine, the idea and the development are unique and different for each firm; therefore, it opens up to a range of diverse possibilities. For example, German-based air-taxi startup Lilium developed an all-electric jet with vertical take-off and landing, which inevitably discards urban infrastructure's leading element: take-off path. Hence, the new technological shift will redefine the necessity of currently used infrastructure.

The paper questions expansion necessity while considering technological shift that could desert what has already been built. Hence, would non-immunity to technological advancement mean that the world's largest terminal in Beijing – whose roof could span across the 25 football fields, will be substituted with downtown New York flophouse - whose 8 meters wide roof is enough for vertical take-off? According to the media, *"the new airport is located 46 km south of Beijing's city center and is currently 700K square meters big with an 80K sqm ground terminal space. Despite that, there are already plans for its expansion to serve up to 100 million passengers per year in the future."* [15] Therefore, comprehension of the

technological advancement of an aircraft, its reflection upon architectural design, and the potential of adaptability and re-use seems crucial for architectural sustainability of the future.

The paper will target the following questions: What elements could we extract for future design attempts? Could the process of re-design evoke the reversed function for abandoned sites? How do we design for electrical transportation; what parameters do we take in? Does a derivation of sustainability in the future rely on re-use? What is the scale of the new airport? Is it dispersed or centralized? Is it even an airport? Overall, what is an airport in the building timeline while it houses different clients: politicians, pilots, or tech entrepreneurs?

Keywords

Electrical aircraft, adaptability, urbanism, vertiport, transformation

1 Introduction

Electric aircraft development followed by the technological advancement of electric propulsion will necessarily trigger adjustments in urbanism and architectural design. Hence, these changes will be applicable in implementing the new vertiport systems, including an up-to-date approach to future airport design and re-examining relevant design parameters. At the same time, in urbanism, the changes will question the city's functioning per se. The advancement of aircraft technology will redefine the city, its architecture, urbanism. It will reflect upon infrastructure and transport, but it will also challenge contemporary architecture in designing and thinking about the architecture and urbanism of the city. Similar consequences for architecture and urbanism due to the change of transportation paradigm, mainly due to the development of the aviation industry, in the 1920s, were observed by the world architectural visionary Le Corbusier. This examination takes Le Corbusier's method of aircraft analysis as an inspiration while being applied to two types of the so far developed electric aircraft: eVTOL and electric airplane. This research aims to accentuate the correlation between the shifts in aircraft propulsion technology and architectural design. Hence, the focus is to examine how the ongoing electric aircraft development will influence the concept and design of the vertiport and airport and the overall future of the city's vitality; its urbanism and architecture, transport organization, functioning, and sustainability.

2 Learning from Le Corbusier – vision & inspiration

Le Corbusier defined the aircraft as a symbol of the new age due to the broadness of the implications of advances in technology concerning architecture and the city. The plane is a symbol of the new age because of the complete change in the way of seeing and understanding the city, and not even because of the primary transport infrastructure and airports, moreover of the euphoria of perspective of a new aerial view, which indicates the need for a complete change of architecture and city. Guided by a visionary approach, from 1920 to 1935, Le Corbusier based his theoretical work on the observation of changes and the redefinition of architecture, looking, among other things, through the prism of technological progress. Le Corbusier defines his initial thought *Eyes which do not see* [1], expressed as the title of a chapter in the influential book Vers Une Architecture (1923.), through the prism of analysing and connecting three transportation inventions (ship, aircraft, the automobile) with architecture. Therefore, Le Corbusier concludes the necessity of an analogous change of opinion on architecture following the typological development of new industrial inventions.

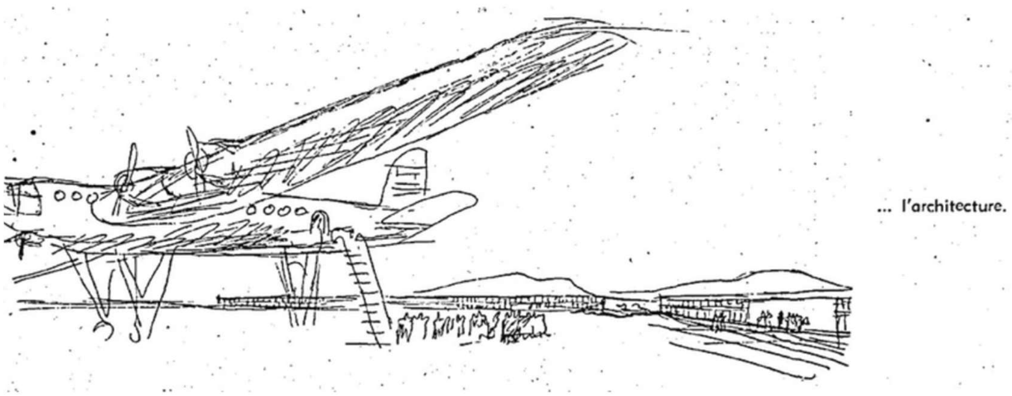

Figure 1. Le Corbusier, "Urbanisme et aéronautique" (1947)

Le Corbusier compares the invention of the ship with the house, where the boat has unity in materiality and simplicity of construction. As a result, the boat has a lighter structure and is devoid of styles, with significantly larger openings and the intrusion of natural light [1]. By comparing the ship and the house, Le Corbusier concludes on the simplicity of the ship's settings and detects better quality levels of the ship's performance concerning the house (light, ventilation). From Le Corbusier's study of the boat, it is concluded that the ship is not just an invention that functions for transportation but is an industrial product with tested performance that, by analogy, should be implemented in architectural design to achieve the quality of life in space.

Le Corbusier defines the car as an object with a simple function (travel) and complicated goals (comfort, resilience, appearance), which has led the industry to an absolute need for standardization [1]. Standardization, therefore, has evolved with two different purposes: speed and comfort. According to Le Corbusier, the standard is a combination of logic, analysis, and careful study: based on a sharply defined problem. The standard is based on an experiment [1]. Therefore, Le Corbusier conceives standardization as a critical factor for the automobile, based on analysis and experimentation, and goes a step further by introducing a level of perfection. In this notion, Le Corbusier clarifies that a standard need to be set first to reach a level of perfection, which is obtainable if the problem is precisely determined [1]. This logic further defines the standard in architecture according to the principle of combining functionality and appropriate construction.

In terms of architecture, the aircraft lesson originates from the efficiency of determining the problem and finding a solution [1]. According to Le Corbusier, in aircraft, the definition of the problem was not in solving the propulsion of an aircraft engine, but in the assumption that in less than ten years, the whole world will fly [1]. The aircraft's function is to transport people, goods. Still, at the same time, Le Corbusier emphasizes that the people of his time could not comprehend the benefits achieved by airline commercialization. Analogously, in architecture, the problem is not clearly defined. Hence, Le Corbusier provides guidelines with which, by using the analysis of the aircraft, exemplifies the standardization of design, which lacks unnecessary characteristics for functionality. From an urban perspective, the aircraft for Le Corbusier opens up a new standard of measurement and the possibility of perceiving and analyzing previous design flaws and the potential for future planning, exerting into account the aerial perspective. In this lesson, Le Corbusier concludes that settlements must be demolished, and new cities built while acknowledging planning criteria and design failures conceded by the age of aircraft [2]. Le Corbusier believes that humanity has made cities based on financial opportunities and earnings while neglecting the quality of life and urbanism principles, emphasizing the ratio of green areas with the city's development [2].

In Le Corbusier's theoretical work and the study of three inventions, the following analytical model has been extracted: 1. Problem definition, 2. Analysis, 3. Experiment, 4. Standardization, 5. Perfection (comfort and pace).

Le Corbusier's analysis concludes a close connection between technology and architecture in joint reflection defined by mutual standardization. However, what would that imply in a matter of electric aircraft while considering architecture? Following Le Corbusier's approach in recognition modifications in comparison with the inventions, the next chapter reveals. Therefore, electric aircraft are primarily analyzed to identify, by contrast, and comparison, potential changes significant for architecture, urbanism, and the city.

3 Take off path – analysis of the current electrical aircraft

The analysis of the electric aircraft is divided into eVTOL (electric vertical takeoff and landing) and electric airplane, which is analyzed in two variants: a hybrid electric airplane and a fully electric airplane. eVTOL is an electric aircraft that uses electric propulsion for vertical landing and takeoff (no runway is required, unlike in the hybrid-electric airplane and a fully electric airplane). The division of electric aircraft into hybrid and fully electric models distinguishes two composite models:
1. Hybrid electric airplane model powered by fuel and electric propulsion
2. Hybrid model based on the combination of a hydrogen-powered engine and electricity.
A fully electric airplane model with a more extended range and passenger capacity is set for future development after the hybrid model phase since modern batteries do not currently have storage capacity. Therefore, a fully electric aircraft cannot be analyzed adequately [3].

In Table 1 are extracted analyses of two types of fully electric airplane models:

1. Airplane with a shorter range and number of passengers - Eviation Alice
2. An electric airplane with a significant number of passengers and range - this analysis is based on IATA (International Air Transport Association) available data.

Moreover, Table 1 contrasts Lilium's eVTOL, Eviation's fully electric airplane Alice (limited number of passengers, shorter range), NASA STARC-ABL and Boeing Sugar Volt hybrid models, and the all-electric futuristic model (more passengers and capacity). According to the data from Table 1, one could conclude that the transition phase from hybrid to autonomous electric aircraft is inevitable by 2035. Still, changes are tangible while concerning architectural design, gas reduction, CO_2, and the need for power plants, hydrogen hubs etc.

Table 1: electric aircraft data examination

Aircraft type	Battery, engine, supply	Passenger capacity	Maximum distance (range)	Speed	First flight (year)
eVTOL[4] (Lilium)[5]	36 x 320 kW Lithium-ion battery, 80% in 15 min 100% in 30 min	6+1 (pilot)	280 km	300 km/s	2025.
Electric airplane Alice (Eviation)[6]	2 x 640 kW magniX 650 engine, 1h / flight = 30 min charging	9+2 (pilots)	814 km	407 km/s	2023.
NASA STARC-ABL [7]	2 x Turbofan and generators + back engine electric propulsion	154 passengers	14,310 km (Boeing 747)	0.8 Mach = 987 km/s	2035.
Hybrid model Boeing Sugar Volt [8]	2 x Turbofan + battery Electricity maintains the engine while flying	150 passengers	6482 km 1666 km on battery	0.7 Mach = 864 km/s	2035.
Hybrid Airbus ZeroE turbofan [9]	2 x hydrogen Turbofan + hydrogen cell that produces electrical energy	120-200 passengers	3704+ km	0.78 Mach = 963 km	2035.
Electric airplane of the future [10]	Electric battery	150 passengers	537 km	-	2035. - 2050.

According to NASA research, the reduction of harmful gases for STARC-ABL is -10%, Boeing Sugar Volt -43.6% (on average, if renewable energy sources are used to charge the battery, the reduction is -58.9%), while the decrease for Airbus ZeroE is -100 % [11]. The period until 2035. is defined as the time of the evolution of electric aircraft, while the time after 2035. is deemed as revolutionary for the future of the aviation industry [12].

4 Identification of potential changes in architecture in relation to the analysis of electric aircraft (1. eVTOL & 2. electric airplane - hybrid and fully electric model)

4.1 eVTOL (electric vertical takeoff and landing)

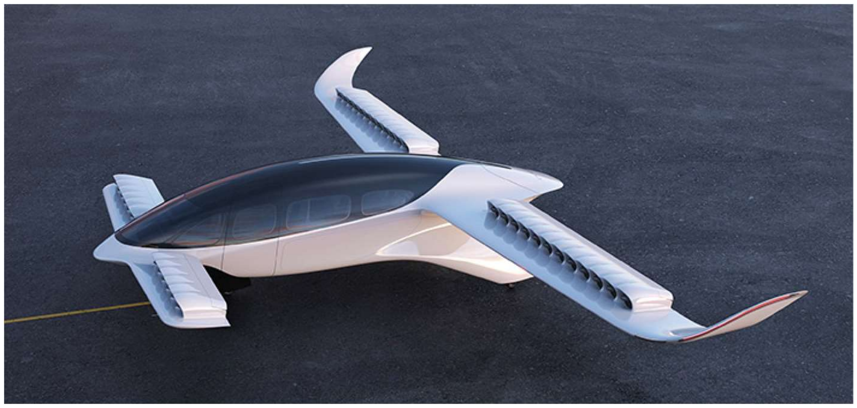

Figure 2. Lilium jet

eVTOL stands for electric vertical takeoff and landing, which in its title discards the essential infrastructural element of a modern airport - the runway. Thanks to electric propulsion, and the vast demand for new modes of transport and urban air mobility, global organizations and startups are developing their versions of eVTOL, such as NASA, Boeing, Lilium, Uber TAXI etc.) [4].

4.2 Case study: eVTOL Lilium & runway infrastructure

Figure 3. Lilium vertiport design variations based on the same modular elements

For a case study, an analysis of the current relationship between eVTOL and novelties regarding infrastructure, architecture and the city, German aerospace startup Lilium is analyzed. Lilium aims to develop sustainable high-speed connections using eVTOL, vertiports (landing pad for eVTOL) and accompanying digital technology [5]. The company has successfully developed the 5-seater eVTOL, as the 7-seater Lilium jet flight is under development for 2022. In correspondence with the progression of their eVTOL, Lilium is developing a vertiport system in Florida and at Munich airport. Planned commercial flights are scheduled for 2025 (1).

4.3 Identification of predictable changes in architecture and urbanism concerning eVTOL

With a high degree of adaptability, the analysis of the concept development in Table 1 suggests that further implementation of landing and take-off vertiports will lead to an opportunity of releasing currently occupied plots used for take-off and landing, such as unison airport runways. However, some other typologies, such as piers, skyscraper roofs, checkpoints in the park, will inevitably become vertiports with minimal intervention that will redefine their function. In addition to these modifications, the following architectural changes have been identified in urbanism, sustainability, energy efficiency, re-use, traffic and flexibility.

Urbanism
1. Prediction of adequate areas in the city as take-off and landing locations
2. Noise protection and redefinition of urban rules for the immediate vicinity of vertiports
3. Definition of the standard for vertiport installation concerning the city center, typology of the neighborhood (residential area, business district, historical center, recreational zone, protected sites, etc.)

Sustainability
1. Facade definition of the existing buildings and the planned ones while concerning vertiports in terms of turbulence protection and the possibility of energy production through a sustainable facade system
2. Abolition of smaller airports by implementing the eVTOL system
3. Predicting and devising ways to supply vertiports through existing architecture and future planning
4. Complete reduction of gas emissions

Energy efficiency
1. Design and construction of vertiports with battery charging systems
2. Identification of techniques for electricity production for eVTOL supply
3. Use of renewable energy sources

Reuse
1. Consideration of the existing infrastructure's capacities (abandoned airports and in use) as potential parking zones of eVTOL and as interim storage and power supply

Traffic
1. Optimization of the highway infrastructure use while concerning adaptation parameters with the electrical energy source
2. Focus on local traffic, with less passenger capacity

Flexibility
1. Enabling multiple vertiports in the city

2. Custom made travel itinerary cancellation ease and flexible rebooking policy through the mobile app

4.4 Implementation of Le Corbusier's theoretical conclusions into analysis for eVTOL with architecture and urbanism

1. Problem definition (distance, number of passengers, charging, noise concerning the city)
2. Analysis (planned locations for vertiport installation)
3. Experiment (survey and analysis of vertiport data, case study implementation of infrastructure in the city, for example - in specific typologies and city areas)
4. Standardization (infrastructure demands redefinition, introduction of new infrastructure)
5. Perfection/level of comfort and speed (reduced number of passengers, custom-made journeys, gas reduction, cruising speed (same or faster than current standard) / less congestion at airports, healthy environment, reorganization of local traffic, the release of existing city infrastructure, projection of the aircraft parking locations and charging points within the vertiport)

4.5 Electrical airplane (hybrid and fully electric model)

Figure 4. Eviation Alice

4.6 Electric airplane

Compared with the observed changes in the architectural parameters of eVTOL, the electric airplane retains a crucial infrastructural element, the runway. However, the substitution of airport fuel collection points and accompanying fuel tanks with the construction of systems and infrastructure for electricity supply, hydrogen hubs, and adequate power supply and hydrogen supply systems is inevitable.

4.7 Case study: infrastructure and current airport

Figure 5. Airbus Hydrogen Hub concept

According to Airbus research, hydrogen, for the same amount of energy, has only 1/3 the weight of kerosene, but, in isolated conditions, is four times larger in volume compared to kerosene [13], which gives clear guidance for designing an aircraft hydrogen tank as well as the following airport infrastructure.

4.8 Identification of foreseeable changes in architecture and urbanism concerning electric airplane

Urbanism

1. Redefine the concept for the future airport planning and current airports expansion with the necessary examination of the need for additional expansion concerning the potential of redirecting traffic to eVTOL or other transport systems of the future, such as Hyperloop

Sustainability

1. Reduction of harmful gases (CO_2)

Energy efficiency

1. Investigate the importance of building power plants to power electric planes near the airport
2. Interdependence of power plant and power supply of electric airplane
3. Anticipation of additional space for the battery charge cycle (based on the example of the Alice electric plane; 30 minutes of battery charging is required for 30 minutes of flight)
4. Hydrogen hub prediction - tank concept and adequate supply [14]

Reuse
1. Reduction of the number of existing airports in terms of mode of use according to distance, flight capacity, and maximum number of passengers
2. Investigation of the abandoned airports potential and their reuse in relation with the location and connection with, for example - electrical power source supply for the airplane; technology and the necessary infrastructure

Traffic
1. Redefinition of local and international traffic concerning airplane capacity (number of passengers, maximum number of flight hours)

Flexibility
1. Organization and redirection of local traffic to the eVTOL system
2. Number of passengers - the same as with standard airplane (the ultimate goal of standardization and commercialization)

4.9 Implementation of Le Corbusier's theoretical conclusions into analysis for electrical aircraft with architecture and urbanism

1. Problem definition (aircraft battery is still not fully electric/various combinations of power supplies are required for the evolution phase)
2. Analysis (existing airport infrastructures concerning aircraft changes - hybrid and electric aircraft)
3. Experiment (survey and data analysis, case study implementation of infrastructure at the terminal, for example - hydrogen hub)
4. Standardization (in the first phase - optimization of the charging criteria and detection of infrastructural changes for the hybrid-electric aircraft model)
5. Perfection/level of comfort and speed (optimal number of passengers, gas emissions reduced to a minimum, travel speed (same or faster than the current standard) / fewer crowds at airports, sustainable environment)

5 Conclusion

An overview of the technological aspects of new electric aircraft and their consequences for architecture and the necessary infrastructure is crucial for understanding the functional necessity and the electric aircraft system implementation possibility.
The new transportation will have potential repercussions for the city, the new architecture, and the regime of use of the urban infrastructure. It can be assumed that there will be new forms of architecture or a combination of elements that architecture will contain to serve as a runway and-or channel for further involvement in urban transportation.

According to NASA research, eVTOL will require new infrastructure, as the functional system is new itself, and electric airplanes will use existing airport infrastructure. There is no doubt that eVTOL will lead to a complete change in the design paradigm of the new architecture, which is inferred from the analyzed data for electric aircraft such as eVTOL and Alice, followed by the implementation of the vertiport system scheduled for 2025.

Although the electric airplane will use the existing infrastructure, the inevitable task is the reorganization of current infrastructure use in terms of construction reduction and future development of the concept for airport extension and the new airport development. In addition, the critical goal is to minimize the emission of harmful gases, which is determined by data analysis as an element of the globally sustainable future. The need for adaptation towards the electric aircraft technology and the options for landing and take-off is expected. However, the focus of further research is to examine in what possible ways this will entirely change architecture and the city.

Figure 6. Zeppelin docking

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POST COVID-19 POULTRY FACILITIES

Hochung Kim, Jinoh Park

University of Tennessee

1715 Volunteer Blvd, Knoxville, TN 37919, hkim96@utk.edu, newnormalist@gmail.com

Abstract

The purpose of the research is to observe and analyse the working conditions of frontline workers who are exposed to hazardous environments. Since the COVID-19 pandemic, the situation for the frontline workers has worsened including a lockdown and Stay-At-Home Orders. Although White-collar workers took advantage of technology to work remotely, it was not the true case for meat and poultry processing workers. This research identifies the current condition of working environmental elements under the theoretical perspective of Functionalism. It aims to address how we can improve the current working environments in poultry facilities. Through the evidence-based design research framework, this research visualized the current and suggested better working conditions. integrating the outcomes of phases two and three through visualization, this research proposes a better workplace in the meat and poultry facility.

Keywords

Front line workers, COVID-19 pandemic, Meat and Poultry workers, Meat and Poultry Processing facilities, work environment

Introduction

This research is a response to the work environment of frontline workers in the meat and poultry facilities which have become COVID-19 hot spots. As COVID-19 spreads worldwide, on March 11, 2020, WHO declared a global pandemic situation. In the United States, starting with the state of California on March 19th, 2020, 43 states have issued Stay-at-Home Orders until the number increases from 9,197 cases on March 18th to 395,480 cases on April 7th (KFF, 2021). In addition to Stay-at-Home Orders, physical distance restrictions have been imposed, including social distancing and CDC guidelines. The orders and restrictions required the working environment to be different from the previous normal working environment. In response to the requirements, professional architectural firms explored strategies and directions for the workplace changes (Tranel, B., 2020 ; Grossmann, J., 2020; Stoltz, A., 2020). Moreover, not only the architectural firms such as Gensler, HOK, and Perkins & Will, but also media companies suggested planned scenarios in the workplaces (BBC, 2020). The efforts of the above companies support an online or hybrid work environment on the premise of working remotely. This move has advanced enough to further consider support for Working-From-Home (WFH) (Baym, N., Larson, J., & Martin, R., 2021). However, there are areas responsible for physical production like Food that cannot replace working environments online. Especially in the early days of the pandemic, the panic shopping for food was rampant because of the fear that the government's lockdown declaration will make it difficult to obtain food necessary for survival. This panic shopping phenomenon has increased the demand for food, which in turn increases the need for increased supply. In particular, as the USDA implemented the executive order issued by the US Government to ensure a stable supply of meat products, the meat and poultry processors continued to operate their facilities during the pandemic (USDA., 2020). As a result, meatpacking plants have become the COVID-19 hot spots (Molteni, M, 2020). In spite of this situation, it is relatively difficult to find studies for these front-line workers compared to studies of transitions to online or hybrid work environments.

1 FRONTLINE WORKERS

1.1 Demographics

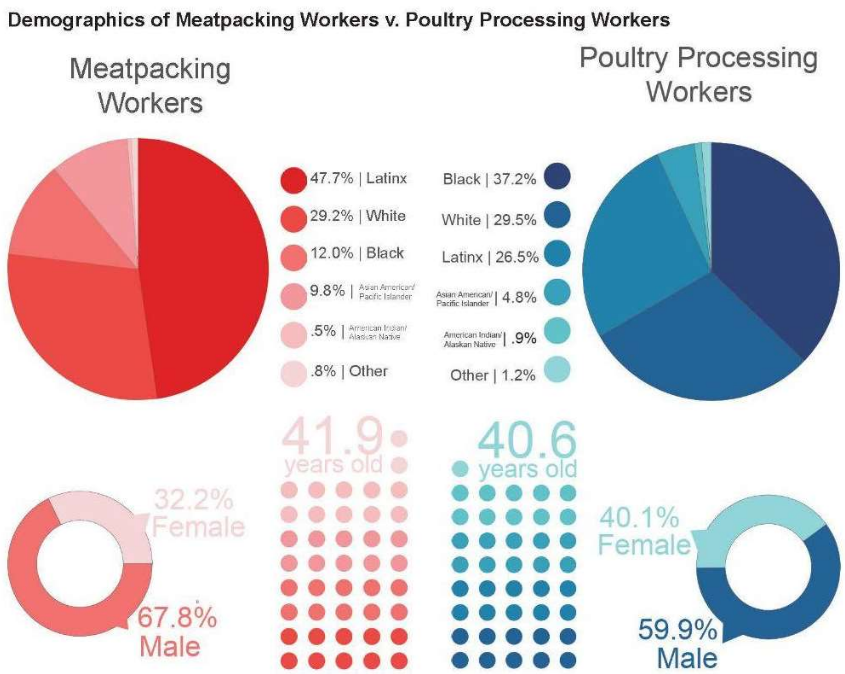

Figure 1. Demographics of Meatpacking Workers vs. Poultry Processing Workers

According to the Quarterly Census of Employment and Wages, the top meat packing industry employment has flourished in the Midwest and Plains states in the order of Nebraska 26,607, Iowa 26,543, Texas 23623, Kansas 17,893 and Illinois 17,143. The poultry industry has flourished in the states of the deep South: Georgia 31,950, Arkansas at 29,014, North Carolina 22,441, Alabama 21,697, and Mississippi 16,036. The employment number represent the five-year average of workers reported by firms, by the industrial sector in each state from January 2014 through December 2018. Beef and hog slaughtering firms are identified by the following North American Industry Classification System (NAICS) codes: 311611 – Animal Slaughtering, Except Poultry; 311612 – Meat Processed from Carcasses; 311613 – Rendering and Meat By

product Processing. Poultry processing firms are identified by the NAICS code 311615 – Poultry Processing.
The meatpacking industry heavily relies on immigrant men of diverse backgrounds. (Streusse, Angela and Dollar, Natha T, 2020). 66.8% of the foreign-born workers speak Spanish, and the second 4.4% are Vietnamese. The country of origin amongst these foreign-born workers are from Mexico in both Meatpacking and Poultry facilities. Among those workers 67.1% are non citizens and earn an annual income of $35000. In contrast, much of the rural South, poultry processing operated predominately on the backs of local African American women and men and poor white women until the industry's more recent turn to immigrant labour.

1.2 Working Conditions

Based on (Stauffer, Brian.2019. Human Rights Watch) Most of the employees are forced to work in a speed driven environment. According to Stauffer, *"In the pursuit of profit, meat and poultry slaughtering and processing companies have sought to maximize the volume of production and minimize the cost of labour by pushing production speeds faster."* This harsh working conditions also results in pain, injury and fatalities among the workers. The employees speak out that *"'We have about two minutes for each piece, that's what the [company's] rules say,'* said Abel S., a worker at a beef plant in Nebraska, who trims cuts of beef from larger pieces of carcass. *'The issue is, when they're running the line, they don't even give us a minute sometimes. It doesn't have to be like that - fast, fast, fast.'"* "*'You'll be asleep and when your hands start hurting it wakes you up,'* said Nicole Bingham, a worker at the Tyson plant in Albertville, Alabama. *'Some days it's like throbbing pain - it's indescribable.'"*
OSHA data shows that a worker in the meat and poultry industry lost a body part or was sent to the hospital for in-patient treatment about every other day between 2021 and 2018."
In the interviews by Dryden, Joel and Sarah Rieger on May 6, 2020, North America's largest single coronavirus outbreak started at an Alberta meat-packing plant. Employees have quoted "when you enter the Cargill facility in High River is the smell something familiar, like that of an animal, but with a distinctive note of blood hanging in the air"

1.3 Social Inequality, Health, and Wellbeing

Under international human rights law, workplace protections apply to all workers, regardless of citizenship status. However, the fear of retaliation and possible deportation causes many workers who are undocumented, or have family members who are undocumented, to be hesitant to speak up in the workplace or report abusive employers and working conditions. Many of the workers have limitations on expressing their rights and finding fair and equal work environments. After the death of his wife, Hiep Bui, husband Nga Nguyen expressed that he felt hopeless and felt numb about the situation. From the interview, Nga Nguyen was asked whether Cargill had called him to express his condolences. Nguyen shrugged and shook his head. The interpreter told the press that he didn't have any feeling but felt the number.
Based on the workers description, the situation of the work environment as *"…the fabrication line, where workers say they're packed elbow to elbow. Here, they work cutting meat for eight hours a day…"* Rebecca G., a poultry worker in Arkansas, explained that *"As soon as we would enter we would start to tear up… It was really strong. We felt like we were getting sick - your throat, nose. For me, I would cry. I was always crying. I also had a really strong pain in my*

throat. Some people would get bloody noses…. Almost every day it was one person or another [complaining to management]. One pregnant woman went to ask what chemicals they were using and what [they would] do to [her] child [but the company] said that it was within the permitted standards. Their solution is to say: 'If you don't want to stay here, go.'"

2 RESEARCH DESIGN

Through the above literary review, this study basically confirmed that the meat and poultry facilities had a non-ideal working environment even before the pandemic and who mainly the workers working there were. As a result, we recognized the phenomenon that resulted in unavoidable social inequality. This study is not an attempt to change the social structure of the main workers, but to find the possibility of solving the problem by recognizing the phenomenon, maintaining social order, and objectively approaching the materialized work environment. As a result, this research draws functionalism to take its perspective which is subjective and keeps sociological regulation (Burrell and Morgan, 1979, p.22). The use of this theoretical perspective is meaningful as a problem-solving approach to ameliorate factors of inequality in terms of human rights, not for progress in a situation where necessary conditions are met.

Under the theoretical perspective, in order to achieve the goal of improving the work environment in the meat and poultry facilities, this study utilizes the evidence-based design process (McLaughlin and et al, 2014) to collect and interpret the standardized data published so far, to suggest a better work environment for the frontline workers in the facilities. The evidence-based design process consists of five phases: Organizational readiness, Pre-design, Design, Construction, and occupation, with nine methods: Opinions, Review of Precedents, POEs, Case Studies, Ethnography, Survey, Controlled Observation, Quasi-experiment, and Randomized Controlled Trials. Under the main questions "How can we improve the existing meat and poultry facilities?" This research has two sub-questions: "What resources are available for meat and poultry facilities?" and "What will the space of a meat and poultry facility improved through design look like?" In order to answer the questions, this research focuses on two phases of the evidence-based design process: Pre-design and Design, by surveying existing resources and reviewing precedents.

This research consists of three phases. First, this research investigated the existing resources addressing workspace guidelines for the health and wellness of meat and poultry facility workers. The investigation has been conducted through the University of Tennessee's library system, Google, and ScienceDirect. As a result, this research found two books: U.S. Inspected Meat and Poultry Packing Plants: A Guide to Construction and Layout (USDA, 1984) and Handbook of Farm, Dairy and Food Machinery Engineering (Kutz, M., 2013). After the investigation, we established built-environmental elements for practically realizing the work environment guides. Second, this research collected a set of drawings and information about an exemplary meat and poultry facility online. Third, this research diagnoses the exemplary meat and poultry facility and applies the established built-environmental elements. As a result, by integrating the outcomes of phases two and three through visualization, this research proposes a better workplace in the meat and poultry facility.

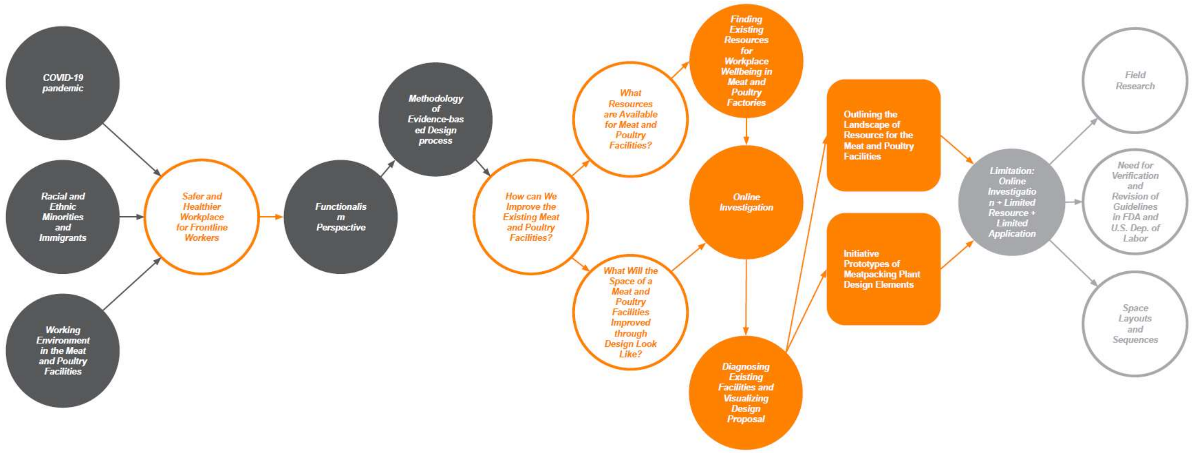

Figure 2. Research Design and Findings

3 FINDINGS

Architectural Minimum Requirements

According to Agriculture Handbook NO. 191 Agricultural Research Service from the U.S. Department of Agriculture/Wellbeing workplace Design Restrictions, there are several guidelines to outline the minimum material requirements. Overall Building materials should be impervious, easily cleanable, and resistant to wear and corrosion. Wall and ceiling surfaces should be white or light colored for light reflection and sanitation. Whenever practical, materials that do not require painting should be used. Materials that are absorbent and difficult to keep clean are generally unacceptable. Examples of such unacceptable materials are wood, plasterboard, and porous acoustical - type panels or tiles

Flooring Requirements

Floors should be constructed of durable water resistant materials . Commonly used acceptable materials are concrete, ceramic floor tile, floor brick, and synthetic material approved by FSIS. As a safety precaution , excessively smooth floors must be avoided. Good results are obtained by using brick or concrete floors with abrasive particles embedded in the surface. Concrete floors should have a wood float (rough) finish . Concrete or mortar floors that incorporate an approved latex or synthetic resin base have better than ordinary resistance to meat fats and acids.

Interior Wall Requirements

Interior walls should be smooth , flat, and constructed of impervious materials such as glazed brick, glazed tile , smooth -surfaced portland cement plaster, plastic , or other USDA-accepted nontoxic, non absorbent material applied to a suitable base . Walls should be provided with suitable sanitary type bumpers or curbs to protect them from damage by hand trucks, carcass shanks, and the like.

Ceiling Requirements

Ceilings should be at least 10 feet (3.05 m) and are more desirable for workrooms. So far as structural conditions permit, ceilings should be smooth and flat. Ceilings should be constructed of portland cement plaster, large - size cement asbestos boards with joints sealed with a USDA- accepted impervious material. If the ceiling has exposed joists, the joists should be at least 36 inches (91.44 cm) on center and designed so that there are no excessive ledges or crevices which would be difficult to keep them clean.

Doorways and Doors Requirements

Doorways through which product is transferred on rails or in hand trucks should be wide enough so that there is no contact between the doorways and the product. In most cases 4.5 - foot-wide (1.37 m) doorways are necessary. Doors in such doorways must be constructed of either rust - resistant metal or other USDA - approved material. If made of wood, they should be clad on both sides with rust-resistant metal having tightly soldered or welded seams. Door jambs should be clad with rust resistant metal securely affixed so as to provide no crevices for dirt or vermin. The juncture at the walls should be effectively sealed with a USDA - approved flexible sealing compound. For safety reasons, double-acting doors should have a reinforced glass or transparent plastic panel at eye level.

Ventilation Requirements

Adequate means for ventilation should be provided in work rooms and welfare rooms. This may be accomplished with ventilating-type windows, skylights, or both, by mechanical means such as air conditioning or a fan and duct system. For the safety and health of the work environment it is necessary to keep the natural ventilation to keep out the dust and foul odors. windows should also be of the fixed-type.

Lighting Requirements

Well-distributed and good-quality artificial lighting is required at all places where natural light is unavailable or insufficient. The overall intensity of artificial illumination in workrooms should be no less than 30 foot candles. At all locations where inspections are made or where special illumination is required to enable employees to properly prepare products to meet the requirements of inspection, the illumination should be not less than 50 foot-candles.

3.1 Design Proposal

Based on the current analysis of meat and poultry facilities in the United States, we are taking the first step to make a design proposal to address some of the current issues.

Lunch Facilities

It is necessary to avoid unsanitary conditions usually associated with employees eating lunch in edible processing departments, adequate lunch facilities should be provided when plant cafeterias or nearby eating places are not available. The key factor is to provide ample space to avoid congestion. The lunch room should also serve as a break room for the workers as well as the reflection of their culture.

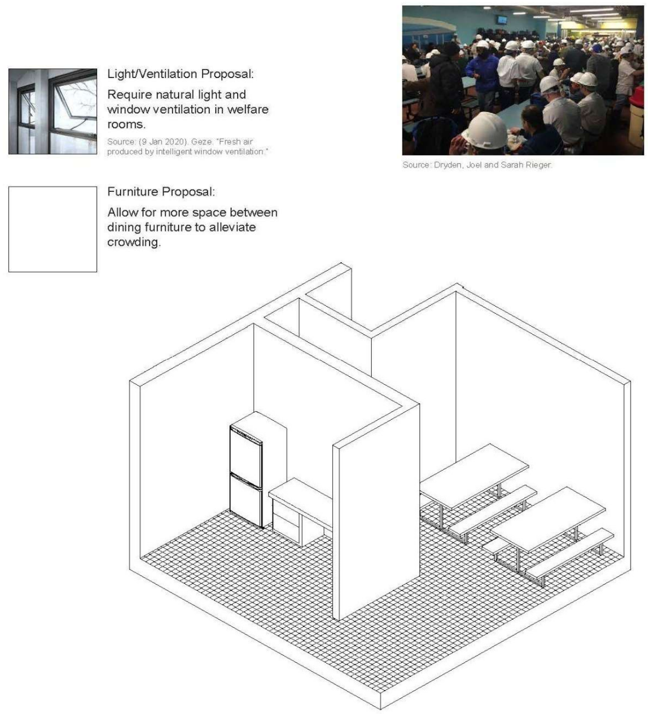

Figure 3. Existing Design & Proposals Canteen / Lunchroom

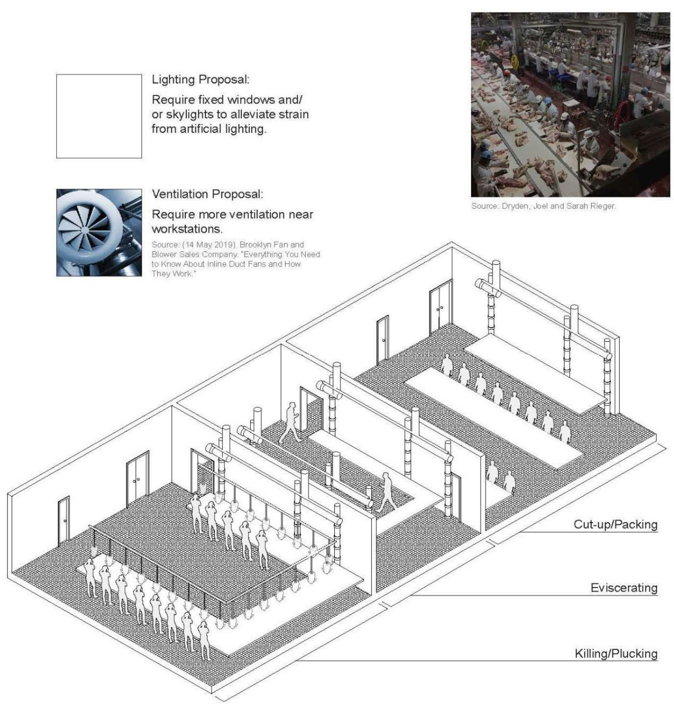

Figure 4. Existing Design & Proposals Killing/Plucking, Eviscerating, Cut-up/Packing

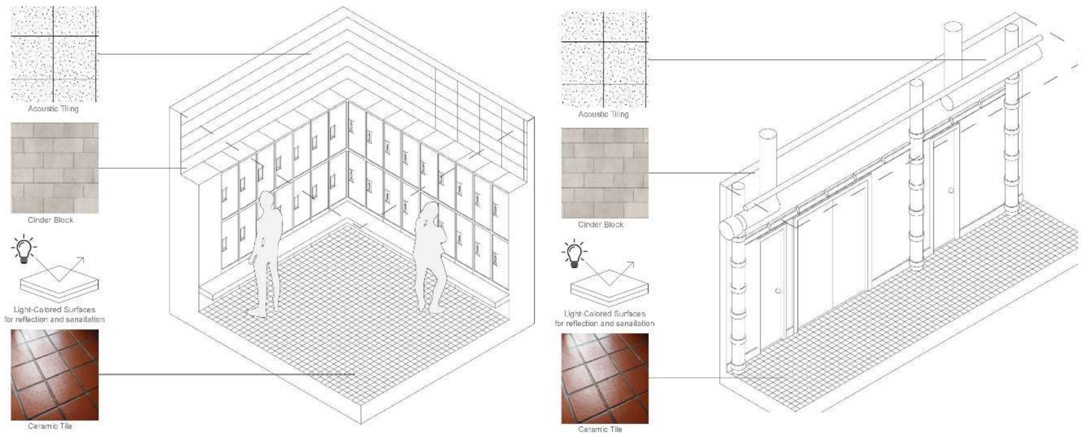

Figure 5. Existing Design & Proposals Changing Room / Corridor

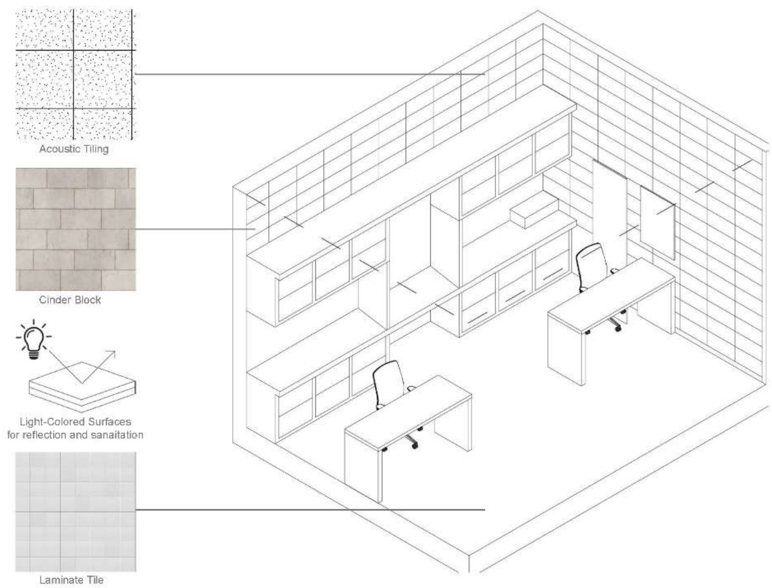

Figure 6. Existing Design & Proposals Office

Lighting

Well-distributed and good-quality artificial lighting is required at all places where natural light is unavailable or insufficient. Also providing UV sensitivity along with blue lights to disinfect harmful bacteria in the facility. This will be critical for the safety of workers. Based on USDA guidelines, all rooms in which poultry is killed, eviscerated, or otherwise processed shall have at least 30 foot-candles on all work surfaces, except at the inspection stations where at least 50 foot-candles of light is required.

Ventilation

Adequate ventilation should be provided in work rooms and welfare rooms. This may be accomplished with ventilating-type windows, skylights, or both, or by mechanical means such as air conditioning or a fan and duct system. When possible, the natural ventilating types will be favourable to reduce the mechanical duct maintained.

Eviscerating and Chilling Areas

The eviscerating department should have adequate floor space, arranged to facilitate sanitary operations and efficient inspection. All eviscerating operations should be readily accessible

Materials/ Other Interior Elements

In general, the building materials should be impervious, easily cleanable, and resistant to wear and corrosion.

4 DISCUSSION

This paper provides visualized work environments in the meat and poultry facility under objective workplace guidelines for employees' health and wellness. This study is meaningful in exploring the direction of improvement and suggesting objective solutions for the materialized element (built environment) of the problem (work environments in meat and poultry facilities) revealed in the ontological perspective composed of social order. This study has two limitations in that it 1) provided a solution by applying only one example space and 2) did not provide a comprehensive direction considering employee satisfaction based on specific information due to 2.a) the inability to conduct field research caused by COVID-19 and 2.b) the absence of a partner. On the other hand, it was found in this study that it is likely that it is difficult to conduct a meaningful survey even if a field survey is conducted through a partnership. United States Government Accountability Office (2017) published a report describing the challenges of identifying and addressing worker safety concerns because of their vulnerable contracts issues. For the following research, this research team is going to develop a generative design toolkit that uses advanced tools such as Dynamo and Grasshopper to generate better work environment solutions for worker health and wellness.

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HEALING THE SCARS

Tahsin Adiba Rahman, Razib Hassan Chowdhury, Khairun Fahmi*

SILT

Dhaka-1206, Dhaka, Bangladesh; adiba.silt@gmail.com, silt.bd@gmail.com,
* fahmi30.silt@gmail.com

Abstract

Infrastructures, a predominant part of urban growth, weaves the city to connect people places and services. But with the advent of urbanism, natural elements are losing their cohesion and continuity. With urbanization, infrastructures are slicing through the terrain and restricting the ecological systems. These urban connectors are flatly placed on the urban surface without ecological coherence.

This study aims to encourage the possibility of an alternative infrastructural system that - instead of creating more and more scars across city fabric- will act as healing strips. Natural elements enable us to decisively reorganize our settlements for wellbeing, encouraging an independent yet interconnected living. Retracing the inherent elements that are embedded in our existence through the reclamation of the ecosystem allows us to share the abundance of its presence while inducing a reversal of social and ecological disparities that have rendered the world uninhabitable.

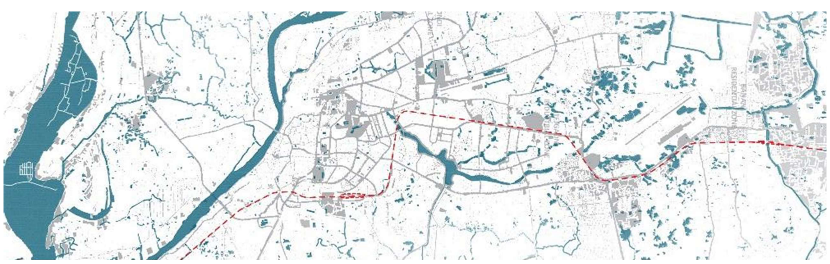

Figure 1. Focus area, Dhaka, Bangladesh

The proposed study area is the existing railway and adjacent infrastructure that cuts through Dhaka north to south flanking the city East to West. Along with literature review and the analysis and examination of urban fabric shall lead the path to an integrated design methodology.

Dhaka, an urban basin of rivers dotted with numerous water bodies–present and extinct, bedazzled with density and disparity, could be envisioned as a network of self-sufficient and modular mixed-use communities (Figure 1). The spinal separator can become the central connector, a civic flux, a linear purifier. Grimm separators can be envisioned as shared connectors. Urban infrastructure could be reclaimed to make way for resilient ecological corridors and connections, ensuring an inherently healthy living condition for its inhabitants.

Keywords

Infrastructure Overtake, Urban Resilience, Ecological Connectors, Urbanization, Dhaka City.

Introduction

Urbanization, its trends and predictions have been a source of consternation. Particularly, in developing countries with rapid population growth. Being a demand driven bottom-up process, rapid and unplanned urbanization is a threat to social, economic and infrastructural stability. Since 2007, more than half the world's population has been living in cities, and that share is projected to rise to 60 per cent by 2030. Specifically, in countries with challenged economic conditions, rapid urbanization and infrastructural developments imbalances and destroys the existing ecologic connectivity without considering the possible environmental consequences [1]

Water, the quintessential force that effortlessly embodies the paradox of being a connector yet separator, enables us to decisively reorganize our settlements encouraging an independent yet interconnected living. And as the infrastructural onslaught severs the ecological connections, hence, the best way to reconnect or restore balance is to introduce water, active top soil and vegetation at the water's edge and gradually connecting with the urban landscape species.

The question then arises, how to introduce water infused active ecologic connectors throughout a city?

Discourse Premise:

And, for a resource starved economically challenged city very widely evident in the developing countries, basic connectivity requirements over shoot the society's intent to acknowledge the dire necessity of ecological connections if the city is to sustain.

Hence, the only way forward is to adopt multi-layered ecological connectors, that accommodate

1. A natural and navigable waterway
2. Vegetated edge conditions that permit human access, walkways and bike paths along with jetties for the water way.
3. Elevated, metro / railway
4. Expressway and vehicular roads.

This paper aims to investigate the possibility of such alternative and integrated infrastructural systems that would induce better and natural storm drainage, water ways, increased and layered connectivity and most importantly ecologically active Hydro-geologic connections that would result in intense cross-species interactivity. Infrastructures thus instead of creating more and more scars across city fabric, will act as healing strips.

Context: Dhaka

The Most densely populated city of the world. According to World Data Atlas, the urban population of Bangladesh increased from 7.9 % in 1971 to 38.2 % in 2020. This population burst influenced massive infrastructure and service developments. Alongside new housings and workplaces to meet the demand of constantly growing population, new road-network, water supply, sanitation, sewerage and drainage services were necessary. Over the years Dhaka, the core city, has densified while crowding the water bodies. At the same time, the city sprawl has expanded in all directions - which in the aftermath has caused shrinkage of the natural drainage and wetlands of surrounding areas. Historically the city's ecological continuity has always been balanced through its connected hydrology. But this rapid growth of infrastructures is slicing through the terrain, causing both division and compartmentalization of the existing ecology.

From a Hydrological spawn to an ecological disaster

Dhaka was once known as the "Venice of the East" or "The City of Channels" [2]. Holocene sediments created different types of landforms surrounding the city such as channels, depressions, high floodplains, and low-lying marshlands. The main old city in the examined region is built on semi-consolidated Pleistocene sediments (Madhupur clay), slightly higher than the extreme western boundary, which is covered by Holocene to recent Buriganga-Turag floodplain sediments [3]. The floodplains of the Balu River cover the majority of the eastern edge and are characterized by low-lying depressions and marshy floodplains that are harvested in the dry season. During monsoon storm-water from the study area drains via streams and canals (locally called "khals") to the floodplain and low-lying area and ultimately towards Buriganga-Turag-Balu, finally connecting to the Ganges-Brahmaputra River system [4].

Dhaka Megacity's past and present is woven with a large number of water bodies. The major lakes are Dhanmondi lake, Ramna lake, Gulshan lake and Crescent Lake. Within the Dhaka city region, there are estimated to be roughly 35 canals. (Khan 2001). Some canals are in severe condition right now, and some have completely vanished. Begunbari Khal, Abdullahpur Khal, Diabari Khal, Manda Khal, Digun Khal, Meradia-Gazaria Khal, and Kallayanpur Khal are the principal canals that are still used as open channels (Figure 2) [8].

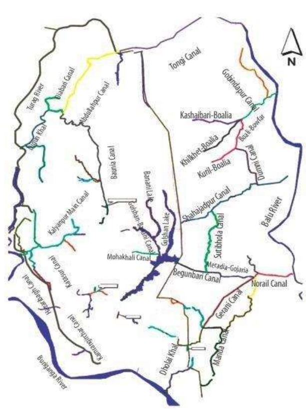

Figure 2. Canals of Dhaka City, DWASA, 2007

Filing activities for infrastructure such as embankments or making room for highways accelerated shrinkage of these wetlands and water bodies, causing natural drainage to be obstructed. Wetlands and other water bodies in Dhaka have been greatly reduced over the years because of reckless urbanization [5]. There were a number of studies that mentioned the two different scenarios of change of water bodies in the western and eastern parts of the city (Figure 3). The older section of Dhaka was in desperate need of land due to population growth and the strain of balding essential infrastructure for the increased population. Water bodies were sacrificed in an attempt to accommodate more people, and the drainage system which was essentially part of Dhaka's hydrology, collapsed [6].

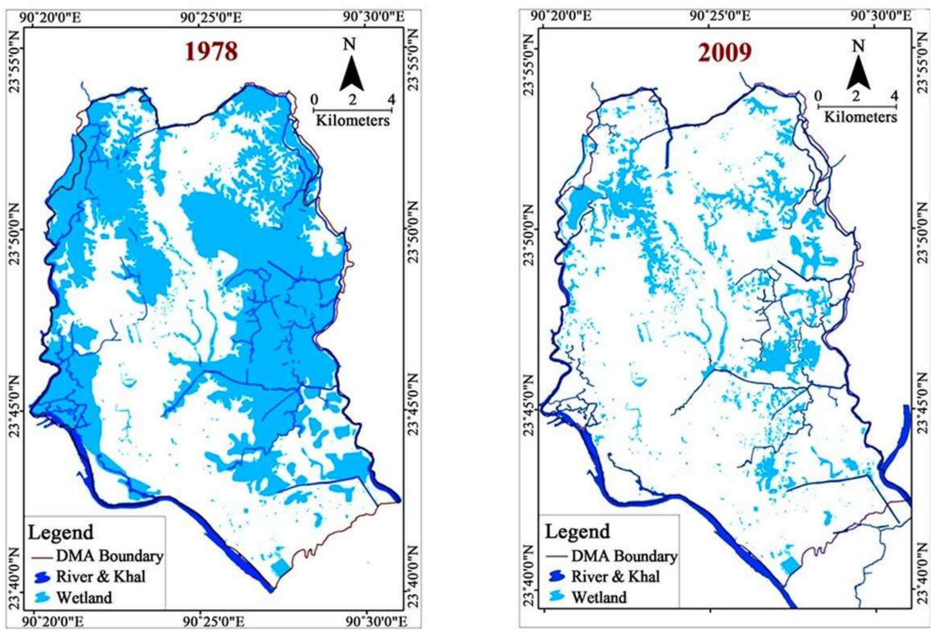

Figure 3. Changes of wetlands, Dhaka, Bangladesh. Source: Remote Sensing & GIS Based Spatio-Temporal Change Analysis of Wetland in Dhaka City, Bangladesh, 2011

Urban growth in the region indicates that the city has been expanding towards the wetlands of eastern part which acted as catchment area for stormwater drainage up until recent decades [9]. It is evident from the figure that urban growth sprawled there during the 1990s as private land development projects bloomed to accommodate housing scarcity. Lack of properly documented records of wetlands of Dhaka has made it harder to define and outline them. This situation made it easy for land-grabbers to encroach the wetlands [8]. The private land development business would buy large chunks of surrounding low-lying areas to implement housing projects and deliberately defy the standing laws and restrictions to grab lands illegally. They lift sand from nearby rivers, carry them with boats and extraction pipes to fill-up low-lying floodplains [8].

Wetland ecology sheds significant light on the potential of wetland and how it plays an important role in water purification. [9]. Harvesting grasslands with waterlogged soil which stays partially inundated during the year (like the eastern part of Dhaka) during dry season assimilates trapped nitrogen and phosphorus. Natural wetlands also play a vital role in the improvement of water quality, as they act as buffer zones surrounding water bodies and as a filtration stage for the effluents from conventional municipal wastewater treatment plants, before they reach the receiving water streams [10]. Hydrological considerations during urban planning can minimize adverse effects by conserving wetlands to use as retention and water purification areas [11]. Major water bodies of Dhaka include the Begunbari Khal, and the Banani, Gulshan and Dhanmondi Lakes, all of which were at one time linked by a system of canals, most of which have been filled and subsumed by urban development [12]. Recently the Hatir Jheel Integrated development project successfully revived that link and became the largest catchment area for stormwater inside the compact city.

Infrastructure: the scars of opportunity

Historically Dhaka was centred at south-western part of the current political/metropolitan boundary and then expanded in the north and east direction after Bangladesh's independence [13]. Even after numerous revision of transportation planning most of the significant roads run in north-south direction without any visible pattern and still lack enough primary connection between east-west (Figure 4) [14,15]. Currently bus, rickshaw, auto rickshaw, ride sharing services, and motorcycle services are available for mass transition.

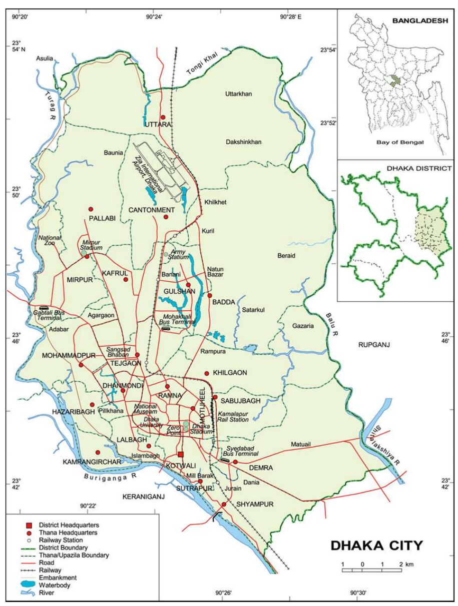

Figure 4. Canals of Dhaka City, DWASA, 2007

As part of the transportation development strategy, the integration of mass transit infrastructure includes Bus Rapid Transit (BRT) and metro-based Mass Rapid Transit (MRT). The plans include 6 MRT lines, partially elevated and partially underground, that will serve touching major traffic points (Figure 5). BRT service will provide exclusive ground level or elevated lanes along existing road networks. Both BRT and MRT require a great amount of resources due to their elevated or underground presence (Dhaka Transport Coordination Authority website).

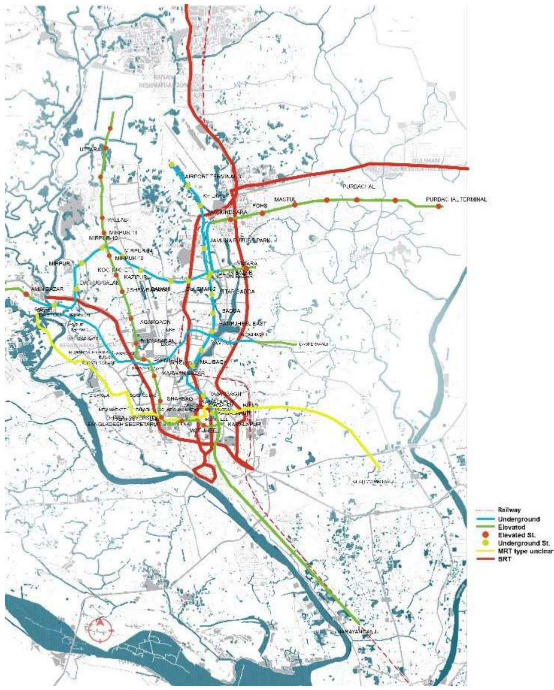

Figure 5. Proposed Mass Rapid Transit (MRT) and Bus Rapid Transit (BRT)

Along with the road network, Dhaka is also covered by the National railway service. The railroad stretches from Narayanganj - its southernmost terminal, to Tongi - its northernmost terminus, within Dhaka. There are ten stations between Tongi in the north and Narayanganj in the south, the most notable of which are Kamalapur and Tejgao. Dhaka's main railway station, Kamalapur Train Station, serves passengers primarily but also has an Inland Container Depot (ICD. Tejgaon Railway Station, in addition to serving passengers, is also the terminus for all freight railway shipments, from where all freight loads are afterwards disseminated across the city. Tejgaon Railway Station also houses Tejgaon Truck Terminal and serves as a marshalling yard and workshop for all freight wagons. [STP]The railroad is underutilized as a mode of passenger and freight transportation. Because of the large number of existing at-grade crossings, the railroad has a significant and disproportionately negative influence on other land-based modes of transportation (STP).

A proposal to relocate the current portion of the railway between Kamalapur Railway Station and the Airport was explored in 2004. A plan to build a circular railway line around Dhaka, preferably utilising the city's flood-protection embankment where possible; and another of the proposals was to elevate the railway inside Dhaka (STP) but the infrastructural cost was not viable. The proposed BRT line 3 is being constructed parallel to the railroads for a significant length from Mohakhali to Nikunja (Figure 6) using the strip of barren land running between the Airport Road and railroads which now presents the opportunity to be integrated with BRT line 3 to accommodate railroads and adjacent infrastructures. Construction of new infrastructure has become almost impossible as most of the inner city area is now built-up and this type of initiatives require land acquisition and demolition of large number of structures [16] and in an overly crowded city infrastructure sharing can be the next step. A hypothesis for that scenario is the complete length of land used for railroads and railway infrastructure inside Dhaka will become railway rust and will be either abandoned or that unique linear space can be used to encourage ecological balance.

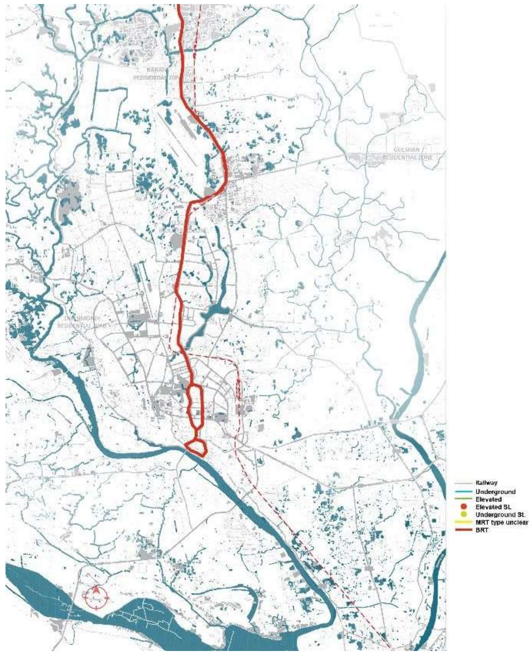

Figure 6. Overlapping of Railway and BRT 3

From a Spinal Separator to multi-tiered hydrologic connector

Taking cues from the STP project proposals, the proposal is to reuse the railway rust space to encourage hydrological connections, which can also serve as a transportation system connected to the hatir-jheel (Figure 7). Retracing the wetness that is embedded in our existence, through reclamation of the hydrologic networks allows us to share the abundance of its presence while inducing reversal of social and ecological disparities that have rendered the world inhabitable.

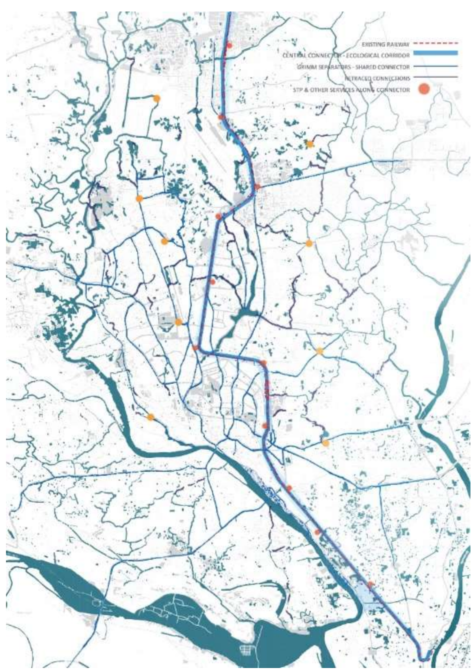

Figure 7. Overlapping of Railway and BRT 3

Thus the spinal separator can become the central connector, a civic flux, a linear purifier. Grimm separators as shared connectors, urban infrastructure to be reclaimed to make way for resilient ecological corridors and connections. An infused existence within our ecological context, a shared existence built on trust and endurance, hence resonates towards a resilient sustenance.

Where multilayer intertwined land bridges connect the communities, ensuring an inherently healthy living condition for its inhabitants.

A replicable opportunity

This design – research investigation, and the resultant observations can be used, adapted and modulated to different urban ecological contexts in a replicable manner. The strength behind this idea and approach lies in the fact, the proposal is to utilize existing urban infrastructural networks to create an interconnected web of ecologically active corridors that would breathe life back in to the otherwise ecologically dead urban fabric.

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EXPLORING FORMS: ARCHITECTURE AND FILMIC WIPES. EXPLORING VISUAL AND STRUCTURAL POTENTIAL OF 25 FRAME WIPES IN FILM, MOTION GRAPHICS, TELEVISION AND ANIMATION.

Sara Nesteruk
University of Huddersfield, Leeds Beckett University, Queensgate. Huddersfield, HD1 3DH, UK, s.nesteruk@hud.ac.uk

Abstract

This paper explores three key texts starting with Eisenstein's theories in Towards a Theory of Montage [1937-1940] (1994). Eisenstein describes architecture and film, ancient buildings and experiencing physical place in comparison to a shot by shot analysis, referencing ancient architecture in Greece. Eisenstein's ideas in contemporary motion graphics relate to production delivery in kits of parts. Rhythms structure and poetic form appear in my current works Recipes for Baking Bread, a series of short motion graphics films telling stories from Holodomor in Ukraine in 1932 and 1933. Memories, physical spaces and poetic architecture are explored in five short films. A 25 frame wipe is used as a physical intersection between stories, between times and geographic spaces.

In comparison to Eisenstein's ideas, Dziga Vertov writes about rhythm and structure in production of films. In On the Organisation of a Creative Laboratory [1936] (1984) Vertov describes technical rhythm. Hito Steyerl writes about architecture *in* film. Film as architecture. In her commentary on uses of wipes as filmic devices Steyerl describes a process of erasure. Deleting and removing present day realities for future visions. These works compare to poetic forms and visual structures in precedents including Samuel Beckett, Laurence Sterne, Oulipo poetry and works by Rilke, Rumi and Brecht.

A digital presentation introduces storyboards and production work for Recipes for Baking Bread due to for release in September 2021. Storyboards, production maps, diagrams. These appear with work in progress and finished sections of film works.

Presented with a map of connections exploring theoretical texts behind key scenes and narratives. These include works relating to mainstream target audiences, Ukrainian communities and academic audiences. These works form part of my PhD project due for completion in September 2021. A visual memory archive.

Keywords: Memories, Motion, architecture, place, loss

This text explores relationships between physical structures, architectural practices and contemporary motion graphics production. I take three key texts as my starting points. In 1937

Eisenstein wrote about montage and architecture (Eisenstein, 1991, pp. 59–81). Eisenstein explores what were then new techniques of film production using cutting, editing and gaps in narratives to create stories. Eisenstein describes film as architectural practice.
He relates this back to ancient Greek architecture (pp. 60–61). As Eisenstein describes these buildings, a person experiences varieties of shots, lengths, contrasts between visuals and details by moving around a space in person. In film these narratives appear from direction. Contrasts, rhythms, shapes, structures and narratives all appear to a viewer in one physical space in architecture a viewer moves around to experience these varieties.

My second text is Kino-Eye: The Writings of Dziga Vertov (1984). Vertov was a Ukrainian Soviet film- maker working in a similar period to Eisenstein. Vertov wrote about processes of his production techniques. He had a production lab and manifestos for his work. In these writings Vertov describes a critical importance of rhythm and structure in work. Structures to practice to create films. He writes of technical accuracy, rhythm in work and as he describes "the laboratory's goal is to organize our work correctly" (Vertov, 1984, p. 138). This as Vertov sees it will create a base for strong technical outputs. My final text is Duty Free Art by Hito Steyerl (2017). Steyerl is a contemporary writer and writes in a specific way about uses of wipes in contemporary motion graphics. Steyerl writes about architecture in film. This she relates to an area derelict and affected by war in Turkey. As renovation
work appears to redesign these areas, renders and videos show future descriptions of these spaces. Steyerl describes wipes as a physical structural device to move what exists in the present to make way for what will exist in future (Steyerl, 2017, pp. 12–13). Steyerl describes: "Wipes as a filmic means are a powerful political symbol" (p. 12).

These three texts explore architecture, structures and films in some way. For Eisenstein film is architecture. this is physical form, has structure space, rhythm and contents emerge from these structures. For Vertov these spaces surround making and artistic practice. Artistic practice emerges from structural forms. For Steyerl architecture
appears in film. Architectural spaces become subject matter and motion graphics devices relate to these physical forms.

I include in my paper analysis of my current work Recipes for Baking Bread. This is a series of five short films exploring stories from Ukraine in 1932–33. This period is now known as Holodomor. Farms in rural Ukraine had a collective farm policy as a result of Soviet government ideals. These collective farms and their management led to huge shortages of grain. Up to seven million people died as a result. Structural forms in my work navigate viewers in time and in space. This appears in my stories. Wipes move viewers between past and present and from one geographical space to another. This links structural devices and histories.

Architectures

Physical space and film connect. Eisenstein describes Greek architecture as "The Acropolis of Athens could just as well be called the perfect example of one of the most ancient films" (Eisenstein, 1994, p. 60). Eisenstein compares a description of these architectural spaces with film scripts "it is hard to imagine a montage sequence for an architectural ensemble more subtly composed, shot by shot, than the one which our legs create by walking among the buildings of the Acropolis" (p. 60). these varieties of shot length, structures and visual details create narratives, forms and rhythms in space. These movements around buildings relate to presentations of work on screen. There is a link here between static architecture, movement around this architecture and motion on film. Physical movement on a static object.

Motion graphics is a term for contemporary and commercial TV practice. This can include animation, film sequences, visuals, graphics, typography and traditional animation. In Software Takes Command, Lev Manovich (2013) describes a critical moment in birth of motion graphics materials. This Manovich links to development of After Effects. After Effects was and is industry standard for motion graphics. This software from 1993 on release has dominated motion graphics and this industry. Manovich describes significance of working in this way, using compositing and layering of effects. Many layers of meaning on top of each other and also narratives in time. Manovich describes ranges of materials available for use in languages emerging in this field. He gives examples of these from "maps, pictograms, hieroglyphs" and other forms of visual content "in short practically all communication techniques developed by humans until the 1990s – are now routinely combined in motion graphics projects" (Manovich, 2013, p. 249). Manovich also describes techniques and outputs for this style of practice. "Typically motion graphics appear as parts of longer pieces: commercials, music videos, training videos, narrative and documentary films, interactive projects" (p. 248). In commercial practice this term is creating kits of parts. These individual elements and components become parts of longer projects. These longer projects are edits including VT and other forms of materials and exist as long form content. Motion graphics then becomes smaller units of time, existing within a larger sequence or narrative.

As a piece of software After Effects combines skills and ideas from many areas. This layering and compositing using all forms of communication creates vivid and distinct visual forms. These are now common in mainstream visual culture. This is fast production commercial, creating parts of larger projects.

Wipes are one of these component parts. Wipes represent smaller structural components. These can be from 12 frames long, half a second. In Recipes for Baking Bread, my current film I use 25 frame wipes to link my project together. There are five short films and each of these films I link using a wipe. These wipes use visuals from architecture in Ukraine. This architecture references Soviet styles and is from a war museum in Central Kyiv. I found these on a visit for a residency in 2017. On TV wipes navigate viewers between past and present. Figure 2 shows an example of a wipe from BBC Sport circa 2014. These are generic replay wipes. These wipes navigate a viewer backwards and forwards in time. From a football match, athletics tournament or sporting event. A viewer can see current action and then a wipe transports for few moments a viewer backwards to a previous moment, a previous experience and then pack to present action again. These wipes can also transport viewers in geographical space from studio to pitch to match and then back again. I take this idea in my films and use it to an extremity. My wipes go backwards and forwards in time from Ukraine in 1932 to present day realities. In my work these are historical devices.

Figure 1. Recipes for Baking Bread Wipes, 2018.
Source: Author.

Figure 2. BBC Sport Generic Replay Wipes, c. 2014.
Source: BBC Sport.

Structures

Production of film work creates structures and also emerges from structures. Dziga Vertov wrote ideas about production of his films in 1930s Ukraine and Soviet Union. His ideas are for a film laboratory. Technical conditions appear and the importance of rhythm and energy. “The proposal on the organization of a creative laboratory was prompted, first of all, by the need to put an end to the waste of our time and energy, by our need to establish rational order in our nonstandardized work processes” (Vertov, 1984, p. 138). In this technical production gives

rise to contemporary and creative practice. Technical rhythm, technical expertise and combinations of expertise in different areas all create examples of innovative practice.
For Vertov these practices, this rhythm and structure around film was critical (Vertov, 1984). This is about rhythm in making and technical structures. This emphasis on production of work is still in existence in contemporary motion graphics. Organisation of projects rhythm in projects and rhythm surrounding work. Structures of making.

Motion graphics also tells stories of architectural spaces. This is how Hito Steyerl describes spaces in her example videos. “The video uses wipes to transition from one state to another, from present to future, from elected municipality to emergency rule” (Steyerl, 2017, p. 12). For Steyerl wipes move between present and future, and back again. From an existing reality to an imagined future. Architectual spaces as they exist and architectural spaces as proposed will appear in an unknown future. These wipes, they have a physical presence, they move and shift what is physical and real (Steyerl, 2017, pp. 12–13). “The transition between present and future is abrupt and literally uneven: frames look as if jolted by earthquakes” (Steyerl, 2017, p. 17). This is a physical relationship between film, between motion and between spaces. For Steyerl wipes are a way to transport people from present to future. In my work wipes transport a viewer from past to present and back again. This is motion graphics as physical objects. These components move and shift architectural spaces. Pieces of motion appear to move and change and transform a space. These, the smallest units of motion time have a powerful impact.

Relationships between time and space exist in other art forms for example in literature. Figure 3 shows a diagram from a Beckett play, Quad (1982). This play is by Samuel Beckett. I reference a script from 1984 (p. 291). This diagram shows a plan of spaces in Beckett’s work. This has four corners and four sides, with two intersecting diagonal lines cutting through this square. There are four characters and four colours each colour
is assigned to a character. There is a coloured light corresponding to each character’s colour and each character has a musical instrument attached to their movements. Beckett describes a mathematical structure to take these characters around this physical space. This appears in such a way so each character never collides with another character and all combinations appear at some point during this play. In this work space, time and character all interconnect. Characters describe a physical space as they move around it. A physical space and structure describes a narrative. A narrative emerges from characters movements around their spaces. Mathematical principles here create a plot a narrative emerges from a physical diagrammatic form.

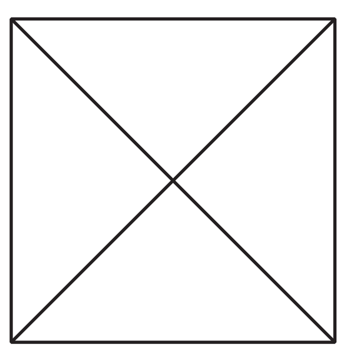

Figure 3. Quad, Samuel Beckett, 1982. *Source:* Beckett, 1984, p. 291.

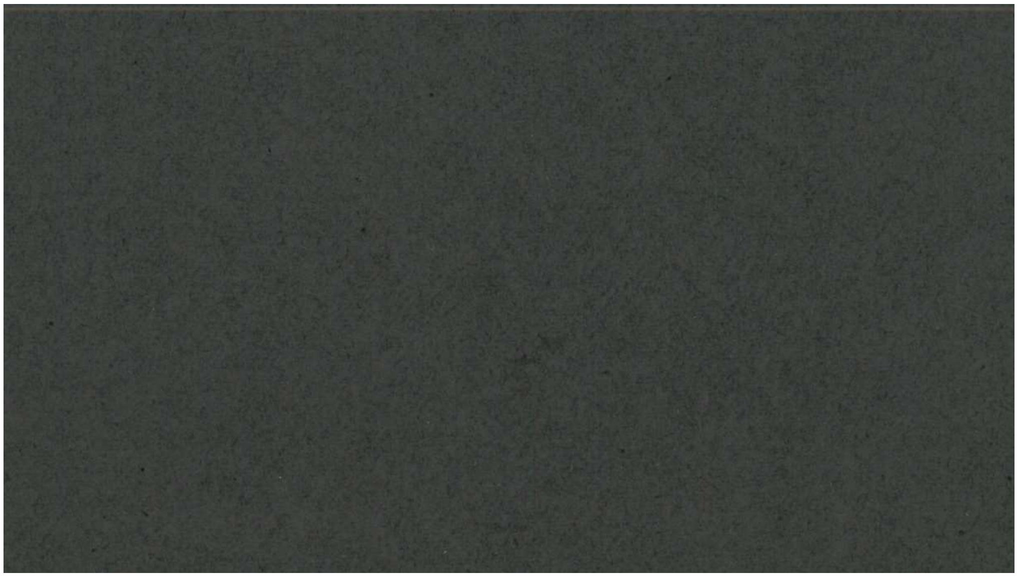

Figure 4. Recipes for Baking Bread Black Soil Scenes, 2016. *Source:* Author.

In conclusion to this section montage allows space to emerge in films. Eisenstein and Vertov are both pioneers of this working in 1930s to invent and create new methods of working in film practice. Steyerl provides contemporary references on these theories using architecture and motion graphics. Architectural spaces exist in this work in physical forms and in content. Spaces expose rhythm and structures and these create and connect to narratives.

Poetry

Time and space appear in all forms of storytelling. Mikhail Bakhtin is a Russian theorist and writes about these ideas (2003; 1986). Bakhtin describes different kinds of time in literature. These range according to novels and storytelling he analyses. For Bakhtin these is epic time. This is a closed historical time and exists outside a frame or narrative structure in a piece of work. This is already completed. “The epic past is called the ‘absolute past’ for good reason: it is both monochronic and valorized (hierarchical); it lacks any relativity” (Bakhtin, 2003, p. 182). This does not connect with a story as it appear. “It is walled of absolutely from all subsequent times, and above all from those times in which the singer and his listeners are located” (p. 182). In contrast to this epic time there is for Bakhtin another kind of time. Epic time exists outside realms of a story, a narrative or a text. It is about a history already decided, already complete and over. Bakhtin also describes “adventure time”. This kind of time only exists relative to a hero, an author and a viewer. It links and connects all elements of a story and relationships to a plot and narrative and only exists with inside a story. This is relative time. It describes moments of action and activity only relative to previous or following activities. Bakhtin’s description is almost identical to construction of motion graphics “adventure time, which consists of the most immediate units – moments, hours, days – snatched at random from the temporal process” (1986, p. 11). Bakhtin’s theories around time and space have a name. “We will give the name chronotope (literally, ‘time space’ to the intrinsic connectedness of temporal and spatial relationships that are artistically expressed in literature" (Bakhtin, 2003, p. 184). These different forms of time exist in all storytelling from motion graphics, theatre, film, poetry and fiction. Bakhtin's units of relative time are almost identical to motion graphics kits of parts. These kits of parts and components are then visual elements to navigate a viewer only relative to a particular programme, event, a channel or a set of ideas. These individual components tell a viewer they are before or after their previous experience. These units connects an author, a viewer and characters within a story. This creates narrative from graphics a language within works.

Visual structures and forms exist in literature. Laurence Sterne in his novel Tristram Shandy (2000) represents a character's death with a full page of black. This is a visual device and represents death. I take this form in my work to represent deaths in Ukraine. There is a Hollywood convention for what are 'campfire scenes'. In traditional Hollywood narrative these exist two-thirds through a story. It is a point where characters sit around a campfire and everything appears to be complete and resolved before a b-plot kicks in. I take this convention and invert it. Two-thirds through my films a black scene appears. This is to represent deaths from Holodomor. In early stages of my project I learnt Ukrainian. One of my first lessons included descriptions of Ukrainian black soil, *chernozem*. This is a dark, rich soil and represents a fertility of land in Ukraine. There is a certain pride in this soil and also a connection to farming.

Structures appear in poetry. Oulipo poetry is one example of this. This is poetry about structure and mathematical objects and principles. One Oulipo poet Jacques Jouet describes a principle behind this work. "The constraint is the problem; the text the solution" (Jouet, 2001, quoted in Perloff, 2010, p. 81). Structures and devices appear and content arises from these structures and devices. One example of this is Jouet's *poème de metro* reproduced in Marjorie Perloff's text Unoriginal Genius (Jouet, 2001, quoted in Perloff, 2010, p. 82). This poem is a poem of a structure for a poem to appear from a metro journey. An author writes a line between each station and stops to write when their train stops.
"There are as many lines in a subway poem as there are stations in your journey, minus one" (Jouet, 2001, quoted in Perloff, 2010, p. 82). These poems then represent a physical journey. A movement in time and space for an author and for a person experiencing this work. Structures reveal themselves through contents of work and a contents or a narrative describes structures as they were as a starting point.

In concluding this section I link Mikhail Bakhtin's chronotopes with architectural spaces and film. Bakhtin's spaces in literary objects and texts connect with Eisenstein's person walking around a physical space. For Eisenstein a person experiences buildings in time and space. For Bakhtin this time and space exists in novels. These devices are also used in film and literature. Short interstitual spaces and gaps, for example in wipes, these spaces create rhythms.

Diagrams

Figures 5 and 6 show storyboards for Recipes for Baking Bread. Visual elements describe parts of stories and moments on screen. These can appear in two scenes. Figure 5 is a scene from a Torgsin ship. These shops were in Ukraine during Holodomor and became a lifeline for people working in Ukraine. Torgsin shops were for tourists and visitors to buy luxury items. During Holodomor people exchanged gold and family jewellery for basic essentials such as bread. In this section I show eradication of churches of buildings and people connected to church life.

These saints appear holding their hands as a method of prayer. These hands also represent giving and exchange as people asked for food and begged for basic essentials. My second scenes show a wheat scene. These drawings appear from traditional Ukrainian folk art. Each drawing shows five ears of corn. This is a reference to a law of five ears.

This was a point at which theft from Soviet property was defined. People suffered exile or even death for stealing as little as five ears of corn from Soviet farms. These scenes appear between three and five times. Each time a wheat scene emerges there is less and less wheat. This becomes powerful and dynamic as an act of sparsity. These scenes become empty and less as my film progresses. Small components of meanings I edit together in my works. These create longer linear pieces.

Figure 5. Recipes for Baking Bread Torgsin Shop Scenes, 2020. *Source:* Author.

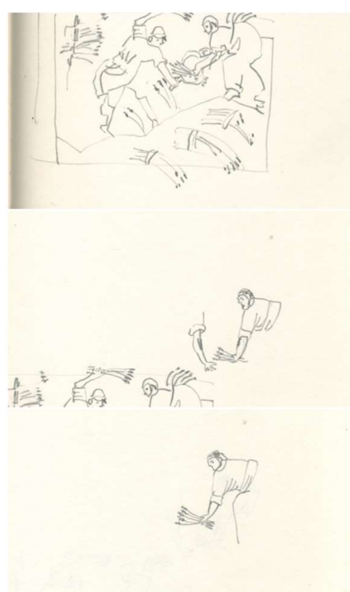

Figure 6. Recipes for Baking Bread Wheat Scene, 2019. *Source:* Author.

Time and space appear in narratives in my work and in literature. Christopher Bollas is a contemporary writer and provides a stunning description of Albert Camus' work in The Outsider. Bollas takes a description of a street scene in Camus' book. This is a specific example of Bakhtin's chronotopes. "Camus continues his description but increases the pace of the observed in a kaleidoscopic way" (Bollas, 2018, p. 28). Bollas describes what happens in Camus' street. Physical appearances of objects and people. "By upping the pace (the temporal) and over-occupying the street with activity (the spatial), Camus condenses space and time in a dizzying way" (p. 28). Physical space here represents to some degree a mind of a character in Camus' work. Camus' themes in The Outsider are about emptiness, about nothing about an existential purpose of way of being. This existential ideal is then brought into comparison by Bollas in a physical sense. A physical street scene of energy and frenetic action in a space opposite to themes of Camus' text. A space where everything happens. A space of busyness, life and activity. Camus' themes are about existential voids and absences. This is an example of a chronotope in action.

Literature and poetry both inspire film-making. Figure 7 shows diagrams for Recipes for Baking Bread and my project structures. For these I take inspiration from Japanese tanka poems. A syllabic structure in Japanese tanka in five lines of poetry of a rhythm 5, 7, 5, 7, 7. I take this structure and extend it so each part of my works is 50, 70, 50, 70, 70 seconds. These are five independent films and can appear independent of one another in any order. I also have a linear version. this linear version shows a more complete picture of events during Holodomor than each individual component. A whole greater than as Leonard Cohen put it "you can add up the parts, you won't have the sum" (Cohen, 1992). In this diagram a small red line represents a 25 frame wipe. I have a black soil scene two-thirds through and a prelude and postscript at beginning and end. this shows uses of traditional structures in contemporary works.

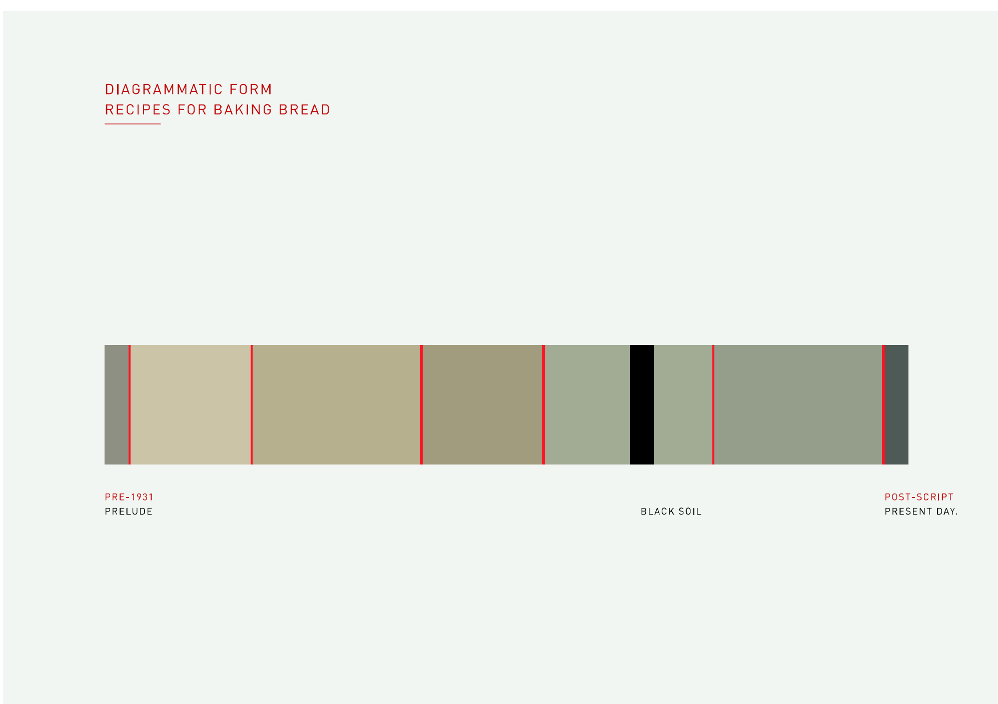

Figure 7. Recipes for Baking Bread Project Diagrams, 2021.

Source: Author.

All sources in my project connect. Figure 8 shows an example and diagram from my theoretical research. This is a links and connections project using html to link sources together. This shows physical structures and forms and how objects, ideas and source materials in connect in both time and space. This is a relationship diagram and shows themes in space. This is a basis for my written works.

In concluding this section I provide evidence of project materials and how these exist from research in all fields. These include maps, storyboards and diagrams. My specific connection is with Bollas' theories and I link these to Bakhtin's chronotopes ideas. This work all describes time and space in different ways. There are examples in here of chronotopes in motion graphics.

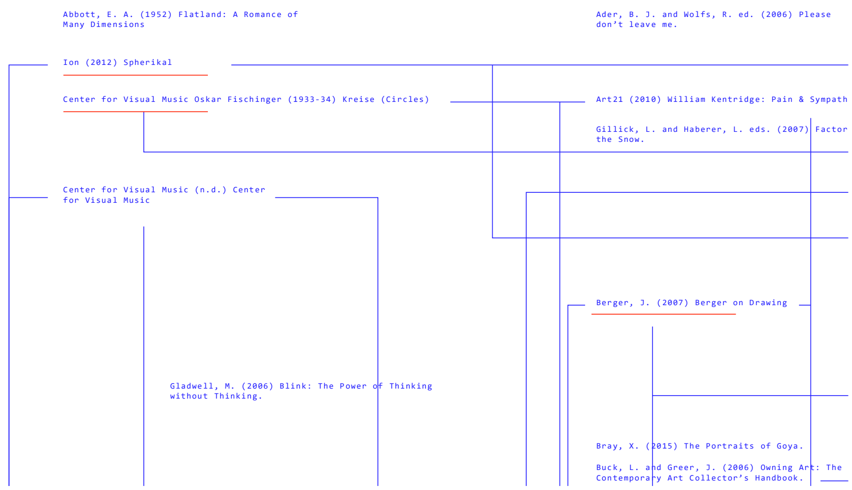

Figure 8. Recipes for Baking Bread Links and Connections, 2021. *Source:* Nesteruk, 2021.

Conclusion

Space and time both exist in motion graphics and architectural practices. Eisenstein, Vertov and Steyerl all approach these ideas in different ways. Their ideas explore relationships between film practice, practices of making, motion graphics in architecture and motion graphics as architecture. These are all approaches to uses of physical on film. Some of these examples date back to 1930s and early examples of film-making. All are relevant today. Wipes are smallest units of time on screen. These relate to Bakhtin's ideas of adventure time.

Wipes are a relative unit. They are visual construction and can transport viewers backwards and forwards relative to their past, present and future. This can work to navigate a viewer in both digital and physical space. For example locate a viewer in digital channels, a channel they are watching, identify a TV programme using branding or show a viewer where they are in a particular course of action or narrative. Wipes navigate viewers in time and also navigate viewers in space, both digital and geographical spaces.

Literary sources provide examples of chronotopes. For Laurence Sterne this is a physical rhythm in literature. Sterne's black page (Sterne, 2000, p. 29) shows impact of visuals in literary forms. This was written in 1759. This is not a wipe, a pause, hold or significant rest in action. A French poet, Stéphane Mallarmé has examples of work designed for a viewer to consume as a whole rather than line by line and word by word. In a description and introduction to this work Elizabeth McCombe provides me with a closing idea. “The drama occurs between the instant and the space that reabsorbs it” (McCombe, 2008, p. xxvi). This I can use as an idea for motion graphics wipes.

Acknowledgements

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STEREOTOMY WALKS:
TOD WILLIAMS—LESSONS FROM ROME

Smilja Milovanovic-Bertram

The University of Texas at Austin
310 Inner Campus Drive B7500, Austin, Texas 78712-1009 USA, smilja@utexas.edu

Abstract

Marcel Proust notes that the essence of past experience is transferred to the present through memory. Nowhere does this transference seem to be more meaningful than in an architect's work. Travel experiences, in particular, can be a critical factor in shaping an architect's design thinking as memorable imagery of places, spaces, and people are stored mentally, to be re-assembled along with new experiences and recollected in subsequent conceptualizations.

This essay examines how walks by Tod Williams (AAR Fellow, 1983) experienced while a resident at the American Academy in Rome affected his design thinking. While in Rome, Williams explored "things that are heavy" — he sketched and explored both permanence and materiality to assimilate the connection between building and site. "I could see buildings emerge from Rome's landscape almost as clearly as Michelangelo's slaves emerged from the stone and I could feel the descent of the water from fountains," As Williams also said, "Hadrian's Wall did not exist in a sketchbook or in a photograph; it was everywhere."

It was through stereotomy (from the Greek "stereos" meaning solid and "tome" for cut) that Williams physically experienced Rome in his walks — stone that can be cut and concrete that can be cast. Williams' subsequent work emphasizes the relationship of building and site, but it is also about permanence and heaviness, craft and materiality. His work can be described as closed from inside to outside, protective, with a meditative quietness — buildings with a sense of gravity and craftsmanship.

This essay will bring forward how those walks, walking on cut stone and observing the power of stacked stone walls that Williams assimilated and processed his design thinking — how it was recollected, revealed and reconstructed in subsequent architectural production.

Keywords

Stereotomics, stone, Rome, Pantheon, memory

Marcel Proust noted that the essence of past experience is transferred to the present through memory. Nowhere does this transference seem to be more meaningful than in an architect's work. Travel experiences, in particular, can be a critical factor in shaping an architect's design thinking as memorable imagery of places, spaces, materials, and people are stored mentally, to be re-assembled along with new experiences to be recollected in subsequent conceptualizations.

This essay examines how walks throughout Rome by Tod Williams (AAR Fellow, 1983), a resident at the American Academy in Rome, transformed his design thinking. Williams arrived in Rome on his 40th birthday with the aim of using his fellowship to gain perspective on his previous body of work.

As Dimitri Pikionis (1887-1968), Greek architect points out in his essay, *A Sentimental Topography*, the feeling of joy in walking, as he links buildings in landscape and memory of the place. His observations of the environment encompass both visible and invisible qualities of the site, as bodies experience the surface of earth physically, acoustically, and visually.

> *We rejoice in the progress of our body across the uneven surface of the earth and our spirit is gladdened by the endless interplay of the three dimensions that we encounter at every step, the shifting and changing that occurs with the mere passage of a cloud high in the sky. We walk past a rock, or a tree trunk…we move up and down, following the rise and fall of the ground…we rejoice in the wide, flat expanse of the plains; we measure the earth by the toil of our bodies*. [1]

With this quote we understand the innovation of Pikionis's most unique project—the landscape intervention of stone paths leading to the Acropolis (1950-57). The path begins at the base of the Acropolis and consists of individually paved materials of salvaged and repurposed materials—stones, clay tiles and expressive concrete shapes. Pikionis had to maneuver the conflicting design dichotomy of the classic Parthenon and the emerging modernist International Style of the 1950s when he developed the project. He was able to achieve a balance of form and function through his reverence for stone and its layering throughout history. Pikionis's work demonstrates an understanding of the relationship between building, landscape and memory. This same veneration carries on in Tod Williams' work as influenced by the stereotomics of Rome.

One can view stereotomics and tectonics through the writings of the architecture historian, Kenneth Frampton (b.1930). Frampton posits that an understanding of tectonics and stereotomics are vital in analysing the development of contemporary architecture. Stereotomy is derived from the Greek "stereos" meaning solid and "tomia" to cut—an expression for the construction of cutting, carving, and removing solid material like stone, masonry, and concrete. Tectonic is derived from the Greek "tectonics" pertaining to carpentry or construction in general. It implies an expression of component parts as a frame, or lighter elements.

In his writings, *Studies in Tectonic Culture* (1995) and *Rappel à l'ordre: The Case for the Tectonic*, Frampton presents tectonic architecture as appropriate for the development of modern architecture and discusses the ontological aspects of tectonics. Ultimately, his writings are a stand against the commodification of architecture and a response to Robert Venturi's concept of architecture as "decorated shed". Frampton posits that through the dialogue of constructive elements, materials, the making of form and the resolution of structural forces, beauty and meaning arise. "Tectonics is defined as pertaining to building or construction in general especially in reference to architecture, framework tends toward the aerial and dematerialization of mass, whereas the mass form is telluric, embedding itself deeper in the earth. One tends toward the light and the other toward dark." For Frampton "these gravitational opposites…may be said to symbolize the two cosmological opposites to which they aspire; the sky and the earth." He reasons that tectonics express a higher level of construction, beyond the statics of construction; tectonic is a method of making and revealing, creating truth for mind and eye. [2]

Frampton credits Gottfried Semper's writings, *The Four Elements of Architecture* (1851) and *Style* (1860, 1862) for breaking conventions in architectural theory. Semper (1803-1879) developed an ethnographic theory of culture by classifying the four elements of primitive architecture as earthwork, hearth, framework (roof), and (light-weight enclosing) membrane. Semper further classified the process of building into two critical elements: the stereotomic and the tectonic. Semper's stereotomic was an extension of the earth through earthworks and the repetitive stacking of heavy-weight units. Stereotomic mass creates volume whereas the tectonic creates an open frame. Tectonic architectural elements correspond to light-weight, linear components. Semperian tectonics defines the constructed act and links the artisan to context. These definitions broadened the understanding of architecture. [3]

In Rome, Williams sketched and explored both permanence and materiality to assimilate the connection between building and site. "I could see buildings emerge from Rome's landscape almost as clearly as Michelangelo's slaves emerged from stone and I could feel the descent of water from fountains…Hadrian's Wall did not exist in a sketchbook or in a photograph; it was everywhere." Le Corbusier was also influenced by his visit, in 1911, to another of Hadrian's structures—Villa Adriana outside Rome. Corbu viewed this Roman wall as a place where architecture and nature merge as the materialization of nature itself. He viewed the villa's ruins as primeval, the essence of the construction process

Much of the stone used in groundwork, foundations, and walls of various Roman periods have been repurposed from previous structures. Those walls, the underpinnings, of Rome were of particular interest for Tod Williams.

As Williams explained, "experiencing Rome was largely seeing it through my feet. The Janiculum Hill (location of the American Academy) became a springboard from which I explored Rome." Williams sketched daily, exploring both the texture of his drawings and the density of Roman architecture. Walking through various itineraries and neighbourhoods, Williams drew quick sketches which he worked over and over. His daily drawings were in small format, "small commitments, only one drawing per sheet, drawing with a black 314 pencil. In this way I explored the density of the paper and the density of Rome". [Image 1]

Williams experienced Rome physically, by walking. His investigations focused on the weight of Rome, while he searched for the roots of buildings, retaining walls, and foundations. This pursuit was a tactile and visceral experience for Williams. His search through Rome was driven by his attention to context; a deep desire to discover buildings and their connection to the earth—the connection between building and site. The importance of the experience of walking and drawing Williams remarks: "In this manner I began to sense the city, the wear of the street and the weight of the Rome. Topography was measured intellectually and physically by eyes and feet." Williams also realized that Rome awakened ambition—he wanted his projects to be a personal commitment, to outlast his existence. Williams' daily walks can be compared to Louis Kahn's "walk and talk" tours with Roman historian Frank Brown. Brown presented ancient Roman architecture as ritual, reducing the chaos of experience to manageable human measures. In this manner, Williams explored the underpinnings of Rome's construction.

Williams explains that he preferred Rome's pre-Renaissance buildings because they are more powerful, of greater solidity with less gesture than the Mannerist and Baroque. Instead of focusing on individual structures, his investigations focused on the "weight" of Rome, while he searched for the roots of buildings. It was important for Williams to assimilate the connection between building and site. Williams's interests approached a tactile sense of materials and the compressive qualities of stone. In this sense his work after Rome shows a stereotomic aspect — carved from stone.

For Williams the experience of "being" is most profound in ancient Roman spaces, particularly Rome's Pantheon (126-128 A.D.) with its inside/outside character of its oculus. Sunlight enters and tracks across the dome's interior coffers and floor. Light, rain, and snow enter seasonally to provide a kinetic visual effect "The Pantheon still finds itself in our work. It is the building that I feel I am inside and I am outside simultaneously. It is a living breathing structure that always feel comfortable. The power of the Pantheon comes from its interior (coffered ceiling and oculus), its universality of concept enabled it to outlive Roman civilization, to embrace the Renaissance and to be critical to architecture today".

Following are three architectural themes that are critical to Williams's design thinking—carved light (Pantheon oculus); stereotomic earthworks; the Roman wall [Image 2].

The connection of outside to inside appears in Williams's Natatorium at Cranbrook School (Bloomfield Hills, Michigan, 1999). In Cranbrook's pool enclosure the Pantheon's oculus is conceptualized as two cones penetrating the roof. The twin oculi are sources of light that register the sun's movement throughout the day. Rejecting computer-aided placement of the openings, Williams wanted the light to vary as it entered the building in the morning and exited in the afternoon. [Image 3]

In The Center for the Advancement of Public Action (Bennington College, Bennington, Vermont 2011), Williams brings in light not as oculi but as a square light funnel. A section shows the Lens, a multi-use space on the left and the Symposium room on the right. In this example, Williams uses two different ways to bring light into the space [Image 4].

In the David Rubenstein Atrium (at Lincoln Center, New York, 2009), Williams uses sixteen architectural lighting clusters as oculi leading visitors through an extraordinary public procession through space from Broadway between 62nd and 63rd streets to Columbus Avenue and connect vertically by a textile wall, art installations, and a green vegetation wall. [Image 5]

In the Barnes Foundation (Philadelphia, 2012) a giant carved light box allows light into the lobby (Light Court). The folded plaster planes appear as stereotomic, but in fact they hide a tectonic steel structure to present a sense of heaviness and thickness. The space seems to be carved out. The construction appears to be stereotomic space. Stone is used as a stereotomic phenomenon in truly Semperian terms in both its horizontal floor plane and vertical plane as well. Williams displays his passion for the heaviness of the wall and the manner in which the building is anchored to earth. In the Barnes Foundation stone appears stereotomic in exterior as well as interior. In Williams's search for the perfect stone, limestone from the Negev desert in Israel was selected. [Images 6, 7].

Another derivative of Williams's Rome experience is the building-as-wall metaphor, which appears in his projects. The Neurosciences Institute complex (La Jolla, California, 1995) is treated as a wall that opens outward. Inspired by Vatican City, Williams canted the walls inward, holding the earthwork back. Whether instrumental toward containment, inhabitation, or circulation, the building-as-wall remains a transcendental metaphor in Williams's work, as it makes possible the experience of being inside and outside simultaneously [Image 8].

Williams's work after his Roman sojourn emphasizes the relationship of building and site, but it is also about permanence and heaviness, craft and materiality. His work can be described as closed from inside to outside, protective, with a meditative quietness — buildings with a sense of gravity and craftsmanship. Williams makes a clear delineation of his work before his Rome experience and afterwards. His Rome experiences awaked his ambition. Rome both re-equipped and redefined his design philosophy. After Rome he realized that he wanted his buildings to outlast him, to have a sense of permanence, and to be "grounded" with an emotional quality. Williams saw the creative strength in foundations, the under-structure of Rome, and in the materiality of stone and concrete. Each project became a personal commitment to evoke both the visceral qualities of materials, and the emotional qualities of space and site. (6)

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* Note: Tod Williams quotes are from interviews with author July, 2005, New York City and
* Tod Williams/Billie Tsien quotes from interviews with author March, 2021, New York City.

[4] Tod Williams/Billie Tsien. *The Architecture of the Barnes Foundation*, Skira Rizzoli Publications. 2012, p.111-136.

[5] Smilja Milovanovic-Bertram. *Rome Sojourn: Four Architects-Centerline 3*, The Center for American Architecture and Design, Austin. 2008.

[6] Ibid.

Images follow:

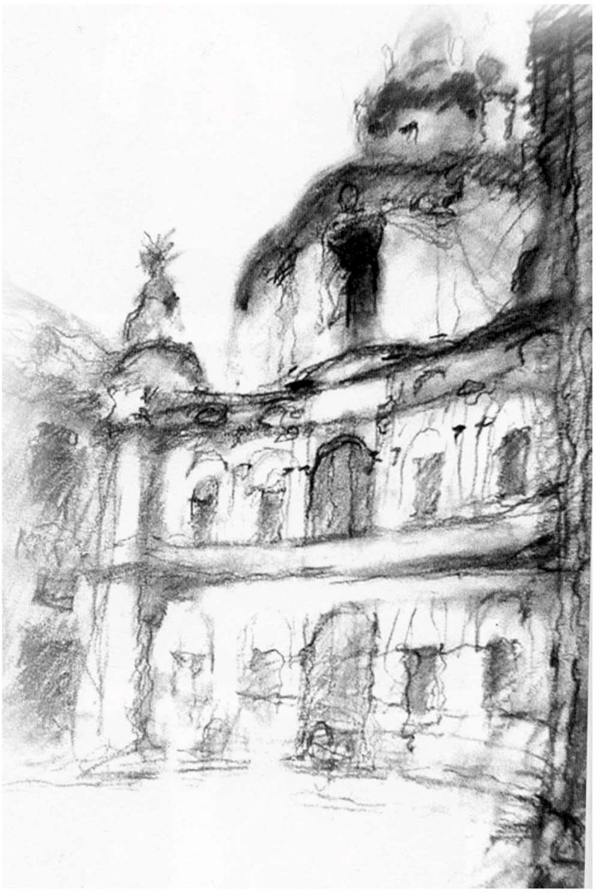


Image 1. Sant'Ivo sketch, Tod Williams

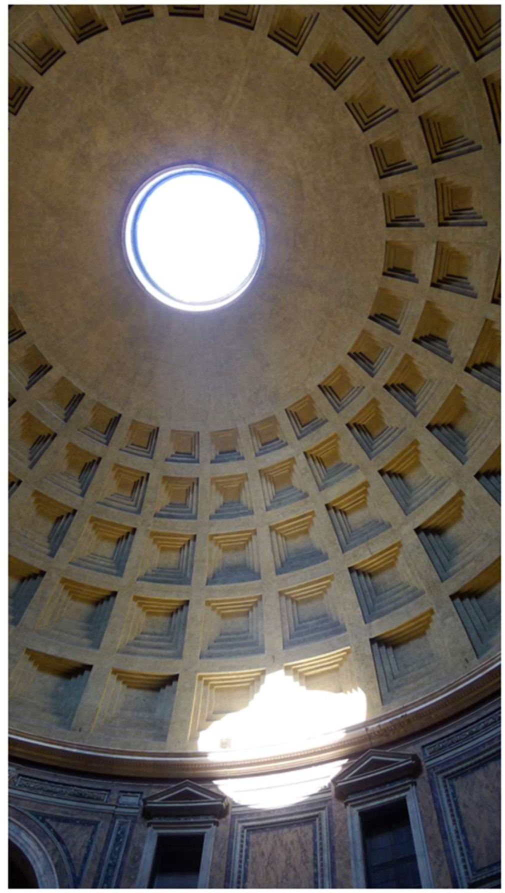


Image 2. Pantheon oculus, by author

Image 3. Cranbrook Natatorium (Bloomfield Hills, MI 1999)

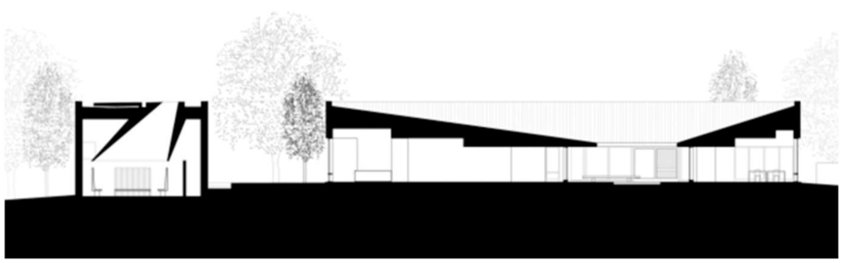


Image 4. Center for the Advancement of Public Action (Bennington, VT 2011)

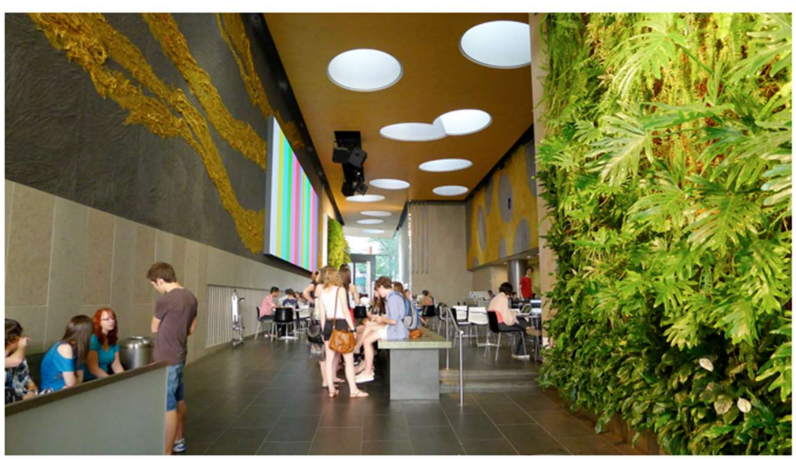


Image 5. Rubenstein Atrium at Lincoln Center (NYC, NY 2009)

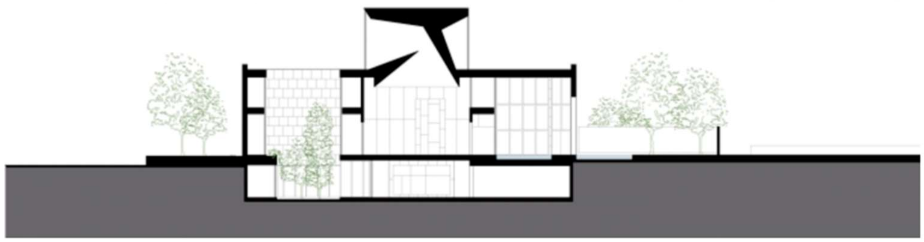


Image 6. Barnes Foundation Section (Philadelphia, PA 2012)

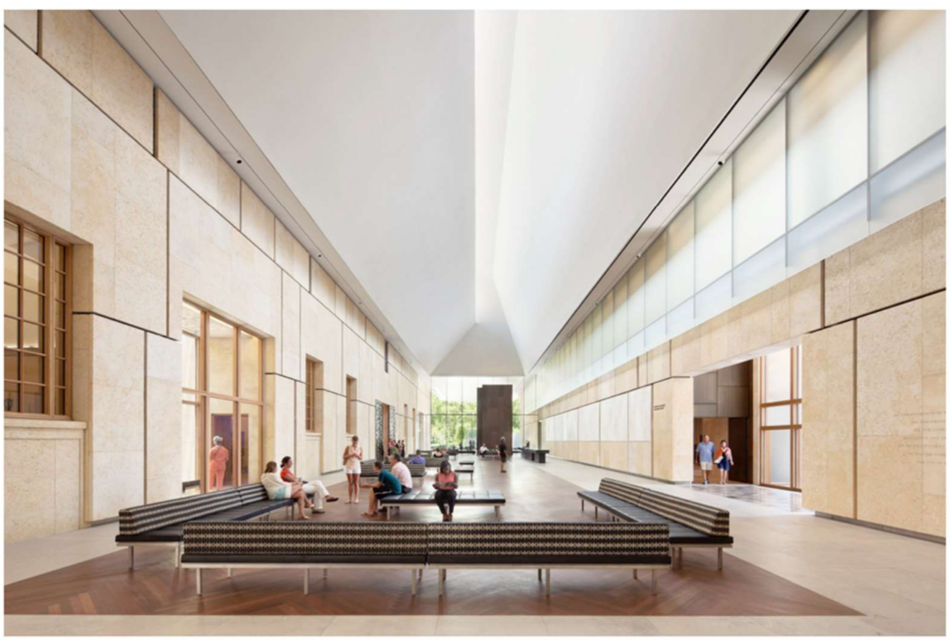


Image 7. Barnes Foundation Light Court (Philadelphia, PA 2012)

Image 8. Neurosciences Institute (La Jolla, CA 1995)

RHYTHMIC RELATIONS BETWEEN TECTONIC EXPRESSION AND DAYLIGHTING OF BAGSVAERD CHURCH AND KUWAIT NATIONAL ASSEMBLY IN JORN UTZON'S WORKS

Ezgi NALCI*, Ryo MURATA

School of Environment and Society, Tokyo Institute of Technology

152-8552 & Tokyo, Japan; nalci.e.aa@m.titech.ac.jp

Abstract

In Jorn Utzon's works, the treatment of material in construction and his distinctive daylight-oriented design aim to generate space and form centered around understanding the sun, sky, and local daylight characteristics. This research has identified the importance of clarifying the relations of two realization methods to be essential in order to understand his cross-cultural explorations in architecture. The interest of this research is the materialization methods of Jorn Utzon's expressive design approach, which include 'tectonic expression' and 'daylighting' in Bagsvaerd Church and Kuwait National Assembly, among his institutional designs. Tectonic expression examines the fabrication methods and assembly of concrete building elements with combinational characteristics. The daylighting aspect studies the changes of received sunlight on surfaces in the built environment through computational simulation on selected days and times. Finally, the correlated results look for correspondence of daylighting's dynamic rhythm to tectonic expressions' static rhythm during the specified periods. The above serves as a quantitative approach to understanding Jorn Utzon's lesser-known explorations in architecture.

Keywords

Utzon, Tectonics, Daylighting, Unit, Rhythm

1 Introduction and Background

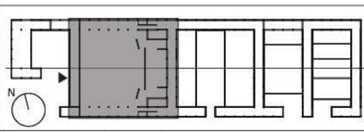
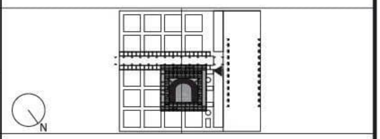
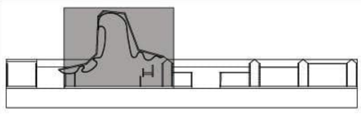
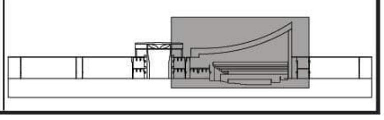
In architectural practice, materialization methods can be considered as an essential aspect of design for an expressive approach. Jorn Utzon's explorations on tectonics in architecture are known for their commitment to providing methods appropriate to the conditions that are flexible, economical, and organic while realizing complex geometries[i]. He also uniquely worked with daylighting as a material to be cropped, shaped, and adapted [ii]. Tectonics and daylighting developed a mutual relationship in this distinctive approach as informed by an understanding of sun, sky, and daylight–essential characteristics of a particular place–and basic architectural elements [3]. As Ginzburg mentions, "Each architectural form is the result of rhythm: a particular quality and quantity of movement generate a particular character of shape" [4]. Hence, this research aims to explore the rhythmic relations between uniformed, repetitive tectonic expression of concrete material and temporal, recurring effects of daylighting in Utzon's works.

2 Case Studies and Methodology

2.1 Case Studies

Utzon used expressive language to reveal the structure and building elements in his public building designs. Within the context of this study, two cases sharing similarities - Bagsvaerd Church (BC) and the Kuwait National Assembly Building (KB) (Table 1), are selected among Utzon's institutional architecture projects based on structure and form. These similarities include the column-beam system, large-span freeform roof, and usage of a single type of concrete material. Even though the building purposes are different, they share the same planning in main space (MS) with sidelight and its surrounding circulation corridors (CC) with skylight. These areas are assigned for the analysis. The reason for the selection is the sectional variations in roof height and the emphasized shape of the roof compared to the rest of the building.

Table 1: Case Studies' Information and Analysis Area Boundaries

Case Study	Bagsvaerd Church (BC)	Kuwait National Assembly B. (KB)
Location	Copenhagen/Denmark	Kuwait City/State of Kuwait
Type	Church	Parliament Building
Year (completed)	1976	1982
Area (Analysis/ Total sqm)	545/ 1.700	3.050/ 18.000
Grid Size	2.2m x 2.2m	5m x 5m
Plan Analysis area		
Section Analysis area		

2.2 Methodology

Technical drawings and photographs are collected from publications (Jorn Utzon Logbook Vol. II, Bagsvaerd Church, and Jorn Utzon Logbook IV/ Kuwait National Assembly) and online architecture editorial websites. For the analysis, the case studies are divided into units. "Unit" is defined as the fundamental analysis component of a building. The units are determined according to their column-beam structure planning. In this study, a unit is defined as a column-to-column boundary within the closest four columns. Based on Utzon's design strategy, Ground (Platform) and the Roof (Floating Roof) are defined as a unit's vertical direction boundaries [iii]. Later, the unit's four vertical and two horizontal sides are examined (Table 2). There are 39 units in Bagsvaerd Church and 79 units in Kuwait Building (Table 3).In Chapter 3, the tectonic expression of concrete is examined by the assembly methods and enclosure of units. In Chapter 4, Daylighting is studied by the illuminance simulation to analyze the contrast and intensity in units (Table 4). Chapter 5 investigates the rhythmic relations between tectonic expression and daylighting.

Table 2: Unit and Unit Sides

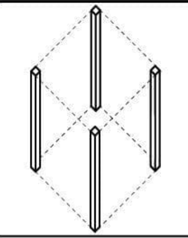
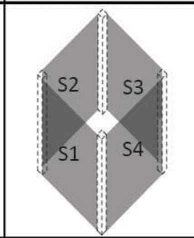
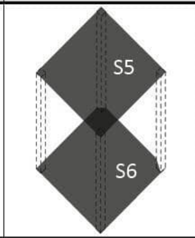
One Unit	Unit Sides	
	Vertical Sides	Horizontal Sides
		
BC-CC(29)-MS(10) KB-CC(40)-MS(39)	BC-CC(116)-MS(40) KB-CC(160)-MS(156)	BC-CC(58)-MS(20) KB-CC(80)-MS(78)

Table 3: Case Studies' division into Units

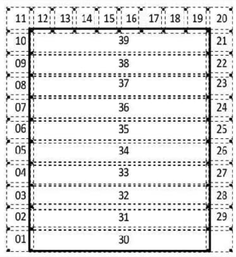
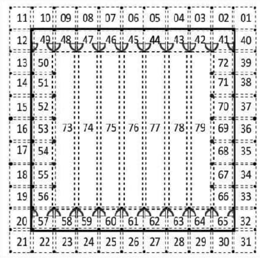
Case Study	Bagsvaerd Church (BC)	Kuwait National Assembly Building (KB)
Division into Units		
Amount	CC : 01-29/ MS: 30-39	CC : 01-40/ MS: 41-79

Table 4: Example Unit Analysis

Unit BC14	Zone CC		Chapter3								Chapter4							
	Position	Unit Side	Fabrication Method: Building Elements B	W	G	R	Assembly: Element Assembly V: Void	Assembly Type	Enclosure C - P - O	Discontinuity Ds - Cs	Surface: Receiver (R) Distributer (D)	Contrast (9 a.m.): MAX (lux) Value	Domain	MIN (lux) Value	Domain	Contrast Type	Intensity (9 a.m.): Average Brightness (lux)Value	Brightness Type
	V	S1	○				VB	A1	P	Cs	R	1503	C3	1308	C2	M	1466	B2
		S2		○			VWP	A1	P		R	1230	C2	578	C2	L	801	B2
		S3	○				VB	A1	P		R	1546	C3	1134	C2	M	1348	B2
		S4		●			WCI	A1	C		R	1894	C3	651	C2	M	989	B2
	H	S5			○		G	A1	C	Cs	R	1188	C2	1034	C2	L	856	B2
		S6				–	V	–	O		D	–		–		–	–	–

3 Tectonic Expression of Concrete

This chapter deals with the architectural environment as a formation of the material. Tectonics is related to the application of concrete material as form and technique where the parts-to-whole relationship defines that expression. The building elements are analyzed from fabrication method to assembly combination in units. In this study, concrete is the primary analyzed material in selected buildings.

3.1 Fabrication Methods and Assembly of Elements

Concrete building elements are analyzed according to their fabrication methods on unit sides. First, building elements on six-unit sides are analyzed according to their fabrication methods, and different shapes of elements are categorized separately (Table 5). Based on the existence of building elements on the unit sides, prefabrication is the dominant construction method as opposed to cast-in-place in both buildings. However, in Bagsvaerd Church's Main Space, cast-in-place plays a significant role rather than prefabrication for Wall and Roof. Followingly, the assembly of building elements on the four vertical sides is examined (Table 6). Distinctive concrete elements with repetitive characteristics are categorized into seven assembly types (A0/A1/A1R/A2/A2R/A3/A3R). In Bagsvaerd Church, the one-element assembly type, A1 (72/156), has the majority, while in Kuwait Building, the two-element-repetitive assembly type, A2R (170/316), has the majority. Finally, the combination of four vertical sides' (S1-4) assembly types in the unit are classified in Table 7. According to the variety in the combination of assembly types in units, four-unit types (AU1/AU2/AU3/AU4) are found with the majority in the combination of two different assembly types AU2 (BC [17/39], KB [47/79]), in both cases.

Table 5: Fabrication Methods and Shape of Elements

Position / Building Elements		Vertical						Horizontal			
Case	Zone	Fabrication	Beam	Fabrication	Column	Fabrication	Wall	Fabrication	Ground	Fabrication	Roof
BC	CC	○	B (55)	○	Cl (116)	◒	WP (50), WCI (31)	○	G (29)		No Concrete
BC	MS		No Beam	○	Cl (40)	◒	WP (4), WCI (21)	○	G (10)	●	R (10)
KB	CC	○	Bl (150)	○	Cl1 (160)	○	W1 (56), W2 (20)	○	G (40)	○	R1(31), R2(9), R3(4), R4(4)
KB	MS	○	B1 (138), B2 (18)	○	Cl1 (120), Cl2 (36)	○	W1 (108), W3 (12)	○	G (39)	◒	R1 (32), R (7)

○ Prefabricated ● Cast-in-place ◒ Prefabricated or Cast-in-place

Table 6: Element Assembly Types of Unit Sides

Assembly Types BC (CC/MS) KB (CC/MS)						
A0- The side without concrete. BC (0/19) KB (10/12)						
A1- One element		**A2** - Two elements		**A3** - Three elements		
BC(64/8)	B, WP, WCI	BC(6/2)	B+WP, WP+WCI	BC(0/0)	B+WP+WCI	
KB(17/0)	B	KB(0/0)	B+WP1, B+WP2	KB(0/0)	B+WP1+WP3	
A1R - One element. One element repeats.		**A2R** - Two elements. One/two elements repeat		**A3R** - Three elements. One/Two/There elements repeat		
BC(32/9)	B*, WCI*	BC(10/2)	B*+WP*, WP+WCI*	BC(4/0)	B*+WP+WCI	
KB(57/36)	B*	KB(76/94)	B*+WP1*, B*+WP2*	KB(0/14)	B*+WP1+WP3	

The symbol * indicates repeating elements

Table 7: Unit Types according to Element Assembly Types

Units	Assembly Types S1	S2	S3	S4	Assembly Pattern	Unit Types BC (CC/MS) KB (CC/MS)
BC14	A1	A1	A1	A1	4	**AU1** One assembly type (8/0) (1/7)
BC19	A1	A1	A1	A1	4	
KB48	A2R	A2R	A2R	A2R	4	
BC21	A1R	A1	A1R	A1	2-2	**AU2** Two different assembly types (8/9) (29/18)
BC38	A0	A2	A0	A2	2-2	
KB03	A1R	A2R	A1R	A2R	2-2	
KB50	A1R	A2R	A1R	A2R	2-2	
BC01	A1	A1	A2	A1	3-1	**AU3** Three different assembly types (11/1) (10/14)
BC29	A1R	A1	A1	A1	3-1	
KB16	A1R	A1R	A1R	A2R	3-1	
BC03	A1R	A1	A2R	A1	2-1-1	
BC11	A1R	A1	A2	A1	2-1-1	
KB04	A0	A2R	A1R	A2R	2-1-1	**AU4** Four different assembly types (2/0) (0/0)
KB24	A0	A2R	A1R	A2R	2-1-1	
KB51	A1R	A3R	A1R	A2R	2-1-1	
BC9	A2R	A1	A1R	A2	1-1-1-1	

3.2 Enclosure

The placement of the building elements on unit sides is examined according to their enclosure types (Table 8). Since the ground characteristics are consistent on the horizontal sides, the analysis includes only the roof. Horizontally, due to skylight placement, an opening on the roof emphasizes one of the tectonic characteristics of a unit in Circulation Corridors (BC [29/29], KB [17/40]). For the unit enclosure type categorization, Partly and Open characteristics are grouped together due to their openness aspect on the sides. The enclosure is categorized as dominant or balanced in Closeness and Openness. Three enclosure types of units' (EUC/EUE/EUO) vertical side enclosure types are classified (Table 9). Partly/Open dominant EUO unit type has a majority in both cases (BC [36/39], KB [47/79]).

Table 8: Enclosure Types of Unit Sides

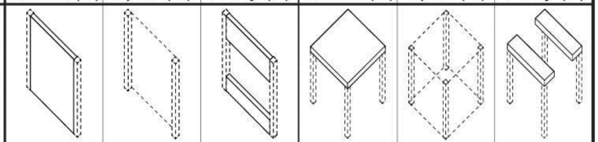
Position		Vertical			Horizontal		
Characteristics		Closed (C)	Open (O)	Partly (P)	Closed (C)	Open (O)	Partly (P)
Diagram							
BC	CC	32	0	84	0	29	0
	MS	0	19	21	9	0	1
KB	CC	50	10	100	23	0	17
	MS	65	12	79	39	0	0

Table 9: Unit Types according to Enclosure Types

Units	Enclosure Types S1	S2	S3	S4	Unit Types BC (CC/MS) KB (CC/MS)
KB46	C	C	P	C	**EUC** Closed Dominant (0/0) (0/9)
KB62	P	C	C	C	
BC15	P	C	P	C	
BC29	P	C	C	P	
KB12	P	C	P	C	
KB36	P	C	P	C	
KB65	C	P	C	P	**EUE** Equal Closed-Partly/Open (3/0) (16/7)
BC01	P	C	P	P	
BC14	P	P	P	C	
BC25	P	C	P	P	
BC33	O	P	O	P	
KB01	P	P	P	P	**EUO** Partly/Open Dominant (26/10) (24/23)
KB05	P	P	O	C	
KB39	P	P	P	C	
KB66	P	P	P	C	
KB78	C	O	P	O	

3.3 Discontinuity

The elements inside the unit are analyzed as discontinuity (Ds) (Tab.10). Vertically, discontinuity examines the existence of stairs and concrete partition walls and, horizontally, the second floor. Almost half of the units in Bagsvaerd Church (16/39) and the majority of the units in the Kuwait Building (70/79) are discontinuous. The rest is continuous (Cs).

4 Daylighting

Natural light's temporal qualities create dynamic effects on architectural space expression.

4.1 Daylighting Simulation

The Illumination Simulation is applied to analyze the daylighting effects on each side of the unit. The surfaces receiving daylight include the columns, beams, walls, and floor facing the unit's interior side. For the analysis, the 21st of June (summer solstice) is selected to examine the maximum potential of daylighting effects. In order to observe the changes throughout the day, 9 a.m., 12 p.m., and 3 p.m. are selected. The analysis boundaries to classify the values are set separately based on the results of each building. One of the examples of the difference in output in the daylighting effects is that daylighting shows strong characteristics in Bagsvaerd Church at 12 p.m. while at 9 a.m. in Kuwait Building (Figure 1).

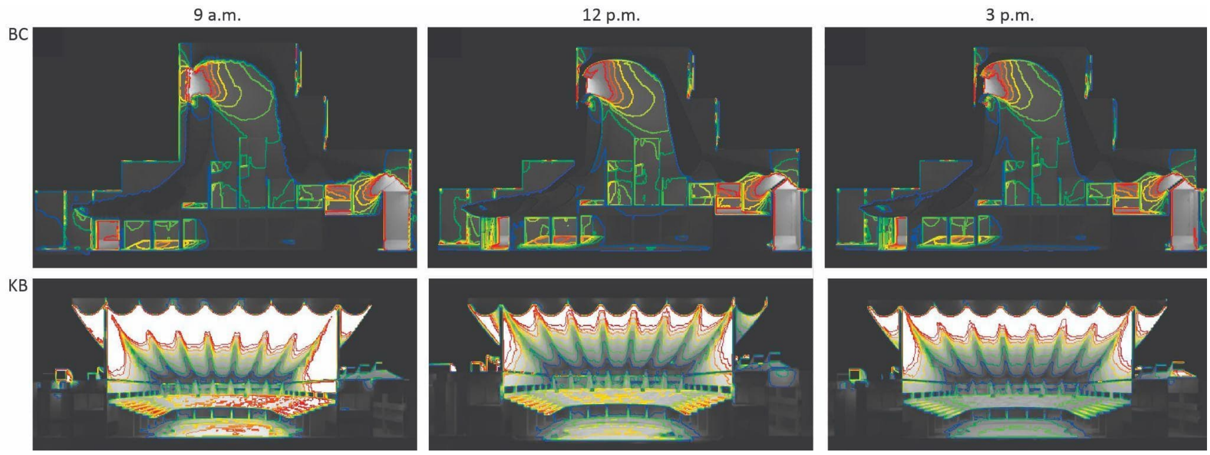


Figure 1: Simulation Results in different analyzed hours

4.2 Contrast

The contrast between the maximum and minimum brightness levels on the surfaces is measured. First, the boundaries are defined in accordance with the average minimum and maximum values of all hours. Three domains are extracted (C1/C2/C3). Then, the contrast types are categorized into three types according to the relation of C1, C2, and C3 as High (H), Medium (M), and Low (L). In Bagsvaerd Church, the amount of High, Medium, and Low are similar in number. However, in Kuwait Building, Medium and Low have the majority. Finally, the unit's contrast characteristics (CU1/CU2/CU3) are classified according to the combination of contrast types on unit sides (Table 10). In both cases, two types of contrast types in unit CU2 (BC [28/27/29] and KB [45/45/47]) have the majority in all hours.

Table 10: Unit Types according to Contrast Types

Units	Contrast Types						Unit Types
	S1	S2	S3	S4	S5	S6	BC (9/12/3) KB (9/12/3)
BC31-9	-	L	-	L	L	L	**CU1** One type of contrast (M-L) (7/8/6) (20/21/20)
BC31-12	-	L	-	L	L	L	
KB12-12	M	M	M	M	M	M	
BC03-12	H	H	M	H	M	-	
BC19-12	L	L	L	M	L	-	**CU2** Two type of contrast (H-M, M-L, H-L) (28/27/29) (45/45/47)
BC30-3	-	L	-	L	M	L	
KB02-3	L	M	L	M	M	L	
KB26-12	M	L	M	L	L	L	
KB65-9	M	M	M	L	L	M	**CU3** Three type of contrast (H-M-L) (4/4/4) (14/13/12)
KB73-12	H	M	M	-	M	M	
BC09-3	M	H	M	H	L	-	
KB29-9	L	H	H	L	L	M	

4.3 Intensity

Intensity is a measure of the average brightness values of each side. To define the boundaries, 15% of the difference between the lowest and the highest average lux value (sum) was calculated. The boundary is thus for B1 (dark), 15% sum + (lowest value), for B3 (extra bright), highest value - 15% sum. B2 is the domain in between. In the majority, Kuwait Building shows dark (B1 [413][416][424]), and Bagsvaerd Church shows bright (B2 [133][123][134]) characteristics in all hours. Then, according to the existence of B3 (extra bright) and dominance and balance in between B1 and B2, the unit's intensity characteristics (IUD/IUB/IUE/IUB+) are classified (Table 11). In Kuwait Building, Dark dominant, IUD (68/72/76), and Bagsvaerd Church, Bright dominant, IUB (29/20/29) has the majority in all hours.

Table 11: Unit Intensity Types according to Brightness Types

Units	Brightness Types						Unit Types
	S1	S2	S3	S4	S5	S4	BC (9/12/3) KB (9/12/3)
BC30-9	-	B1	-	B1	B1	B1	**IUD** B1 dominant (9/9/9) (68/72/76)
KB06-9	B1	B2	B1	B1	B1	B1	
KB21-12	B1	B1	B1	B1	B1	B1	
KB61-3	B1	B1	B1	B1	B1	B1	**IUB** B2 dominant (29/20/29) (6/5/2)
BC01-12	B2	B2	B2	B2	B2	-	
BC22-3	B2	B2	B2	B2	B1	-	
KB75-9	B1	-	B2	-	B2	B2	**IUE** B1-B2 equal (1/1/1) (1/2/1)
KB77-12	B1	-	B2	-	B2	B2	
BC33-9	-	B2	-	B2	B1	B1	
KB01-3	B1	B2	B1	B2	B2	B1	**IUB+** There is B3 (0/9/0) (4/0/0)
BC15-12	B3	B2	B3	B2	B2	-	
KB23-9	B1	B1	-	B1	B1	B3	

5 Rhythmic Relations

This research uses rhythm terminology adapted from music into a quantitative tool that systemizes and specifies unit characteristics throughout the buildings. Consequently, for the purpose of this study, rhythm is the movement in the quantity and quality of each analyzed aspect. In the previous chapters, factors of the rhythm were analyzed. The shape of the roof, tectonic expression, and daylighting are the essentials of the rhythm study.

The combination of movement in characteristics is analyzed as rhythm types. As shown in Table 12, regular rhythm is defined as consistency for at least three adjacent units. The rhythmic relations are defined as the change or consistency that happens simultaneously between tectonic and daylighting. Harmony explains the interrelations in the movement. It is classified as No Harmony, Harmony in regularity, Harmony in change.

Table 12: Rhythm Terms

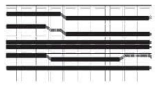
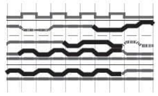
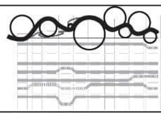
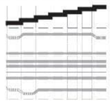
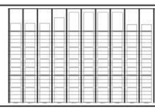
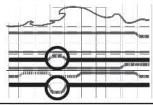
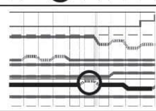
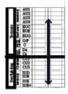
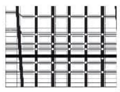
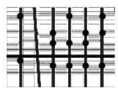
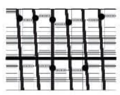
Continuous	**Regular (Re)**	Characteristics remain constant for at least three adjacent units	
	Alternating (Al)	A pattern formed by repetitive change in characteristics	
	Flowing (Fo)	The repeated elements follow bends and curves	
	Progressive (Pr)	Even and consistent changes across units	
Moment	**Interval (I)**	The moment of change from unit to unit	
	Arrhythmia (Ar)	Sudden and discontinuous changes in characteristics between **Re** and **Re**	
	Random (Ra)	Sudden and discontinuous changes in characteristics between **Re** and **Al**	
Relations	**Harmony (Ha)**	Synchronized movement in the vertical direction	
	Ha1 Harmony in Regularity	**Direct**. Consistent tectonic and daylighting	
	Ha2 Harmony in Change	**Direct**. Simultaneous changes in tectonic and daylighting	
	Ha3 Harmony in Change	**Indirect**. Change in tectonic affecting daylighting of adjacent unit	

Figure 2 shows the overall characteristics of rhythm and rhythmic relations. In the tectonic rhythm of Bagsvaerd Church's Main Space, Regular Rhythm with Arrhythmia is present; in Circulation Corridor, Alternating and Regular Rhythm with Arrhythmia are seen. In daylighting rhythm of Bagsvaerd Church's Main Space, Regular Rhythm with Arrhythmia is present; in Circulation Corridor, Regular Rhythm with Arrhythmia is seen. On the contrary, Kuwait Building shows more variety in rhythm types, as the Circulation corridor is dominant over Alternating and Regular Rhythm, even though the construction language appears consistent. In daylighting rhythm, in Kuwait Building's Main Space, Regular Rhythm with Arrhythmia, in Circulation Corridor, Regular and Alternating Rhythm are seen.

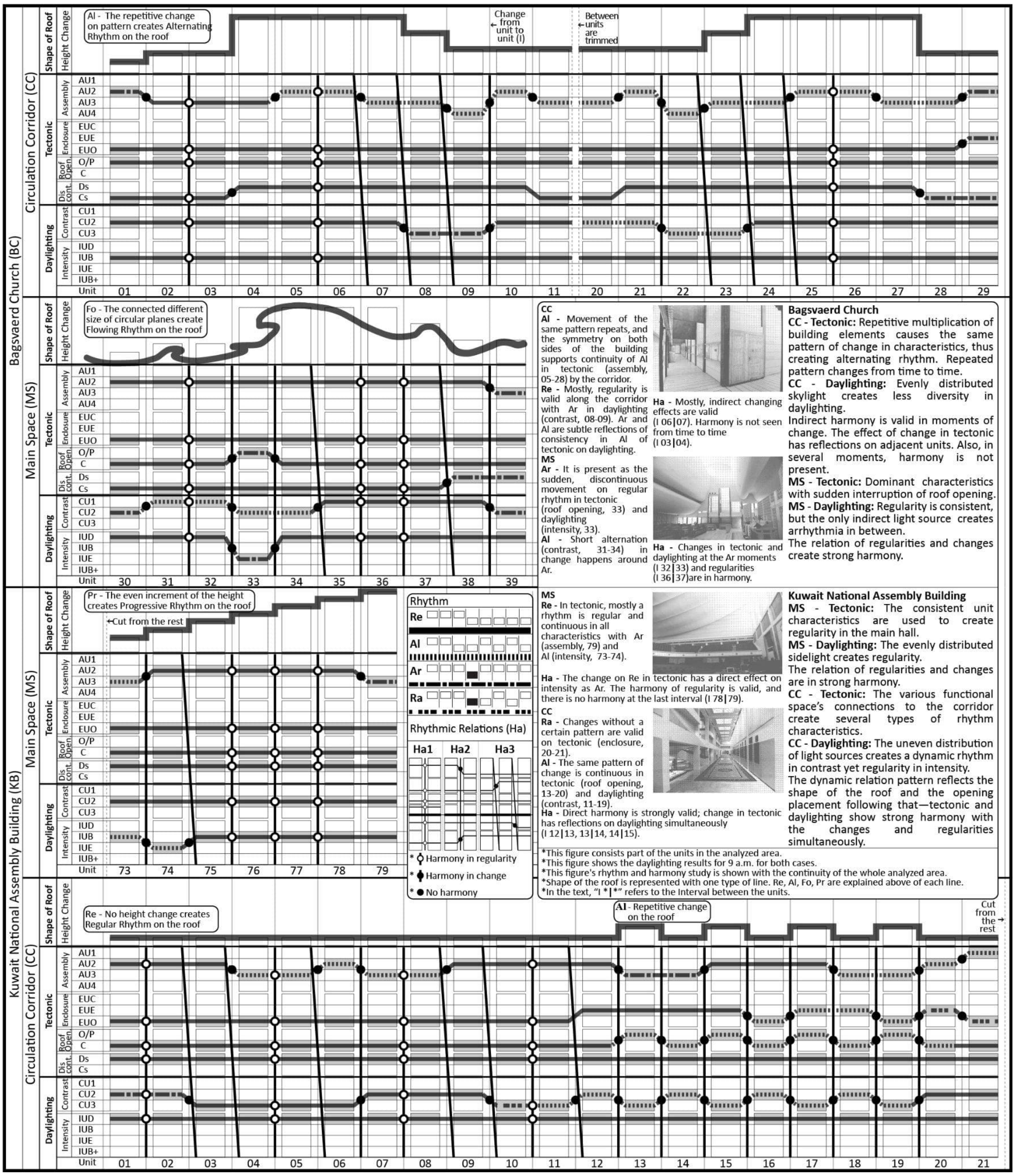


Figure 2: Rhythmic Relations

6 Conclusion

In both cases, the result shows that for tectonic rhythm, in the Circulation Corridor, it is possible to name only one type of rhythm along the same corridor, but the whole building shows variations. In the Main Space, regularity is dominant, but the shape of the roof creates dynamic effects over the frequency of the surroundings. In daylighting, the Circulation Corridor and the Main Space show different characteristics in terms of brightness.

In terms of harmony distribution as defined in the rhythmic relations, this research concluded that Harmony in regularity shows density in the distribution due to the dominant appearance in a regular rhythm. Secondly, due to the strong correspondence of simultaneous changes in characteristics between tectonic expression and daylighting, Harmony in change is seen as much as Harmony in regularity. A lack of Harmony is rarely seen, but the cases of no Harmony encountered serve to confirm the selection of Harmony as a research criterion. Thirdly, by compiling different hours' simulation information, Bagsvaerd Church's Main Space shows the same pattern in Harmony at all hours. Lastly, in the Kuwait Building's Circulation Corridor, a slight interchange between the harmony types is apparent, thus harmony types showing a consistent distribution pattern between analyzed hours.

As a result of the rhythmic characteristics of the compositional materialization of tectonic expression and daylighting in the two buildings, it is found that Utzon created various rhythms in tectonic expression by using uniformed and repetitive construction methods with concrete. At the same time, less diversity in temporal effects of daylighting rhythm by regulating the light environment is being observed. The analysis concluded that tectonic expression and daylighting create strong rhythmic relations as Harmony in Jorn Utzon's institutional works.

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Notes

[i] Tectonic exploration refers to the prefabrication of construction material(concrete) which comments on tectonic formation, as understood from reference [1].

[ii] In reference [2], working with daylight refers to the materialization of daylight and the architect's method of controlling it in the architectural environment.

[iii] Platforms and Floating Roofs is Utzon's important design strategy which reflects his cross-cultural explorations

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FROM BILLY BOOKCASE TO CHECKERED PLAYROOM | READY-MADE CAM-LOCK FASTENER FOR BUILDING SYSTEM ASSEMBLY

Rico Samuel DIEDERING, Prof. ZHU Jingxiang

The Chinese University of Hong Kong, Shatin, N.T., Hong Kong, China;
rs.diedering@link.cuhk.edu.hk*, zhujx@cuhk.edu.hk

Abstract

The success of ready-to-assemble furniture is built on highly specialised joints that ease the construction for the end-user. Based on the spatial panel system, this study compares the role of one of these joints, namely the cam-lock fastener, in the assembly of the Billy bookcase and the Checkered Playroom – a prefabricate building system that combines playground, house and furniture into one. Working on the treshold between architecture and furniture design, the question poised to answer is whether modern joinery known from flat-pack designs can be equally utilied for building system assemblies. If so, how is the potential of readymade cam-lock fastener used in the Chekcered Playroom; and, what are the effects on its assembly? Learning from the assembly manuals of the furniture industry, a database has been created that reshuffled the consumer-oriented order of their catalogues according to components and joining method. Furthermore, relying on more than 175 constructed playrooms by the time of this publication, this study draws on the consistent design idea and the long lineage of the spational panel system but also include subsequent changes to its manufacturing chain. As such, it links the sudden shift from the cam-lock fasteners to a change of the building material and takes into account the impact this had on the assembly and disassembly process. The paper concludes with the assessment that readymade joints from the furniture industry successfully decrease the time for detailing in the early design phase and during construction but also acknowledge the necessity integrate the architectural design into broader chains of manufacturing.

Keywords

Cam-lock joints, flat-pack furniture joints, panel construction, building system, design for manufacture and assembly (DfMA)

1 Introduction

Based on an economy of scale, the wide-spread success of ready-to-assemble furniture is largely owned due to the outsourced assembly to the end-user. As a consequence, these furniture pieces are centred around flat-packed particleboards that are vital to reduce costs and ease operational handling during transportation and storage. However, in pushing the final assembly out of the factory – and thus into the hands of the customers - the design has to incorporate techniques to ease the joining of components. Here, the furniture industry adopted design-for-manufacture-and-assembly (DfMA) principles as early as in 1990s to remain competitive in terms of cost and time reduction but also for quality improvements (Hung, Mak, 1998).[1] In its current definition, DfMA manifested itself for the first time and on a large scale in the weaponry industry of WWII. However, early developments like the demountable No. 14 Chair by the Thonet Brothers in 1859 suggest that small and medium sized companies in the furniture industry were akin to utilize serial production for affordable furniture and space-saving packaging as soon as industrialization questioned conventional modes of production. Even though the construction industry was equally challenged by this shift, modern architects explored the limits of standardization due to the varying degrees of contextualization in architecture. Because, "*unlike manufactured products which are designed in-house, mass-produced, and sold to end-users, construction products like buildings are bespoke*" (Lu et al., 2020).[2] As such, it is hard to imagine the construction of a building without the assistance of professional construction worker. But, with an emerging shortage of an increasingly ageing work force in service-oriented societies like Hong Kong (LegCo, 2019)[3] certain parts of the construction industry have to innovate on the DfMA theorem. Inspired by the ease of assembly of flat-pack-furniture, this research identified the joint detail as crucial in reducing complexities during the construction. It furthermore hypothesis that an easy-to-join detail will likely decrease the reliance on skilled builder in construction and consequently lift cost saving potentials in architecture. With a myriad number of ready-made joints available from the furniture industry, the purpose of this research is to catalogue potential joints for later application in architecture and define the common factors that facilitate such change in scale. The question is, how to use furniture joints in architecture and where are the limits to such approach? Following the introduction of the Checkered Playroom, a prefabricated lightweight building product consisting of spatial panels that integrate playground, house and furniture into one, this study portraits the initial design derivation as well as the later replacement of its joinery (Figure 1). Working on the threshold of architecture and furniture, the playroom was drawing on cam-lock fasteners for the connections of its checkered panel system. Thanks to its far-reaching success – over 170 buildings have been constructed by the time of this publication – the extensive production of the Checkered Playroom qualifies this building product for a comparison with flat-pack furniture and its use of easy-to-assemble joinery. According to Prof. Zhu Jingxiang, the led-designer of the playroom, the research on modern metal joints is critical to rapid assembly and mass-production. Even more so in remote and rural areas, where the lack of skilled labour requires a construction without quality control (Zhu, 2018)[4].

Figure 1. Checkered Playroom in Gansu Province, China

The cam-lock fastener represents a group of modern joints that incorporate tolerances for multiple assemblies of particleboards, an engineered wood type composed of woodchips. Beyond the simple dichotomy of fastened and unfastened, these joints open up in-between categories that are defined by the range they have been fastened. Relying on ready-made joints well-known from the furniture industry, the architects are able to absorb imperfections caused by the soft engineered wood and its assembly by non-professionals. Because as Zhu pointed out this kind of building assembly *"created opportunities to involve members of the local community and bring them together"* (Zhu, 2018). Hence, the designers were not only able to reduce the time for designing the joint-detail but to cut costs for professional construction worker.

2 Research Material and Methods

From spatial panel system over flat-pack bookcase to cam-lock fastener, the three study objects comprise materials from three focus areas. Investigating the scalability of modern furniture joints in architecture, the primary study area is focused (1) on small scale building systems with a high degree prefabrication and duplication. This allows for a comparison to (2) the industry of mass-produced furniture, which is similarly specialized around prefabrication but often includes an assembly by the end-user to cut costs. As such, these furniture pieces rely on (3) ready-made joinery that incorporate tolerances to absorb imperfections of the material and during assembly. Yet independently of its size, the subject that guided the research through all three focus areas was governed by their construction, which in its essence is about connecting pieces together; or as Alvar Aalto wrote in a letter to Swiss architect and cabinet-maker Werner Blaser:

"For designing a piece of furniture what is required as a basic element is a standard part that permits combinations of any kind, possesses a structural function and contributes to the formation of a style. The principle of furniture design is determined by the timeless problem of joining vertical and horizontal parts. The way they are connected - say, the joining of a chair

leg to the horizontal plane - determines in turn what is called 'style': the chair leg is, so to speak, the small sister of the architectural column." (Aalto, 1956).[5]

Modern design for serial fabrication and outsourced assembly (see DfMA) intensified the relationship between construction and the joint-detail. Revealing these commonalities in furniture design and architecture is the subject of this research.

2.1 Spatial Panel System

Based on concave and convex squares the Checkered Playroom – with the renowned Dou Pavilion as a spin-off for the 2016 Architecture Biennale in Venice – is a key example in the field of spatial panel construction from Southeast Asia. Beside this, Professor Zhu Jingxiang and his design and research team developed six more lightweight building systems at the Chinese University of Hong Kong (CUHK). Although all these building systems are designed with serial production and ease of construction in mind, it is especially the spatial panel system of the Checkered Playroom that is almost entirely made of engineered wood – a group of building materials well-known from the furniture industry. This qualifies the spatial-panel system for a direct comparison with flat-pack furniture, which is predominantly based on particleboards. Since the selection of the joint-type is closely linked to the choice of material, the different properties of the varying engineered wood types will emerge troughout the study. But at this stage it is important to first distinguish the internal differences within the Checkered Playroom. Even though its more than 170 buildings are based on one and the same standardized system, the design evolved over time. As a senior researcher of the team wrote: *"This unique building system enlarged both design and construction 'spaces of possibilities', thus enabling infinite possibilities and contexts in which it can be constructed and adapted, not once but repeatedly"* (Ghelichi, 2020).[6] This space of possibilities allowed for the customization of the building product to various climatic and programmatic conditions. For example, the preliminary study concluded that only three percent of the 170 buildings were made of plywood. Different from other engineered woods, plywood is made of wood veneer instead of chips, flakes or fibers. The vast majority of the spatial panel system has been built with oriented strand boards (OSB), which is made of wood flakes. Thanks to the comparable density of 700 kg/m3 to 600 kg/m3, both plywood and OSB share similar structural performances that justified the change to the more modern and cheaper OSB variant. The material shift was largely owed due to ongoing improvements in the 2015 manufacturing chain but eventually also affected the joining technique. The factory of the spatial panel prototype for Gansu province, China is specialized on the production of furniture. Choosing from a catalogue of ready-made joints for the prefabrication of the panel, they Shenzhen based factory opted for the cam-lock fastener as joining technique, a well-known joint for ready-to-assemble furniture (RAF). Next to its self-assembly characteristics during construction, the joints main advantage is the capacity to be fastened and unfastened without harming the structural integrity of the soft plywood panel. The factory produced four more playrooms that are based on the cam-lock nut and bolt, some of which have been assembled and disassembled five times. But independent of the final material and program – from early childhood education to lakeside tearoom, or from outdoor exhibition booth to indoor office space – the basic construction principle remained the same: lightweight panel with simple joinery for an easy assembly and disassembly process based only on manpower and basic tools. Beyond the typical forms of architectural representation in form of pictures, plans and sections this study draws on the playroom's building information modeling (BIM) and resulting shop drawings as well as personal accounts by the design and research team. Different to computer aided design (CAD)

"BIM addresses a major shortcoming of the design and construction process – that of interoperability of construction documents and information […]*. **Whereas the traditional approach involved producing contract drawings that were subsequently converted to more detailed drawings for shop fabrication purposes, a BIM model can readily generate such shop drawings"*** (Forbes, Ahmed, 2010).[7]

With that, the design and research team can bridge the common gap between design and construction and communicate more closely to the to the factory in Shenzhen. As the majority of mass-produced furniture pieces are produced and marketed in-house by one company, BIM becomes an important tool for architects to re-connect the splintered parties involved for a much more complex construction processes in architecture. In reverse, the BIM tool allows the researcher to trace back design decisions from the detail to early design ideas. In regard to the study of the joint-detail, this means allocating and counting of all cam-lock fasteners within the five Checkered Playrooms – and its recurrent assemblies – that are based on the plywood and cam-lock joint.

2.2 Flat-pack bookcase

A noticeable fact about traditional Chinese architecture and furniture design is that it anticipated some of the very principles that later defined modern design, namely the modularity of components and an increased emphasis of the joint. This requires a degree of prefabrication that Professor Zhu Jingxiang describes as *"the art and sciences of piecing things together"* (Zhu, 2018).[8] Even though not less relevant for architecture, the furniture industry seemed to be more susceptive to the technical and social transformations of the industrial revolution. At least, they were quick to adopt to prefabrication and serial production on a much larger scale and earlier than the building industry. This study takes the stance that furniture design can be considered a forerunner for architectural innovation and that many of the achievements seen on small scale furniture design will be later adopted by the building sector. This very adoption from one scale to the other is the cause of this research. As introduced earlier, the bentwood Café chair No. 14 designed in 1859 by the Thonet Brothers is considered a prime example for this thesis. Because,

"It was one of the first pieces of furniture designed for all society rather than only for the wealthy. Conceived for mass production and flat-pack distribution, Model. No. 14 was far ahead of its time in form and in the direct use of materials. It embodied and foreshadowed the ideals and spirit of modernism, which emerged nearly 70 years later" (Postell, 2012).[9]

Acknowledging the merits and the wide-spread success of the Checkered Playroom in Southeast Asia, as well as its linkage to the cabinet making company in Shenzhen, the aim was to find an aspiring forerunner from the furniture industry for comparison. The market dominating role of IKEA Systems in the field of RAF design makes it an important distributer of innovation that may affect the way we design and build future architecture. However, before browsing the company's comprehensive product catalogue, it is important to

differentiate how they ordered their furniture products into categories. Different from this study's perspective on structure and construction of panels and their joints (conf. 2.1 Spatial Panel System), the furniture company catalogued its products according to functions like sleeping, sitting, shelving, bathing or cooking. Furniture pieces can be designed by strut and strut, strut and plane or plane to plane. Relevant for this study are pieces designed around planes, because they may involve comparable joining techniques to the Checkered Playroom. This brings tables, cabinets, bedframes on the spot for this research. However, following the abovementioned categorization, a cabinet can be found similarly in sleeping, shelving, bathing and cooking section. Consequently, it became clear that the data collected from the catalogue has be presented in a new, tailormade data base. This data was organized using FileMaker Pro 12, an advance software which allows to include further variables such as a joint number, component number and order of assembly. This information has been obtained through assembly manuals openly available on the IKEA website.
Given to the end-user for the first assembly, these manuals explain the step-by-step construction without the help of any text. Even more, the readily understandable line drawings in axonometric view indicate simple actions for each step. The focus on the assembly action with arrows showing the rotations of relevant components rather than the technical illustration of simply the next step in the construction sequence makes the assembly manuals different easy understandable. Lamenting the limited research on procedural assembly design and their instructions, Miles Richardson criticized the generally poor understanding of difficulties in DIY-assemblies. What discern the IKEA assembly manuals from others is the integration of both, the illustration of the components and the single task, with the assembled product. (Richardson, 2004).[10] In other words, the assembly manuals manage to link the assembly action with the component illustration, but what makes the furniture design exceptional is that the design itself integrates the assembled furniture piece and its construction by the end-user through in the design manual (Figure 2). In this way, the construction process becomes an integral part of the design.

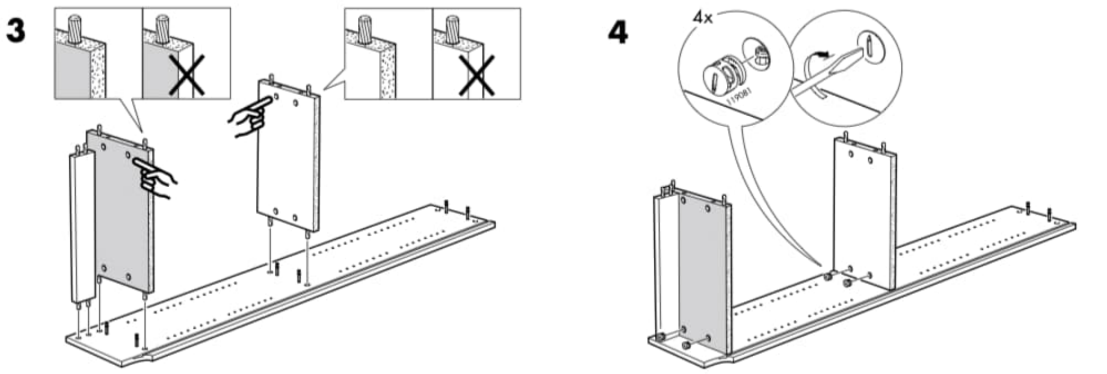

Figure 2. Assembly manual indicating construction steps

In architecture, construction drawings provide a representation of the complete building with all its details. They indicate the dimensions and positions of components within the overall plan. Even though *construction* suggests the dynamic depiction of the building process, the actual nature of the construction drawing is static. Similarly, the shop drawings for the manufacturing process of the single components: it is usually a mere representation of what the final building product should look like and not an explanation of its actual fabrication. Since these drawings are circulated between experts, there is no need for a procedural step-by-step depiction of the construction or manufacturing process like in the case for RAF. This only becomes relevant if the circle of decision-making people is enlarged to non-experts. Nonetheless, with the introduction of CAD and BIM software, architects were capable to produce large numbers of 3D representations for their designs. In the decision-making process this is often utilized to generate design options for the clients. But it was not before prominent architecture offices like MVRDV and BIG, that the procedural diagram in 3D made its way into architectural schools and became popular among smaller practices. In breaking with the static representations of plan, section and elevation, the axonometric view added a more process-oriented perspective to the architectural representation. However, their use is often limited to the ideation of the design strategy or analysis rather than an explanation of the manufacturing or construction process. For example, the competition entry of BIG for the Energy Mansion in Shenzhen used the axonometric diagrams exclusively for analysing the existing green space and the sunlight exposure, upon which the tower volume then opens up in order to let in sunlight and minimize the energy consumption (Figure 3). That means, the axonometric drawing serves as the mediator that justifies the final building volume by introducing the higher forces that shaped the project in this context. In contrast, the assembly of the sophisticated curtain wall system with its changing shadowing devices is not represented, even though this drawing typed prominently proofed its qualities for construction related representation in furniture assembly. But *"without a more profound role for the users in constructing the common project* […]*, the architect stays as the sole gatekeeper* […] *by bringing to bear on it the threat of salvation by an already unified nature"* (Latour (2004), as seen in Lindgren, 2021). [11] This said the axonometric drawing is solidifying the centre role of the architect in the decision-making process, rather than expanding its procedural virtue for a larger group of people in manufacturing or assembling. This stands in strong contrast to the use of the axonometric drawing for RAF (conf. Figure 2), where the easy-to-understandable 3D effect is utilized to walk the broadest number of people through the assembly process.

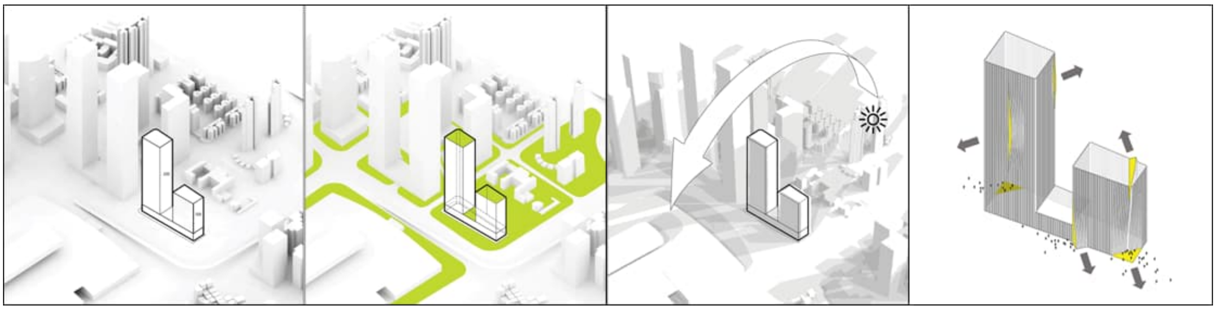
Figure 3. Procedural axon's explaining volume, green area, sunlight, openings

2.3 Cam-lock fastener

In his work at Hochschule für Gestaltung (HfG) Ulm, Swiss architect and cabinet maker taught his students about the correlation between material and joint, saying *"No form and structure without reference to the material"* (Blaser, 1992).[12] In reverse, the decision to single-out the cam-lock fastener for this research on easy-to-assemble joints has been governed by the materials it links. This joint type is highly adapted for connecting engineered wood boards that are very common in the flat-pack furniture industry. Here, the camlock is designed to link panel-to-panel and panel-to-hollow profile with a rigid joint. Made of wood chips, these particle boards have a lower density when compared to conventional lumber which is around

1000 kg/m3. In fact, with a density of 300 kg/m3 chipboards are the lightest but also the weakest of all engineered woods. Composed of resin-soaked woods chips, which are then glued and pressed under heat, this type of particle board is relatively soft and thus prone to deformation. As consequence, special joints are necessary to obtain satisfactory connections. Coinciding with the introduction of the Billy bookcase in 1979, the early 1980s saw a high number of patents filled for connection fittings for detachable joining of two slab-like furniture parts. Tracing back the origin of this joint, the earliest patent close to the cam-lock fastener dates back to 1919. Its purpose was to reduce the reliance on precision after the bedstead was reassembled for a second time. If overtightened or not carefully unscrewed the wood panel were easily damaged by conventional joints. Although particle boards made their way into furniture construction in the 1950s, the possibility to demount furniture concerned designers much earlier. However certain designs could not be implemented at that time because previous joint solutions were either not demountable or too thick for the thin furniture panels. Even during the manufacturing process, conventional screws were known to have damaged the polished surfaces. These screwed furniture pieces had to be polished for a second round after their final assembly, which caused delays in the manufacturing chain. The demountable cam-lock fastener solved these problems in providing a hidden joint without any protruding parts, which limit corrosion of the metal hardware. Whereas the Espacenet database from the European patent office provided access to the original patents, it was the google patents search engine that proofed reliable for filtering and linking patents of the similar type. The automatic translation matches citations of previous inventions throughout different times and languages.

3 Results

Two criteria define the design of flat-pack furniture, first the assembly by the customer and second, the ubiquitous use of chip boards. The joints that facilitate this kind of self-assembly are highly specialized to these criteria and require little knowledge, strength or tools to link the rather soft panels. In general, this fastener are non-permanent joints, which opens up the possibility to be fastened and unfastened at any point. An investigation of early inventors from the furniture industry shows their clear intention to design detachable joints for panel-based furniture (conf. 2.3 Cam-lock fastener). The recent introduction of disassembly instructions by IKEA – including for the Billy bookcase – shows that this design aspect gains more attention in the future. But one aspect that often goes unnoticed, is how the half-fastened/half-unfastened cam-lock facilitates the construction process without experts. Since this assembly incorporates tolerances, the construction gets on without the requirement of overly high precision akin to the involvement of professional workers. Even though rarely mentioned, this aspect becomes prevalent throughout the study of the assembly manuals, for which the Billy bookcase construction is just an early example. Here the combination of dowels with cam-lock fastener is crucial to understand this mechanism. Both are inserted into the predrilled holes of the chipboard before slot together with the other panel. During this phase the wood dowels and the cam-locks keep all the components in place while allowing enough freedom to insert the other shelving units into the rectangular frame. Once everything is assembled, the cam-lock changes its function from providing hold to tighten all the butt joints and holding the chipboards safely in place (conf. Figure 2. step 3 and 4). Although not depicted, the same technic facilitated the construction the first Checkered Playroom in Gansu province, China. The checkered pattern is composed of plywood panel that are eligible for this type of cam-lock construction. But different in size, the forces subjected to the structure are a multiple to that of a conventional bookcase. Rather than increasing the size – and thus the strength – of the single joints, the number of cam-lock joints has been increased to facilitate for the higher forces at play. In a direct comparison, the frequency of joint per panel perimeter has been increased by 20 cm, from 50 cm per joint in the bookcase example to 30 cm per joint for a standard playroom panel (Figure 4). It is important to note, that the plywood panel for the playroom are 5 mm thinner than the standard 20 mm shelve in the bookcase. It was for thin engineered wood panels like this, that the cam-lock joint has been invented in the first place. Originally designed to hide the appearance of the cam-lock, the predrilled openings were here positioned inside the space formed by the checkered pattern, which protects the metal joint from exposure to the elements.

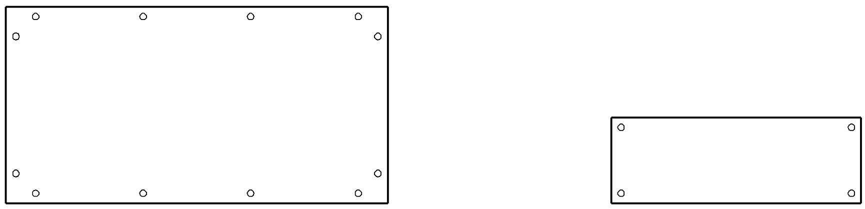

Figure 4. Comparison of the pre-drilled holes in the playroom and bookcase panel

The promise to reduce the reliance on professional worker during the construction process could be fulfilled insofar that it mirrored the prefabrication of ready-to-assemble furniture. But a self-assembly based on assembly manuals known from flat-pack furniture could not be achieved because the complexity of the building task increased exponentially in scope and time. If the building components remain to be sized according to the limitations of the human body – in dimension and weight – then the number of steps and time required to assemble the playroom exceeds that of ordinary RAF products by far. Nonetheless, on-site a team of five villagers guided by one designer is sufficient enough to complete the structure within eight days of work. Based on this experience, the cam-lock joint still allows unskilled labor to significantly assist the construction process, hence reducing costs for specially skilled and equipped worker and machinery. Beyond this, the role of the cam-lock is to secure a safe fastening of the butt joint with limited tools, even though it is a non-permanent connection. In tightening the cam-lock bolt and nut against each other, the joint first positions itself within the two connecting panels before its firmly tightened. This tightening works with tolerance to assure a firm connection of the panel, even with material imperfections (Figure 5).

Figure 5. Worker positioning a plywood panel shortly before the cam-locks are fastened

The multiplication of joints – compared to the bookcase – adopts a similar logic and works with a certain degree of redundancy that secures a stable structure even in case one of the non-permanent joints fails. Four more playrooms have been built based on cam-lock joint, one of which has been reassembled five times. Between 2015 and 2019 the arrangement of this playroom was adapted four times to react to the ever changing contexts it was transported. Dr. Ghelichi reporting from one re-assembly: *"Instead of thoroughly revising the entire design configuration, we simply omitted one row of blocks from the top to adjust for height differences and omitted one set of boxes from the side to resolve the width differences"* (Ghelichi, 2020).[13] Thanks to the detachable joints, the components are not only easily demounted but allow for changes to the original design scheme (Figure 6). That means in the possibility to unfasten the cam-lock goes hand in hand with the modularity of the checkered boxes. Nevertheless, this design flexibility was later abandoned. With the introduction of screw joints as the favoured connection method, the playroom changed this construction feature while keeping the checkered pattern for its structural system.

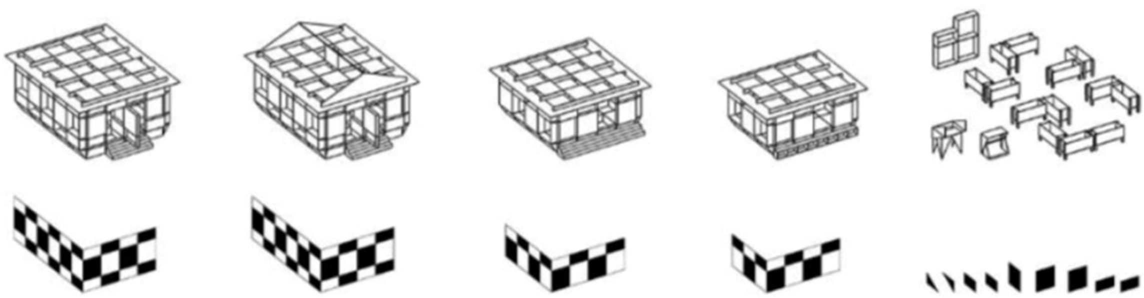

Figure 6. Checkered Playroom: schematic diagram, indicating five cycles of dis-/re-/assembly

This decision was forged to increase the manufacturing capacity of the playroom. In lieu of plywood the new second version utilized oriented strand boards (OSB) as construction material. In a direct comparison OSB can be produced in larger panels, which makes the building product less expensive. At the same time the production is more environmentally friendly and the OSB panels come in thicker dimension than plywood, which improves insulation and climatic capacity inside the playroom. But first and foremost plywood is not as weather resistant than OSB, which makes is more durable against rain and humidity. As the new manufacturing facility is not designed to handle the production of furniture pieces but building products, it lacks some of the prefabrication machinery for drilling the holes that hold the cam-lock. Hence, the decision to change the joint need to be seen in light of the new introduction of the material and the enhancements in the production chain. Whereas plywood is the oldest engineered wood used as building product, OSB panel made their way into construction much later. Since the cam-lock is not designed to connect panel with the thickness of an OSB, it can be concluded that the cam-lock joint has never fully advanced to a building level but only diversified within the field of furniture design. Although the cam-lock proofed its safety in the DIY assembly of flat-pack furniture, these advancement did not make their way into the regulatory bodies of the building industry. For now, the use in architecture seemed to be limited to temporary structures, or for the public-private realms with less stringent building regulatory oversight. In this respect, the joint is suitable for advanced chains of mass production, which are usually rare to achieve in architecture. At this point there are 25 playrooms manufactured annually. Thus, if a building design is treated as a product on the threshold between architecture and furniture, this type of joinery might be a feasibly solution. Drawing on catalogued joints from furniture industry does not only circumvent cost intensive labour expenditures during construction but it facilitates the incumbent detailing of the joints in the early design phases of project, especially if a swift realization and prototyping are required.

Conclusion

Researching on the threshold between architecture and furniture design, this paper compared the role of the cam-lock fastener in the assembly of the Billy bookcase and the Checkered Playroom. Designed for an easy assembly by unskilled workers without special tools, the hypothesis was that these simple furniture joints may equally innovate construction in architecture. Although different in scale, both the bookcase and the playroom are composed by a system of spatial panels that are made of engineered wood. The findings point to the crucial link between the material and the choice of the joint. Not least because the later shift away from the cam-lock fastener to conventional screws convened with a change to the manufacturing chain of the playroom and the subsequent replacement of the wood type that the cam-lock was designed for. Two points can be taken from this: relying on readymade furniture cuts time and thus costs during the detail design phase and the final assembly by unskilled workers but similarly, these highly specialized furniture joints require a sophisticated degree of prefabrication that architects usually fail to achieve due to lower margins in serial production. Nevertheless, the joint well known from the flat-pack furniture industry proofed to be effect in kick-starting the initial series of the Checkered Playroom. Beyond this, the possibility to fasten and unfasten the cam-lock allows for multiple rounds of assembly and disassembly, a feature that qualified the end-user to take actively influence the construction process.

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Figures

Figure 1. Unitinno, Bazzar Sunshine Checkered Playroom, 2016, Huining, Gansu - Derived from https://www.unitinno.com/gansu-kindergarten 30th of July 2021

Figure 2. Inter IKEA System B.V., Billy, 2016 – Derived from https://www.ikea.com.hk/dairyfarm/hk/pdfs/assembly_instructions/597/AA-1894597-3_pub.pdf

Figure 3. BIG, Shenzhen Energy Mansion, 2016 – Derived from https://big.dk/#projects-sem

Figure 4. RSDiedering, From Billy Bookcase to Checkered Playroom, 2021

Figure 5. Unitinno, Bazzar Sunshine Checkered Playroom, 2016, Huining, Gansu, construction picture

Figure 6. Ghelichi, P., Becoming Constructed: Beyond the Duality of Exactitude and Error in the Works of Sverre Fehn, Enric Miralles, and Unitinno Studio, 2020

3-YEAR RESULTS OF LEARNING STRUCTURES WITH THE INTEGRATION OF GRAPHIC METHODS IN INSTRUCTION

Bronne DYTOC

Kennesaw State University
1100 S. Marietta Parkway, Marietta, GA 30068, USA
Email - bdytoc@kennesaw.edu

Abstract

This paper has the prime aim of reporting on the results of graphic methods integration in the learning of basic structures, building upon an initial paper presented in the S-ARCH conference of 2017. The first paper positioned in favour of using graphic techniques in the teaching and learning of the foundational topics of structures for architecture students. The graphics-integration approach in basic structures instruction remains in constant development and refinement, improving upon the conventional lecture-drill-calculations format (with its fair-mediocre levels of student performance and engagement). This instructional model combines different aspects of multimedia learning, active-collaborative learning, embodied learning, as well as critical reflection in its learning process. This research limits its content scope to the first basic topics of structures, including forces, equilibrium of forces, and the analysis of external and internal forces in trusses.

Shortly after the 2017 paper, a first pilot study was conducted to seek an answer to the question of whether the use of graphic techniques was able to contribute to the students' learning performance and experience. This first study followed the quasi-experimental format and yielded results that marginally hinted better performance, while having slightly stronger student feedback in preference for the graphics-integration approach. Upon reviewing this initial study, modifications were applied to refine the methodology. Whereas the first pilot study assigned one class to be the control and the other class to be the intervention, the modified method assigns "control" to the computation-dominant Method of Joints (***MoJt***) and the "intervention" to the graphics-dominant Maxwell Diagram (***MaxD***) method. Two classes each year are instructed similarly with both methods of analyses. In this modified method, students, now having learned both approaches, are asked to freely select the method they wish to use, and to apply it in their assessment task. Using the midterm test's major exercise of truss analysis, students' performances were evaluated based on the task's required processes and outputs, as well as their testing efficiency.

Data were collected over three years, 2018, 2019, and 2021. Data for the year 2020 was not considered due to the global Covid-19 pandemic's abrupt effects to the learning environment and its normal practices. The author hypothesized that the graphical approach would be strongly preferred by students. And this held true except for 2019. Nevertheless, despite this variance in student preference, the findings generally show that the graphical MaxD approach outperformed the conventional MoJ approach in terms of correctness of truss analyses as well as efficiency of task completion. More details are enumerated and discussed within the paper.

With an emerging trend that suggests consistency in these results over 3 years, the findings lend support for the integration of graphical teaching and learning methods in the multi-faceted instruction model of basic structures pedagogy for architecture students, strengthening the position that visually biased learners, such as the undergraduate students in an architecture program, would benefit from a correspondingly graphics-attuned pedagogical strategy. The author aims to continue improving on this research direction and refining the instructional design model accordingly.

Keywords

Architectural structures education, teaching learning strategies, multimedia coding, active learning, embodied, learning, reflective learning, visual -kinesthetic learning styles

1 The Case for Developing a Multifaceted Instructional Model that Integrates Graphics in the Teaching-Learning Process

1.1 Seeing is ~~Believing~~ Learning; Seeing Better is Learning Better

Recall “Activating Graphics and Collaboration in Architectural Structures Education” [1] (presented in the 4th international S-ARCH conference of 2017 in Hong Kong), where the topic of designing and developing an alternative teaching and learning (T&L) strategy for architectural structures was proposed. Noted was the architecture program’s introductory structures course’s employment of traditional lectures and computations as its instructional model, and how the conventional techniques may be mismatched with the architecture program’s patterns of design studio projects, collaborative peer reviews, and copious generation of visual outputs in the form of drawings, models, and their iterations. While it may be self-evident to most that architecture students are learners that are biased towards the visual and kinesthetic [2], it is but logical and informed to adapt teaching and learning strategies to correspond to these particular learning styles, so as to position the architecture students better learning opportunities towards success and mastery [3][4].

In fact, teaching and learning strategies that make accommodations for the visual pathways of building knowledge have often met with better learning success, be it in the learning of science and math based content [5], or other subjects [6][7].

1.2 Operational Graphics in the Knowledge Construction Process

Thus, with the purpose of improving on the limited efficacy of the traditional lecture-drill-computations model often used in this first class on structures, the author proposed the design of an active-graphics teaching and learning strategy that is more architecture-student-attuned (see Figure 1). Such an instructional model would build upon the multi-coding aspects of Mayer’s multimedia learning theory [8][9], where graphical standards familiar to the students are logically linked to the dominant dialect of computations used in this class [10]. Intentionally associations between drawing actions and algebraic processes are constructed through scaffolded instruction for the learning of complex tasks [11].

Active learning (vs passive learning) may be understood as the age-old method of “learning by doing”; but what types of “doing”? Thus, it may be appropriate to include different dimensions under its emergent umbrella [12]. A first example of “doing” by the student would expand on the commonly cognitive activity of math equation work which, for most architecture students, has always had its limits and challenges. The integration of graphics (controlled and precise actions of drawing and model-building) position such familiar and developed architectural skills into the learning process, thus tapping advantages inherent in embodied or kinesthetic learning [13][14][15]. Through the exacting craft of drawing actions, the instructor coaches students in associating spatial motions to corresponding codes practiced in algebraic computations. This framework of graphics-computations linkages serves as a major element in the alternative teaching-learning model for architectural structures [16][17][18]. This craft of doing-thinking-learning is deliberately done in manual and iterative modes to better imprint learning by directly interfacing with the student's senses, motions, and perceptions [19].

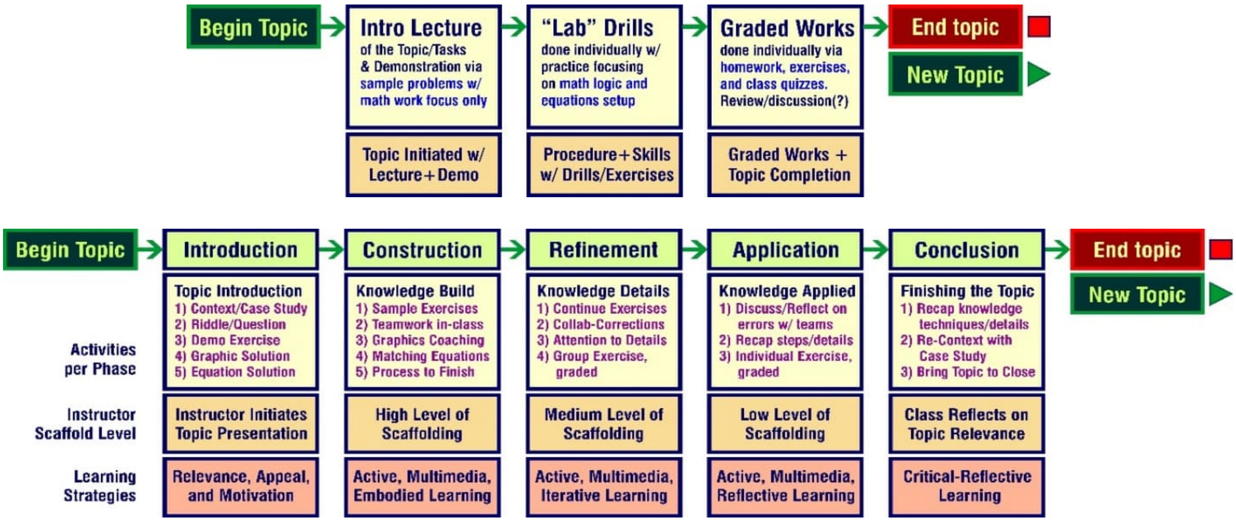

Figure 1. The traditional lecture-drill format (top) and the proposed active-graphics instructional model (bottom), updated 2021. The alternative model combines scaffolded active-collaborative learning with graphic actions. Mastery of knowledge develops with iterations; and topics are always given critical reflection to reaffirm their context and relevance to architectural thinking.

A second example of "doing" would be in the form of group work, where the key factor of collaboration among peers can be seen as "learning by talking" [20], even "arguing" [21]; quite effective in participatory education [22][23]. Learning in designed settings as these is not novel; such collaborative learning with peers and instructors are an example of Vygotsky's "zone of proximal development", activated [24]. Collaboration is effectively multilateral; therefore, affording more pathways for communication and action is vital in such a mode of active learning (see Figure 2)[25].

Figure 2. Collaborative teams build knowledge via discussion and argumentation in their own "territories". The instructor roams around as a visiting "coach" with clarifying questions and cues.

1.3 Relevant Motivation, Critical Reflection, and a Good Venue

This alternative instructional approach may pose substantial changes to the normal lecture-class environment : a compelling reason for establishing group-teams. The power level that is normally wielded by the faculty member is now more readily borne not by one individual but by a team of peers; and such an approach allows for a higher-engagement alternative to the traditional lecture-drill format that architecture students, with, perhaps, a level of acquired worries about math and physics, may yet cling to because of familiar anxieties. Ironic.

Setting this renovated teaching-learning model into operation, course content is initiated to motivate with relevance, mastered with reflective appreciation, and ideally, conducted in a venue designed to support the engagement nature of the instruction. By beginning with, say, a case study riddle, students start a topic with appeal and curiosity. Furthermore, using a real architecture project to begin discussion induces motivation "gravitas" with the introduction's contextual relevance, and thus may contribute to volition in learning [26]. The instrumental content proper of the module is then dovetailed into the instructional sequence's scaffolding.

Upon finishing a topic or module, a recap session serves as a perfect opportunity to appreciate the learned material from a few levels of critical reflection. Firstly, the post-topic discussion may help to highlight particular steps and details of the newly learned tasks; secondly, the discussion may also address cognitive attitudes and behaviours that students may take for granted yet may influence their learning and performance. Lastly, the discussion also serves to bring the content back into the context of their major field and their larger goals as future design professionals [27][28].

As a final note about designing instruction: similar to the way traditional science and math have been taught and learned, we recognize the assumption that learning such subjects happens in the head. This is very short-sighted as it does not consider that a student's means of receiving information to construct knowledge is dependent on their communicative senses of sight and sound, and their abilities to respond by motion and speech. Thus, a teaching and learning approach that practices active learning and higher student engagement would be best served with a learning environment that physically, technologically, and socially supports the traits of today's learners working within this instructional model [29].

2 The Study Method and its Necessary Modifications

2.1 The First Pilot Study: Quasi-Experimental Limits

To ascertain whether the proposed instructional model has merit, a pilot study was conducted using the quasi-experiment format. By random selection, the morning class was assigned to receive the conventional lecture-computations format, while the afternoon class received the graphics-integrated strategy; the major task of truss analysis in the midterm examination was chosen as the assessment device. Data was presented in the ACE 2018 conference [30].

While raw findings suggested that the graphics-based teaching-learning model contributed to better learning performance, the measured difference was not statistically significant; furthermore, variance for both classes were similarly high. More than likely, the low student count in the test population lent a foggier picture with its statistically low-power factor.

However, other factors such as the naturalistic settings of a class environment, and the inevitable (unavoidable) discussion across both classes regarding their differing instruction may have also added to the study's having a confusing air regarding its results.

To be clear, peer bonding amongst architecture students develops strongly as they build their knowledge and professional character with demands on their time and effort in studio. The author believes that this factor of peer bonding also equates to communication between students across the control and intervention class. Having been informed of the intentional difference of instruction between the two classes, students may have also conversed with each other regarding the different manners of instruction, their particular details, and pros and cons. It is only normal to expect that students may perceive inequality in their instruction, and even attempt to "equalize" the situation by sharing what and how they have learned their content across classes. They may feel treated unfairly, even short-changed. In fact, after that first pilot study was conducted, informal conversations with students revealed these concerns to be valid. While having a small degree of resentment for the unequal approaches to the instruction, the difference between classes also caused doubts, confusion, and certainly, dissatisfaction. Certainly, these factors would affect their attitudes towards the class, just as they would also cloud the validity of the pilot study's initial findings.

2.2 The Modified Study: Redefining "Control" and "Intervention"

Thus, the author modified the study's data gathering strategy to address the perception of inequality in instruction and consider the inevitable cross-communication across the tightly knit student population concerned. Because it is not possible to prevent "crosstalk contamination" between students, then defining "control" and "intervention" went to the conventional and alternative instructional methods, instead.

Truss analysis was the selected complex-task assessment chosen for this research; and the conventional computations-based Method of Joints (***MoJt***) was assigned as the "control", while the graphics-based Maxwell Diagram (***MaxD***) was assigned as the "intervention". Instead of having a "control" and "intervention" class, both classes were taught these two methods. Efforts were given to render instruction similarly to both classes with the same sequences, pacing, activities, exercises, and language; both approaches were scaffolded with collaborative learning phases as outlined in the instruction design model (Figure 1).

As argued in the author's earlier paper [1], graded individual exercises could have also served as assessment devices to generate performance data; however, they have to be thoughtfully conducted to measure individual performance with minimal peer influence. Therefore, for this study's data clarity, learning performance was measured using the midterm examination's major task of truss analysis as the assessment device.

3 The Measurement Device: The Midterm Exam's Truss Analysis

The first major test in this first structures class covers the basic topics of forces, force addition, equilibrium, moments, reactions, and analyzing a truss for its internal bar forces. Truss analysis, this study's device, may be produced by either the computation-heavy Method of Joints method (***MoJt***), or the graphics-dominant Maxwell Diagram method (***MaxD***).

The exam has a total of four sections in its composition : a first section with simple warm-up questions, a second section with discrete items requiring math operations, a third section testing logic through a conceptual analysis of a particular case study (Figure 3), and the last section with the major task of truss analysis that calls on the student's full learning to analyze a truss for its internal forces. This test generally has a completion time of two and a half hours.

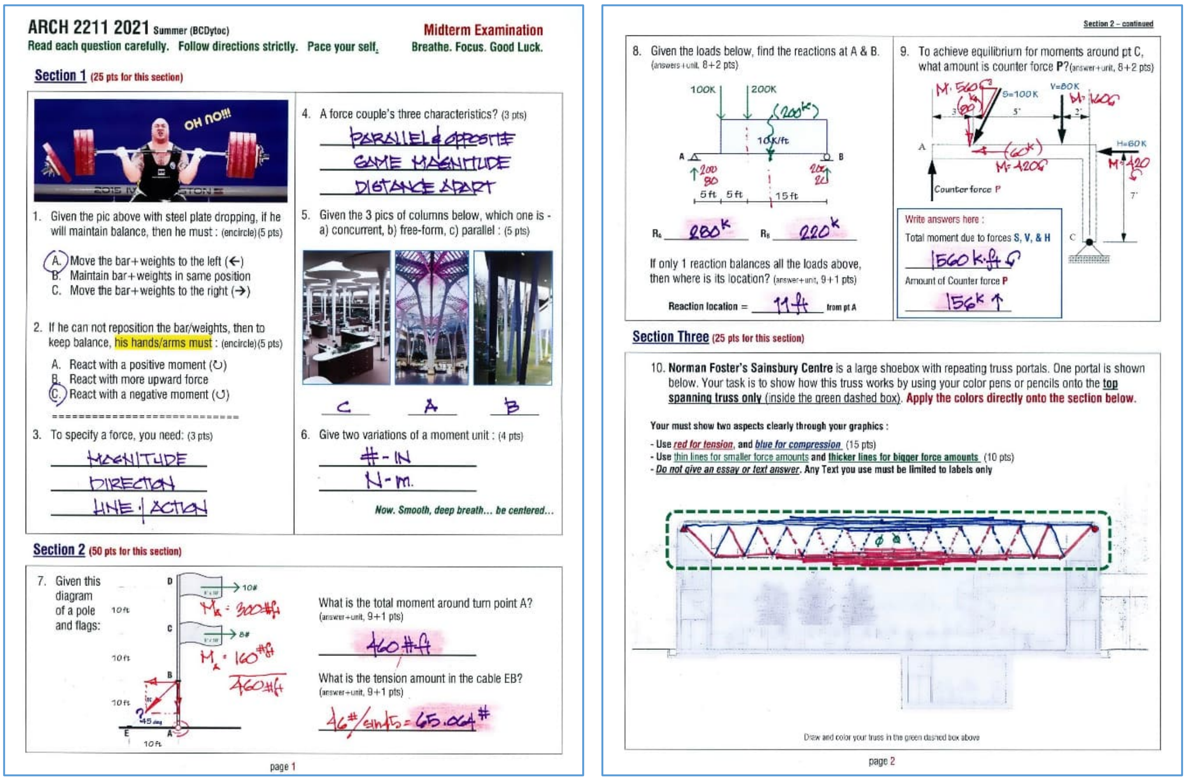

Figure 3. The first sections of the midterm examination, with its answers: 1) warm-up questions, 2) discrete analysis items, and 3) a conceptual / graphical analysis of a case study's structure.

In the examination's final section, a simply supported truss is defined, complete with loads and dimensions, along with relevant information for the student's generation of required analytical solutions and their corresponding final outputs. This final section contains three parts to its analysis : 1) finding external reactions, 2) analysis by sectional method, and 3) the main task of analysing the truss for internal bar forces. The student, by instruction, is trained to do both methods, but is asked to select their analysis method of choice. The full exam is weighted at 200 points, with the final section weighted at 100 points. For the study's purposes, the first part (reactions) and third part (full truss analysis) are considered; the second part, analysis by section, is not included. In Figures 4a and 4b below, the truss problem is given in detail with its solutions for reactions, and its analyses for internal truss bar forces via both the Maxwell Diagram (***MaxD***) method and the Method of Joints (***MoJt***) method.

Data was gathered from both the morning and afternoon classes, across three years, during the spring semesters of 2018, 2019 and 2021, and the summer term of 2021. Data gathering was halted during spring and summer of 2020, due to the significant disruption to normal instructional practices caused by the Covid-19 pandemic. By the end of year 2020, the learning environments were returning to a level of normalcy and, thus, research resumed anew in 2021.

With regards to administering the examination, students took the test in the same room with the same conditions of desk space, ambient lighting and sound levels. Upon submission, each test was noted to document the total time used; exams were then subsequently evaluated and scored, extracting the raw performance data for the truss analysis, in particular. For this paper, these data are then compiled in simple values of raw score averages (performance), standard deviation (variance), and testing time (efficiency).

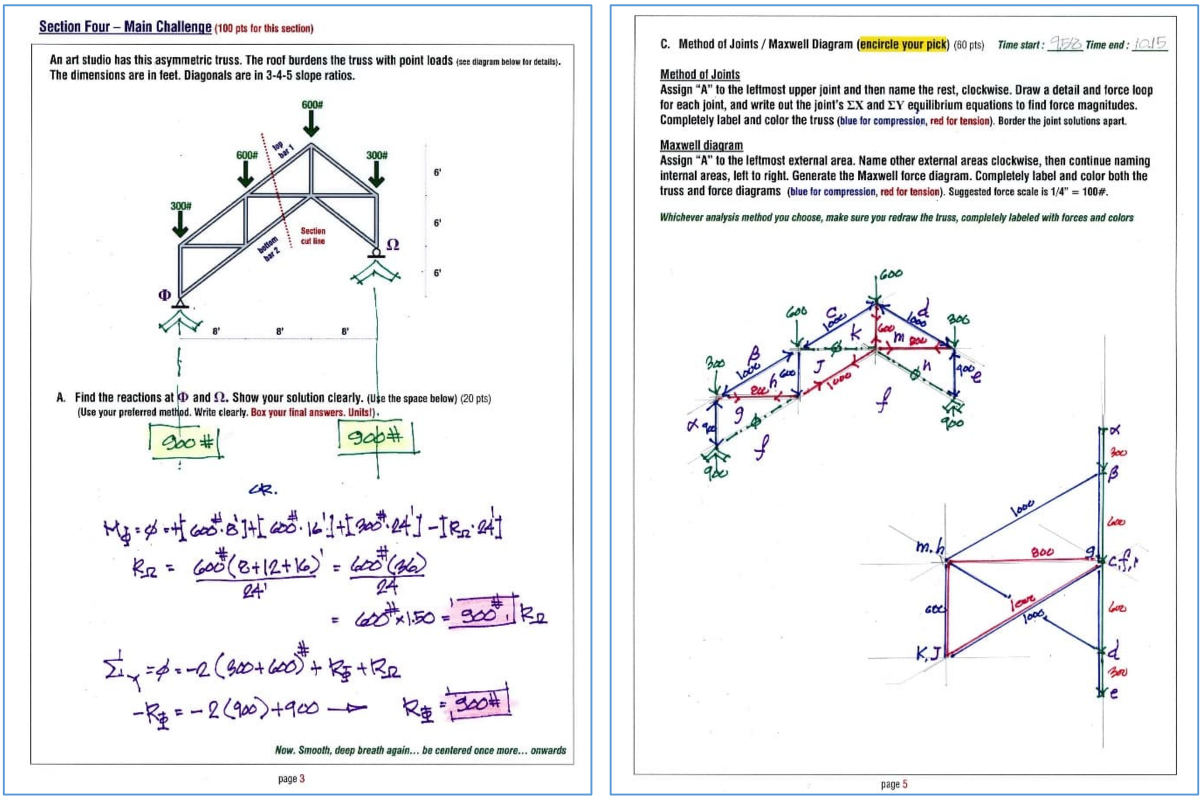

Figure 4a. The simple truss with its solutions for reactions (left), and the truss, fully analysed using the graphics-based Maxwell Diagram method (***MaxD***). Solving for individual force amounts employs knowledge of geometry in drawing and reading the precisely scaled force-loop graphics.

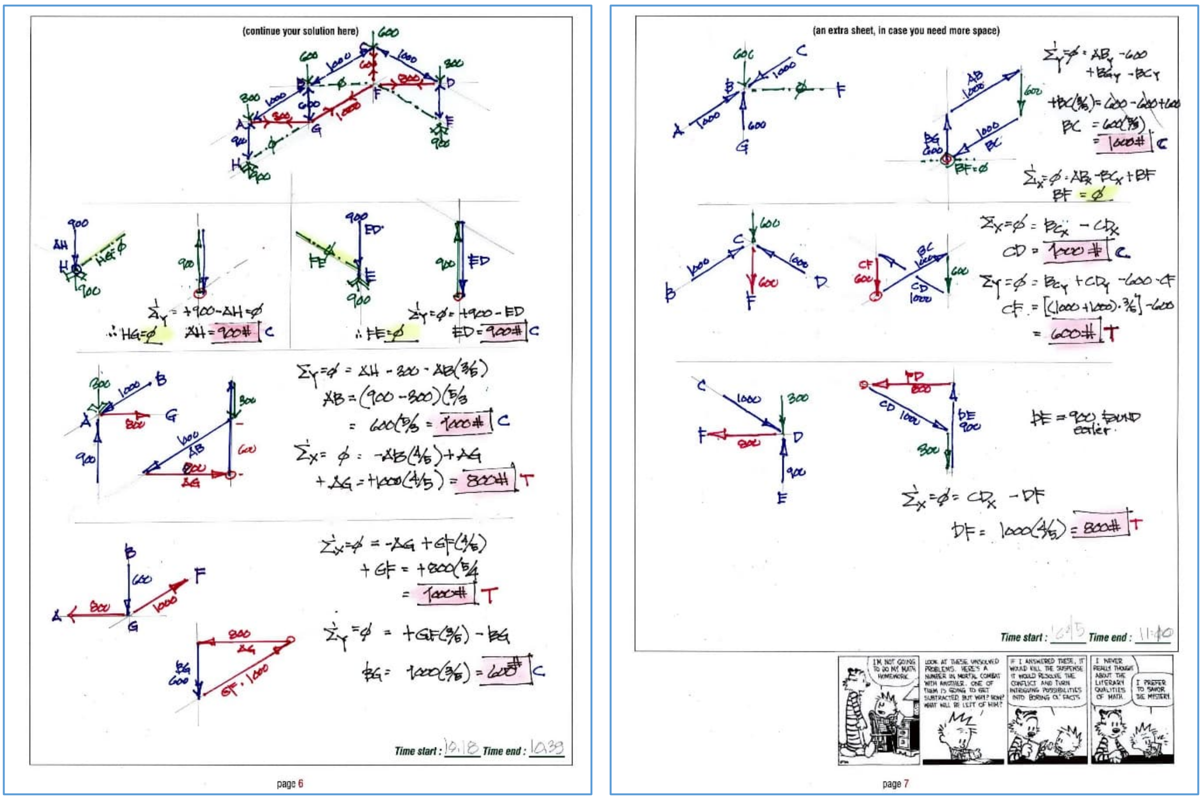

Figure 4b. The full analysis of the truss using the Method of Joints (***MoJt***) method. This conventional method employs the traditional writing of X and Y calcuations which take their equation forms based on each joint's detail and force loop.

4 What the Data over 3 Years Suggest

Data that were compiled from the examinations were manifold, including the scores from the truss analysis task proper, the time taking the full test, and the time doing the truss analysis task. Averages and standard deviations were generated for both the full test and the truss analysis task. Times are reviewed as suggestive of performance efficiency and confidence.

Full-test scores are not included in this paper. The exam has four different sections; and it was evident that students take the test in varying ways, just as they may have studied for it in as many different ways. Many students engage every, while many other students skip questions and even skip whole sections. Understanding that this testing behaviour is part of the naturalistic setting of a class, it becomes clearer to the author that focusing on the truss analysis task itself would lend to better data review clarity.

Data was initially studied from a standpoint of including the total student population; as the study continues to develop its methodology, the same data was reviewed through a validating filter to identify and exclude outliers. Sections 4.1 and 4.2 expound more on this detail.

4.1 The Performance Averages and their Variances

Listed below in Table 1 are the performance score averages for the test's truss analysis task.

	Table 1. Truss Analysis : Performance															
	Spring 2018				Spring 2019				Spring 2021				Summer 2021			
Class	***MoJt***		***MaxD***		***MoJt***		***MaxD***		***MoJt***		***MaxD***		***MoJt***		***MaxD***	
	n	average	n	average	n	average	n	average	n	average	n	average	n	average	n	average
AM	10	66.20	22	84.18	19	71.05	11	84.16	5	44.80	24	67.50	13	62.88	8	63.75
PM	10	68.00	19	89.58	21	63.81	10	83.17	9	49.67	21	85.29	4	51.56	11	74.09
Total	**20**	**67.10**	**41**	**86.68**	**40**	**67.25**	**21**	**83.68**	**14**	**47.93**	**45**	**75.80**	**17**	**60.22**	**19**	**69.74**

Table 1. This table shows the performance averages for the truss analysis task. Data are organized in four class-term samples, detailed according to class (AM or PM), and chosen method (Method of Joints – ***MoJt***, or Maxwell Diagram – ***MaxD***). The number of students (n) that opted for each truss analysis method, per class., is also shown.

Table 1 generally shows how performance for the truss analysis task scored better with the graphics-based ***MaxD*** method than the conventional ***MoJt*** method. Notable, however, are the classes of Spring 2019 and Summer 2021-AM, where the conventional method was preferred over the graphical alternative in undertaking the task of truss analysis.

	Table 2. Truss Analysis : Variance															
	Spring 2018				Spring 2019				Spring 2021				Summer 2021			
Class	***MoJt***		***MaxD***		***MoJt***		***MaxD***		***MoJt***		***MaxD***		***MoJt***		***MaxD***	
	n	std dev	n	std dev	n	std dev	n	std dev	n	std dev	n	std dev	n	std dev	n	std dev
AM	10	24.06	22	17.56	19	20.62	11	24.12	5	11.75	24	22.49	13	23.66	8	30.21
PM	10	28.92	19	16.18	21	23.58	10	18.51	9	19.09	21	19.29	4	29.39	11	26.69
Total	**20**	**26.62**	**41**	**17.14**	**40**	**22.52**	**21**	**21.64**	**14**	**17.01**	**45**	**22.85**	**17**	**25.58**	**19**	**28.68**

Table 2. This table shows the standard deviations, or variance, of each class-term sample. These numbers are a measure of how tight or loose the performances are from the mean, per class.

Table 2 shows data on standard variations. A larger dispersion from the performance mean may point to a wider range of learning mastery. While the author hypothesizes that a learning method that is more attuned to the architecture student would also result in better learning mastery, hence a tighter variance, data show that this is not always so. Possible contributors to this inconsistency are natural differences in students' study habits, as well as the effect of very low "n" (less than 10 in the 2021 class terms) in calculating standard deviation.

The author infers that this discrepancy in variance, as well as drops in performance averages for 2021 classes, may also be influenced by the school's evolving responses to the class environment's acceptable practices and arrangements, in continuing response to the Covid-19 pandemic. Also of possible influence is the different level of academic loading that the Summer 2021 AM class had, versus the lighter load borne by the Summer 2021 PM class.

4.2 Performance Times

Shown in Tables 3 and 4 below are test times for taking the exam, and time in doing the task of truss analysis. Times for the analysis task were not taken in 2018 and thus, are not reported. Overall, however, the Maxwell Diagram consumes less time than the conventional Method of Joints. Nevertheless, inconsistencies remain (see Summer 2021 data). The factors mentioned above may have similar influence manifesting in this measure.

Table 3. Total Time for Examination

	Spring 2018				Spring 2019				Spring 2021				Summer 2021			
Class	***MoJt***		***MaxD***		***MoJt***		***MaxD***		***MoJt***		***MaxD***		***MoJt***		***MaxD***	
	n	minutes	n	minutes	n	minutes	n	minutes	n	minutes	n	minutes	n	minutes	n	minutes
AM	10	149.20	22	141.55	19	142.53	11	124.73	5	151.00	24	136.45	13	140.95	8	150.42
PM	10	144.20	19	131.21	21	122.57	10	108.10	9	143.45	21	107.67	4	142.29	11	117.43
Total	**20**	**146.70**	**41**	**136.76**	**40**	**132.05**	**21**	**116.76**	**14**	**146.15**	**45**	**123.02**	**17**	**141.28**	**19**	**131.79**

Table 4. Truss Analysis Task Time

	Spring 2018				Spring 2019				Spring 2021				Summer 2021			
Class	***MoJt***		***MaxD***		***MoJt***		***MaxD***		***MoJt***		***MaxD***		***MoJt***		***MaxD***	
	n	minutes	n	minutes	n	minutes	n	minutes	n	minutes	n	minutes	n	minutes	n	minutes
AM					19	54.79	11	35.36	5	50.00	24	54.00	13	48.21	8	59.38
PM					21	47.33	10	32.60	9	75.88	21	52.90	4	86.46	11	52.65
Total					**40**	**50.88**	**21**	**34.05**	**14**	**66.57**	**45**	**53.48**	**17**	**57.21**	**19**	**55.48**

Table 3. These two tables describe the average times per class-term. Table 3a (top) displays total test time while Table 3b (bottom) displays time taken for the truss analysis task.

It is at this point that the researcher considered that the data, which account for every student that took the test, may contain outliers. Being able to identify and filter those out may give better validity and clarity to the data. It is mentioned above how some students did not engage every question (or every section) of the test. A re-review of the exam papers reveal incomplete truss analyses work in a number of exams – perhaps from being ill prepared, perhaps from running out of time, or otherwise. Thus, the author deemed that these particular tests could not provide valid data parallel to the students that did complete the truss analysis. Accordingly, data is re-reviewed with this filter.

4.3 The Data, Filtered and Re-Reviewed

The data in Tables 5 to 8, below, parallel the data in Tables 1 to 4 above, but are now filtered of the particular exam responses which did not submit completed truss analyses work, thus giving consideration only to "valid" (completed) test entries.

Table 5. Truss Analysis : Performance (Completed Task)

	Spring 2018				Spring 2019				Spring 2021				Summer 2021			
Class	***MoJt***		***MaxD***		***MoJt***		***MaxD***		***MoJt***		***MaxD***		***MoJt***		***MaxD***	
	n	average	n	average	n	average	n	average	n	average	n	average	n	average	n	average
AM	5	81.40	15	85.06	19	71.05	11	84.16	2	52.50	21	71.57	8	73.13	4	89.38
PM	5	72.33	15	88.75	21	63.81	10	83.17	5	47.60	17	93.47	2	75.00	10	78.00
Total	**10**	**76.87**	**30**	**86.91**	**40**	**67.25**	**21**	**83.68**	**7**	**55.71**	**38**	**81.37**	**10**	**73.50**	**14**	**81.25**

Table 6. Truss Analysis : Variance (Completed Task)																
	Spring 2018				Spring 2019				Spring 2021				Summer 2021			
Class	MoJt		MaxD		MoJt		MaxD		MoJt		MaxD		MoJt		MaxD	
	n	std dev	n	std dev	n	std dev	n	std dev	n	std dev	n	std dev	n	std dev	n	std dev
AM					19	20.62	11	24.12	2	7.50	21	21.03	8	16.13	4	18.40
PM					21	23.58	10	18.51	5	7.54	17	8.35	2	25.00	10	24.81
Total					**40**	**22.52**	**21**	**21.64**	**7**	**7.79**	**38**	**19.85**	**10**	**24.37**	**14**	**23.72**

Table 7. Truss Analysis : Efficiency (Completed Task)																
	Spring 2018				Spring 2019				Spring 2021				Summer 2021			
Class	MoJt		MaxD		MoJt		MaxD		MoJt		MaxD		MoJt		MaxD	
	n	minutes	n	minutes	n	minutes	n	minutes	n	minutes	n	minutes	n	minutes	n	minutes
AM					19	142.53	11	124.73	2	150.00	21	134.44	8	126.25	4	131.67
PM					21	122.57	10	108.10	5	138.20	17	102.65	2	134.58	10	120.08
Total					**40**	**132.05**	**21**	**116.76**	**7**	**141.72**	**38**	**120.22**	**10**	**122.08**	**14**	**123.39**

Table 8. Truss Analysis : Performance (Completed Task)																
	Spring 2018				Spring 2019				Spring 2021				Summer 2021			
Class	MoJt		MaxD		MoJt		MaxD		MoJt		MaxD		MoJt		MaxD	
	n	minutes	n	minutes	n	minutes	n	minutes	n	minutes	n	minutes	n	minutes	n	minutes
AM					19	54.79	11	35.36	2	63.00	21	54.18	8	52.50	4	38.33
PM					21	47.33	10	32.60	5	72.60	17	47.35	2	97.92	10	55.25
Total					**40**	**50.88**	**21**	**34.05**	**7**	**69.85**	**38**	**51.13**	**10**	**61.58**	**14**	**50.42**

As foreseen, the exclusion of incomplete tests sharpened the data to some degree. Variance was less clear, even as its numbers tightened. Nevertheless, better performance (10+% pts or more) and task efficiency (10+ minutes less) remained consistent with the use of the Maxwell Diagram analysis method. This first leg of longitudinal data, though limited in power, at least shows how integrating graphics operations in the learning process may have merit.

5 Conclusions, Reflections, and Recommendations

This research aims to ask a more focused question of the updated instructional model : can the inclusion of graphic actions and operations in the teaching and learning of introductory structures content improve the learning performance and engagement of architecture students? The answer, based on this set of data, is a cautious "yes".

While the performance numbers and the task times support this tentative conclusion, the author is reminded that the learning environment has also been redesigned to apply active, embodied, and collaborative learning in the scaffolded sequences, as well as critical reflection in the capping off of topics. And these more modern practices may have affected the learning experiences of the students in hopefully positive and productive directions. As an instructor, the author is aware that students carry and process cognitive loads; having a supportive and appealing learning venue may aid in sustaining motivation, volition, retention, and perhaps, knowledge transfer and application.

The methodology continued to refine across the years in this paper's data-gathering period, allowing data to be filtered of inconsistent data that came from outlier (incomplete) tests. The disruption caused by the Covid-19 pandemic prevented a smooth continuity in the research; in fact, its effects seem to still manifest in shakier raw findings of 2021. Despite a "lower-resolution" picture from a low-n power, the data suggests positively for the research hypothesis that instruction integrated with graphics made for better learning performance and efficiency (efficiency being clues to a student's mastery of content knowledge and confidence/competence in its application).

It is noted that the classes of 2019 and the AM class of summer 2021 showed a higher preference for the conventional (computational) Method of Joints analysis strategy, this, despite the consistent showing of better performance by the graphical Maxwell Diagram method. The researcher reflected on this and believes that a combination of academic load and communication amongst students may have negatively affected students' perceptions and anxieties; informal conversations with students post-term seem to support so.

Students' attitudes and perceptions of the course content, the instructional modes, and the physical-social learning environment do matter in their constructed experience and, thus, affect their learning performance and engagement. A post-term survey to gather student feedback on these issues was done in 2018 and 2019 but not for 2020 and 2021. Re-gathering this data may offer better qualitative information on the instructional model, complementing the quantitative aspects of this continuing study.

As a final note to this first leg of what may be a lengthy longitudinal study, these numerical data give positive support for the adoption of a more architecture-attuned mode of teaching and learning structures in an undergraduate architecture program. The author sees this first 3-year iteration as a noteworthy episode that will help shape continuing future research.

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FLEXIBILITY AND CONSTRUCTABILITY OF MODULAR DEPLOYABLE BAMBOO STRUCTURES

Anastasia MAURINA[1,2]*, Vincent BLOUIN[3]

[1]Planning, Design, and Built Environment, Clemson University
2-315 Lee Hall, Clemson, South Carolina 29634, USA; maurina@g.clemson.edu

[2]Architecture Department, Universitas Katolik Parahyangan
Ciumbuleuit no.94, Bandung, West Java, 40141, Indonesia

[3]School of Architecture, Clemson University
2-138 Lee Hall, Clemson, South Carolina 29634, USA; vblouin@clemson.edu

Abstract

Prefabrication approaches, which generally rely on locally available resources and skills, can be helpful to vulnerable communities to improve their building design and construction quality. Even though prefabrication approaches have many advantages, they may result in uniformity and lack of design flexibility. By adding the modular approach to prefabrication approaches can enhance flexibility by allowing the reconfiguration of repetitive components into a wide variety of end-products. Using deployable structures is another strategy for achieving more architectural variety thanks to the geometric and spatial transformability of the structural elements. Applying the modular approach to deployable structures, then referred to as a modular deployable structure, is expected to boost flexibility greatly. Concerning constructability, using local materials, easily accessible tools, and indigenous methods of construction is generally preferable. Bamboo is a forthcoming material particularly adapted to modular deployable structures because of its lightweight, exceptional mechanical properties, and local availability, especially in tropical areas of many developing countries. This paper studies the flexibility and constructability of modular deployable bamboo structures through a parametric computational experiment and multi-criteria analysis. The research focuses on units called scissor-like elements (SLE) units, which are composed of two bars with a pin connection, and modified versions of the SLE unit, referred to as m-SLE, which include up to four bars and/or translatable pin connections. Various cases of deployable structures composed of multiple SLE and m-SLE units are considered and compared quantitatively. The results show that increasing flexibility generally decreases constructability. However, the strategic use of m-SLE units can significantly improve flexibility while only slightly decrease constructability.

Keywords

Bamboo, Deployable, Scissor-Like Elements, Flexibility, Constructability

1 Introduction

Prefabrication approaches, which generally rely on locally available resources and skills, can be helpful to vulnerable communities to improve building design and construction. The heavy and large-scale prefabrication approach, generally encountered in developed countries, is not adapted to the needs of vulnerable communities, especially in many developing countries, because of the high cost, locally unavailable material, unsuitability construction techniques, and on-site assembly inaccuracy issues. The light and small-scale prefabrication approaches are preferred as a part of the 'appropriate technology' movement, geared to locally available resources, skills, and needs. Not only this system reduces the construction cost, but it can also generate employment opportunities, utilize low-skilled labor, and exploit local resources [1]. Even though prefabrication approaches have many advantages, they may result in uniformity and lack of design flexibility. The one-size-fits-all concept has been unsuccessful because of inadaptability. The idea of mass customization emerged to enhance the prefabrication approach by offering highly customized products that meet the public's desire for individuality while maintaining production efficiency [2].

Adding the modular approach to prefabrication can enhance flexibility by allowing the reconfiguration of repetitive components into a wide variety of end-products [3]. The modular approach promotes the users' emancipatory role as a co-designer, co-planner, or co-creator that determines the end-product [2, 3]. Using deployable structures is another strategy for achieving more architectural variety [4] thanks to the geometric and spatial transformability of the structural elements. Applying the modular approach to deployable structures, then referred to as a modular deployable structure, is expected to boost flexibility greatly.

Concerning constructability, using local materials, easily accessible tools, and indigenous construction methods is generally preferable [5, 6]. Bamboo is a forthcoming material particularly adapted to modular deployable structures because of its lightweight, exceptional mechanical properties, and local availability, especially in tropical areas of many developing countries. For example, a modular deployable bamboo structure, developed by Maurina and Prastyatama [7, 8], can create various shapes and dimensions by configuring within the expandable module and arranging them, as shown in **Fehler! Verweisquelle konnte nicht gefunden werden.**. Two community projects (a shelter and a kindergarten), shown in Figure 1, were built with very different forms using the same deployable bamboo structural module. Interestingly, those projects involved the users (laypeople) in the design process by configuring and arranging the structural modules and the construction process in fabrication and installation. These projects are noticeable evidence of the potency of modular deployable bamboo structures in achieving flexibility and constructability.

Figure 1. Two built projects: a community center in 2017 (left) and a kindergarten in 2019 (right) in Indonesia by Maurina and Prastyatama [7, 8]

2 Deployable Structures

2.1 The Flexibility of Deployable Structures

Deployable structures can transform their shape from a compact configuration to a predetermined configuration [9]. One of the most popular deployable structural mechanism, known as the scissor-like element (SLE) unit, and referred in this paper as the regular SLE unit (r-SLE) is composed of two bars and joined with an intermediate pin connection [10]. The location of the pin connection can differentiate the SLE unit: translational unit (center pin) and polar unit (off-center pin) [11], as shown in Figure 2.

Figure 2. A deployable structure composed of multiple r-SLE units:
translational unit (left) and polar unit (right) [10]

The transformability of this structure provides three remarkable advantages: standardized fabrication, ease of transportion (light and compact), and ease of installation (speed and ease of erection and dismantling) [10-12]. As a result, skilled laborers are typically not required [13]. However, this r-SLE deployable structure cannot offer form flexibility as it can deploy into only one configuration [14, 15]. A flexible structure is expected to have the ability to transform into several predetermined configurations, thus offering form flexibility [16].

2.2 Modified Scissor-Like Element (SLE) Units

Fundamentally, increasing the degrees-of-freedom of a deployable structure should increase form flexibility [17]. Figure 3 shows two modifications of the regular SLE unit (r-SLE) to increase the structure's degrees-of-freedom: (1) using a translatable pin connection, referred to as modified 1 SLE (m1-SLE); and (2) using four smaller bars with a pin connection, referred to as modified 2 SLE (m2-SLE).

Modified deployable structures using m1-SLE units were used in other research efforts [18-19]. Rosenberg [20] developed a flexible deployable structure by adding one or more derivative components that can move the position of the pin connection, which is similar to the m1-SLE unit. Umweni [21] invented a modified transformable gear-hinge scissor mechanism while Maden [19] explored the transformability of double-curved hyperbolic paraboloid deployable structures that required translatable pin connections. Kokawa and Hokkaido [22], as mentioned in [17], developed a three-hinged arch deployable structure with a m2-SLE unit. They added zigzag flexible cables to control the transformability and create various symmetric shapes without changing the span. Then, Akgun et al. [23] upgraded this modified deployable structure by adding more than one modified SLE unit and changed the actuator to generate more variants in shape.

Based on the review of the literature, a quantitative performance analysis is needed to assess the flexibility of modified SLE structural modules. Thus, this research evaluates the effect of the type, number, and location of modified SLE units in the structural module on flexibility.

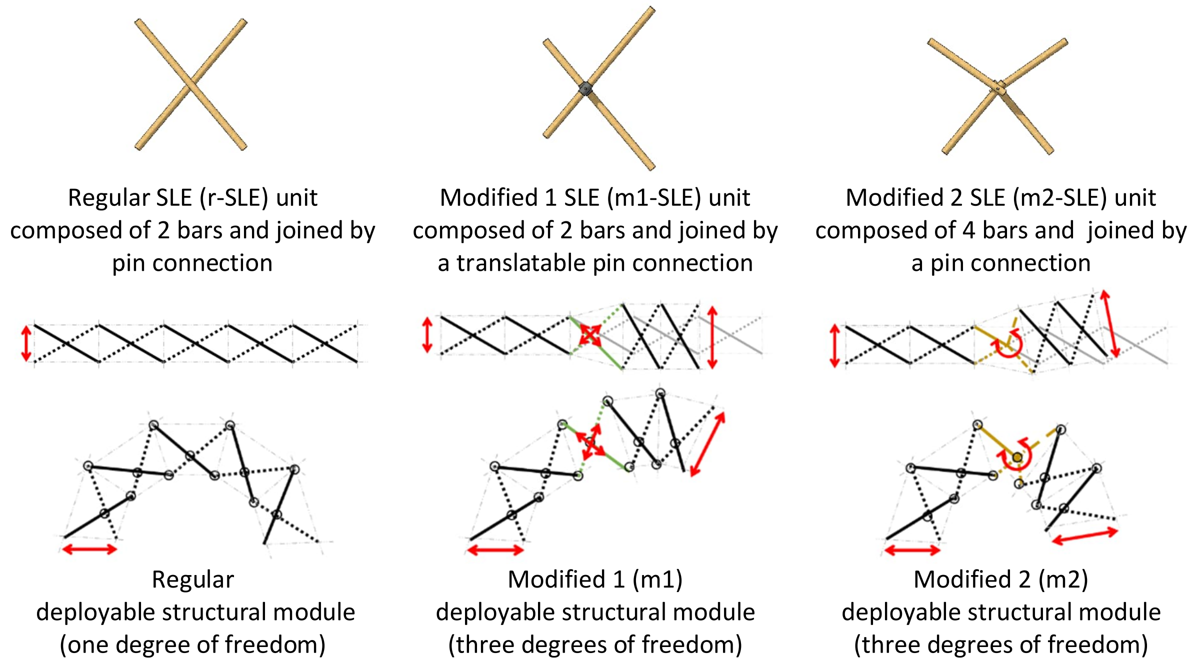


Figure 3. Regular SLE (r-SLE), modified 1 SLE (m1-SLE), and modified 2 SLE (m2-SLE)

2.3 The Constructability of Deployable Structures

Even though the ease of transportation and installation enables laypeople to use deployable structures [13, 24], the primary concern is the complexity of design and fabrication of the connection systems [25]. As discussed earlier, flexibility can be improved by adding more degrees of freedom to the structure, leading to added complexity and, thus, decreasing constructability. This problem goes against the goal of using deployable structures for vulnerable communities. Thus, analyzing the tradeoff between flexibility and constructability should be studied carefully to evaluate the validity of improving the flexibility of deployable structures at the expense of constructability. To this end, the entire construction process from material procurement, fabrication, transportation, and installation, should be considered and analyzed quantitatively.

3 Research Method

The research aims to explain the tradeoff between flexibility and constructability of modular deployable bamboo structures composed of regular and modified SLE units; and identify the optimum deployable bamboo structural modules based on the type, number, and location of regular and modified SLE units within the structure. This experimental research combines parametric computational design using Rhino/Grasshopper and half-scale prototyping to evaluate 15 structural cases. Mixed numerical analysis methods, i.e., weighted sum model and Pareto multi-criteria optimization, are performed to measure and compare the flexibility and constructability of regular and modified modular deployable bamboo (MDB) structures.

3.1 Case Study

The reference case is a deployable arch structural module with predetermined dimensions: eight-meter span, four-meter height, and five r-SLE units of eighty-centimeter depth, as shown in Figure 4. Fourteen cases of modified deployable structures are defined by combining the two types of m-SLE units in any of the five slots (labeled SLE #1 to SLE #5 in Figure 4) as listed in Table 1.

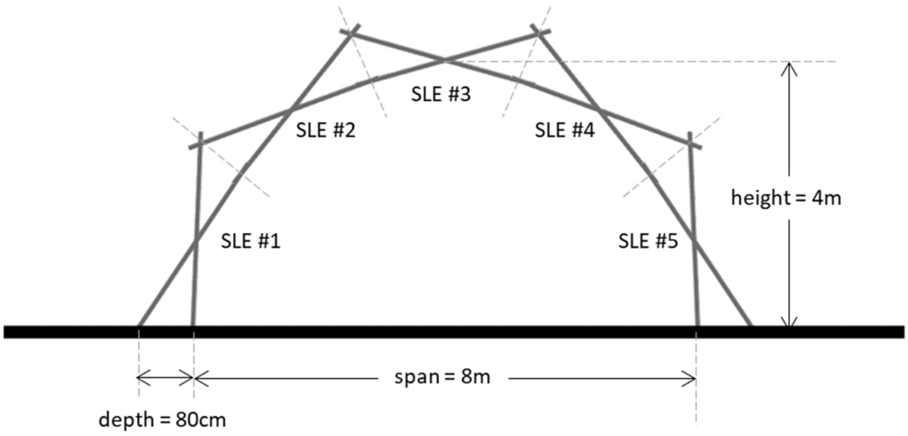


Figure 4. Predetermined configuration of the reference case

Table 1: List of cases of modified deployable structures

Case #	m-SLE's type	# of m-SLE	Location of m-SLE				
			SLE #1	SLE #2	SLE #3	SLE #4	SLE #5
0	-	0	r-SLE	r-SLE	r-SLE	r-SLE	r-SLE
1	m1-SLE	1	r-SLE	r-SLE	m1-SLE	r-SLE	r-SLE
2	m1-SLE	2	r-SLE	m1-SLE	r-SLE	m1-SLE	r-SLE
3	m1-SLE	2	m1-SLE	r-SLE	r-SLE	r-SLE	m1-SLE
4	m1-SLE	3	r-SLE	m1-SLE	m1-SLE	m1-SLE	r-SLE
5	m1-SLE	3	m1-SLE	r-SLE	m1-SLE	r-SLE	m1-SLE
6	m2-SLE	1	r-SLE	r-SLE	m2-SLE	r-SLE	r-SLE
7	m2-SLE	2	r-SLE	m2-SLE	r-SLE	m2-SLE	r-SLE
8	m2-SLE	2	m2-SLE	r-SLE	r-SLE	r-SLE	m2-SLE
9	m2-SLE	3	r-SLE	m2-SLE	m2-SLE	m2-SLE	r-SLE
10	m2-SLE	3	m2-SLE	r-SLE	m2-SLE	r-SLE	m2-SLE
11	combined	3	r-SLE	m2-SLE	m1-SLE	m2-SLE	r-SLE
12	combined	3	r-SLE	m1-SLE	m2-SLE	m1-SLE	r-SLE
13	combined	3	m2-SLE	r-SLE	m1-SLE	r-SLE	m2-SLE
14	combined	3	m1-SLE	r-SLE	m2-SLE	r-SLE	m1-SLE

3.2 Performance Measures

Flexibility is assessed using six measures grouped into three dimensions: arrangeability, configurability, and space-functionality, as listed in

Table 2. Constructability is assessed using nine measures grouped into four dimensions: materiality, fabricability, transportability, and installability, as listed in Table 3.

Table 2: Flexibility Performance Measures

Dimension	Measure
Arrangeability: Modules' ability to be arranged in various formal organizations	**F01. Arrangeability**: *Number of possible formal organizations*
Configurability: Module's ability to be configured in various spans and shapes	**F02. Expandability**: *Ratio between the range of span (defined as maximum span minus minimum span) and the average span (defined as maximum span plus minimum span divided by two) as a percentage*
	F03. Shape-changeability: *Number of degrees of freedom*
	F04. Reconfigurability: *Number of degrees of freedom minus the degrees of freedom of the pedestals*
Space-Functionality: Module's ability to have usable space in width and height	**F05. Ground floor efficiency:** *Ratio between the range of the usable width (with at least 3-m vertical clearance) and span in the initial span (8m)*
	F06. Mezzanine Possibility: *Maximum ratio between the range of the width with at least 4.5-m vertical clearance and span*

Table 3: Constructability Performance Measures

Dimension	Measure
Materiality: Efficiency and ease of supplying materials and joinery	**C01. Material (bamboo) efficiency**: *Percentage of bamboo used per unit length of manufactured bamboo. A higher percentage is expected*
	C02. Joinery complexity: *Number of degrees of freedom of the most complex connection among all connections of the structure. A lower degree of freedom is preferred.*
Fabricability: Ease of fabrication of the structural modules in terms of modularity, fabrication time and process.	**C03. Modularity:** *Ratio of the number of bar variants and connection variants in the structural module and the number of SLE units.*
	C04. Fabrication time: *Sum of the total duration for measuring, coding, cutting, and drilling bamboo poles, assembling connections, and assembling the structural module.*
	C05. Fabrication process: *Score reflecting the required tools (the highest score for handy tools, the middle score for power tools, and the lowest score for professional tools) and the method of assembly (the highest score for horizontal on the ground, the lowest score for vertical 3D.*
Transportability: Ease of transportation in terms of weight and compactness	**C06. Weight:** *Weight of the structural module.*
	C07. Compactness: *Sum of the length, width, and height of the compacted module.*
Installability: Ease of installation of the structural	**C08. Erection time:** *Sum of the duration of erecting the structural module (or sections when applicable) on the footings and joining the sections*

Dimension	Measure
module in terms of duration and procedure.	**C09. Installation process:** *Sum of the scores reflecting the required tools (high score for handy tools, middle score for power tools, and low score for professional tools) and the number of steps of the assembly method.*

A weighted sum is used to calculate the flexibility score, F_i^{score} , and the constructability score C_i^{score} according to equations (1) and (2). Both scores are evaluated for each of the 15 structural cases ($i = 0,1,2, \ldots, 14$) with six measures for flexibility ($j = 1,2,3, \ldots,6$) and nine measures ($j = 1,2,3, \ldots,9$) for constructability. All measures are to be maximized excepts for six measures, i.e., joinery complexity, modularity, fabrication time, weight, compactness, and erection time, which are to be minimized. This study assumes that w_{Fj}, which is a relative weight of importance of the measure F_j for flexibility, and w_{Cj}, which is a relative weight of importance of the measure C_j for constructability, are equal to 1.0 for all measures. f_{ij} is the normalized flexibility measure value of case #*i* and c_{ij} is the normalized constructability measure value of case #*i*. The normalization is done using the minimal value and maximum value shown in Table 4. The scores are defined as follows:

$$F_i^{score} = \sum_{j=1}^{6} w_{Fj} f_{ij} \ , for\ i = 0,1,2, \ldots, 14 \quad (1)$$

$$C_i^{score} = \sum_{j=1}^{9} w_{Cj} c_{ij} \ , for\ i = 0,1,2, \ldots, 14 \quad (2)$$

Table 4: Measure's minimum and maximum value

Dimension	Measure	Code	Unit	Min (0)	Max (1)
Arrangeability		F01	#	1	3
Configurability	Expandability	F02	%	90%	110%
	Shape-changeability	F03	#	1	5
	Reconfigurability	F04	#	0	2
Space functionality	Ground floor efficiency	F05	ratio	50	100
	Mezzanine possibility	F06	ratio	0	100
Materiality	Material efficiency	C01	%	51	100
	Joinery complexity*	C02	#	6	1
Fabricability	Modularity*	C03	ratio	1	0.2
	Fabrication time*	C04	minutes	480	120
	Fabrication process	C05		0	2
Transportability	Weight*	C06	kg	100	25
	Compactness*	C07	meters	6	4
Installability	Erection time*	C08	minutes	120	15
	Installation process	C09		0	2
					**to be minimized*

The general performance score (GP_i^{score}) is also defined as a weighted sum of the normalized flexibility score and the normalized constructability score, as follows:

$$GP_i^{score} = 0.5\overline{F_i^{score}} + 0.5\overline{C_i^{score}} \quad (3)$$

$$\overline{F_i^{score}} = F_i^{score}/6 \quad (4)$$

$$\overline{C_i^{score}} = C_i^{score}/9 \quad (5)$$

4 Results and Discussion

4.1 Performance Analysis

The flexibility, constructability, and general performance scores are shown in Figure 5**Fehler! Verweisquelle konnte nicht gefunden werden.**. Compared to case #0 as the reference, which has the lowest flexibility and the highest constructability, all cases show an increase in flexibility and a decrease in constructability. The modified MDB structure has better general performance (defined as a weighted sum of flexibility and constructability) than the regular MDB structure, except for case #1.

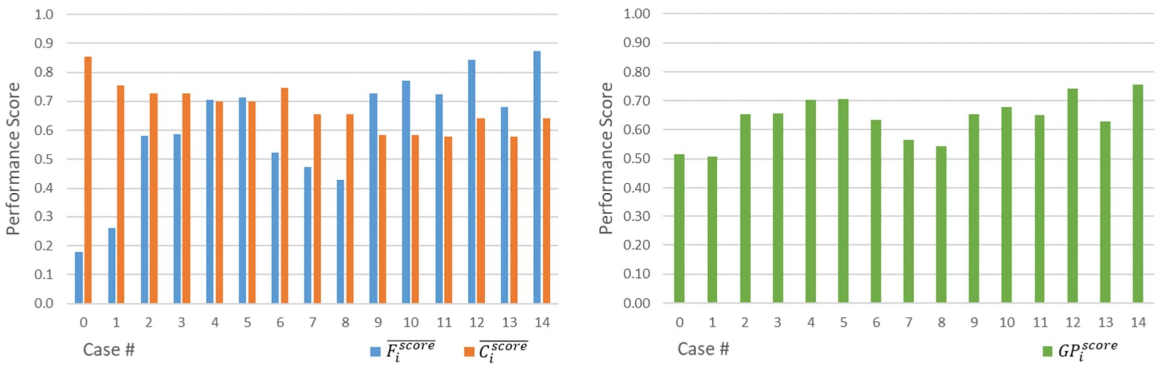


Figure 5. Flexibility, Constructability, and General Performance Scores

Figure 6 shows all measure scores of every case and compares them with that of reference case #0. One can conclude that modifying some SLE units impacts flexibility in most cases except for expandability (F02) and ground floor efficiency (F05). This is somewhat expected since the regular SLE units of case #0 have only one degree of freedom, and replacing them with units that have more than one degree of freedom should bring flexibility into the design. However, the presence of modified SLE units significantly decreases the measures related to the installation process (i.e., erection time, C08, and installation procedure, C09). Materiality (as measured by joinery complexity, C02), fabricability (modularity, C03), and transportability (weight, C06) are also slightly decreased.

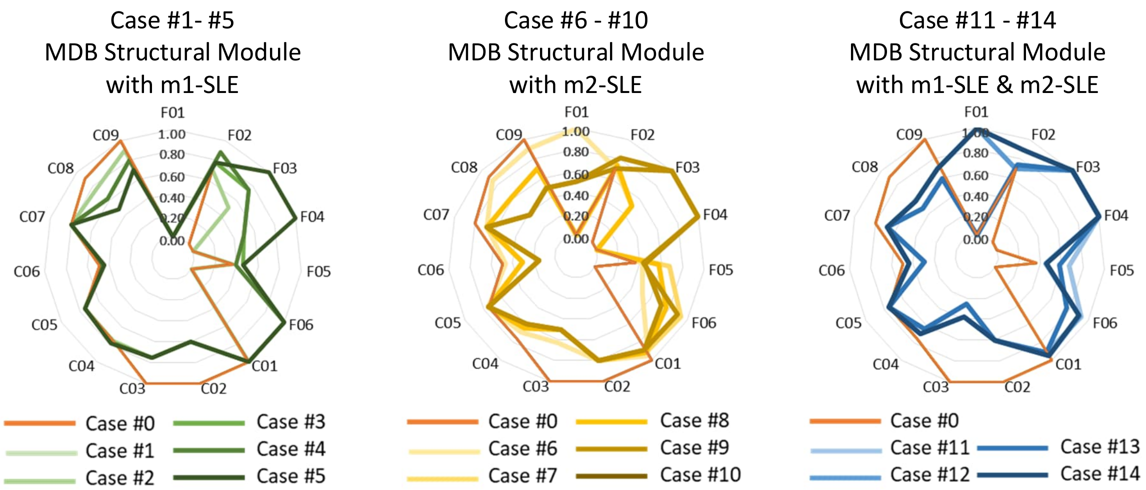


Figure 6. Flexibility and constructability measure scores of all cases

Based on Figure 5**Fehler! Verweisquelle konnte nicht gefunden werden.**, the most flexible is case #14 (FPS = 0.87), which is composed of two m1-SLE units and one m2-SLE unit. Compared to case #0, the structure can improve flexibility by significantly increasing arrangeability, shape-changeability, reconfigurability, and mezzanine possibility. Cases #9, 10, 11, and 13, which are composed of at least two m2-SLE units, have the lowest constructability performance (CPS = 0.58) since, as shown in Figure 6**Fehler! Verweisquelle konnte nicht gefunden werden.**, the modification of SLE decreases joinery complexity (C02), modularity (C03), erection time (C08), and installation procedure (C09), compared to case #0 (CPS = 0.85).

4.2 Pareto Analysis

The normalized flexibility score ($\overline{F_i^{score}}$) and the normalized constructability score ($\overline{C_i^{score}}$) are used in a Pareto multi-criteria analysis to identify the tradeoff between flexibility and constructability. Hunt et al. [26] defined a feasible design $x^* \in X$ as a Pareto efficient design if there is no other $x^1 \in X$ such that $f_i(x^1) \geq f_i(x^*)$, for all $i \in \{1,2\}$, with $f_i(x^1) > f_i(x^*)$ for at least one $i \in \{1,2\}$. If $x^* \in X$ is Pareto efficient, then the corresponding outcome $y^* = f_i(x^*) \in Y$ is called Pareto nondominated. Compared to the reference case #0, the tradeoff at outcome y represents the amount of decay in constructability required to gain one unit of improvement in flexibility.

In Figure 7, the horizontal axis corresponds to the flexibility score while the vertical axis is the constructability score. When placing the 15 cases on the graph, the tradeoff becomes apparent. The overall goal corresponds to maximizing both flexibility and constructability, which means that the points that are closest to the top-right corner of the graph would be preferred. More specifically, the points that are highlighted by the red line, also known as the Pareto line, are the cases that have the highest general performance. When compared to each other, these points are considered "non-dominated" since they are no other points that improve both flexibility and constructability simultaneously [26]. All other points (which are not on the Pareto line) are considered "dominated" since there exist cases (on the red line) that improve both flexibility and constructability.

Compared to case #0 (used as the reference for all comparisons), case #1 includes a m1-SLE unit at the top of the structure, which, as expected, increases flexibility. However, the significant loss in constructability makes this case undesirable. Interestingly, adding three m1-SLE units, as in case #5, increases flexibilty significantly at the point of justifying the loss in constructability. The Pareto line in Figure 7 shows that the optimum cases are #0, #6, #3, #5, and #14. Some dominated cases are near the Pareto line, such as cases #2, #4, and #12. It can be noted that: (1) Placing a m2-SLE unit at the top of the structure provides greater flexibility and constructability than at the other locations, based on case #6 and compared to cases #7-#10; (2) Placing two m1-SLE units at the bottom (as in cases #3, #5, #14) or the middle (as in cases #2, #4, #12) of the structure leads to greater flexibility without losing much constructability; (3) Placing a m2-SLE unit at the top combined with two m1-SLE units at the bottom (as in cases #12 and #14) achieves the greatest flexibility performance; and (4) Overall, adding modified SLE units (m1 and m2) increases flexibility up to 0.70 points while decreasing constructability only up to 0.28 points, which is sufficient to justify the use of modified m1- and m2-SLE units compared to the structure made exclusively of regular units (case #0).

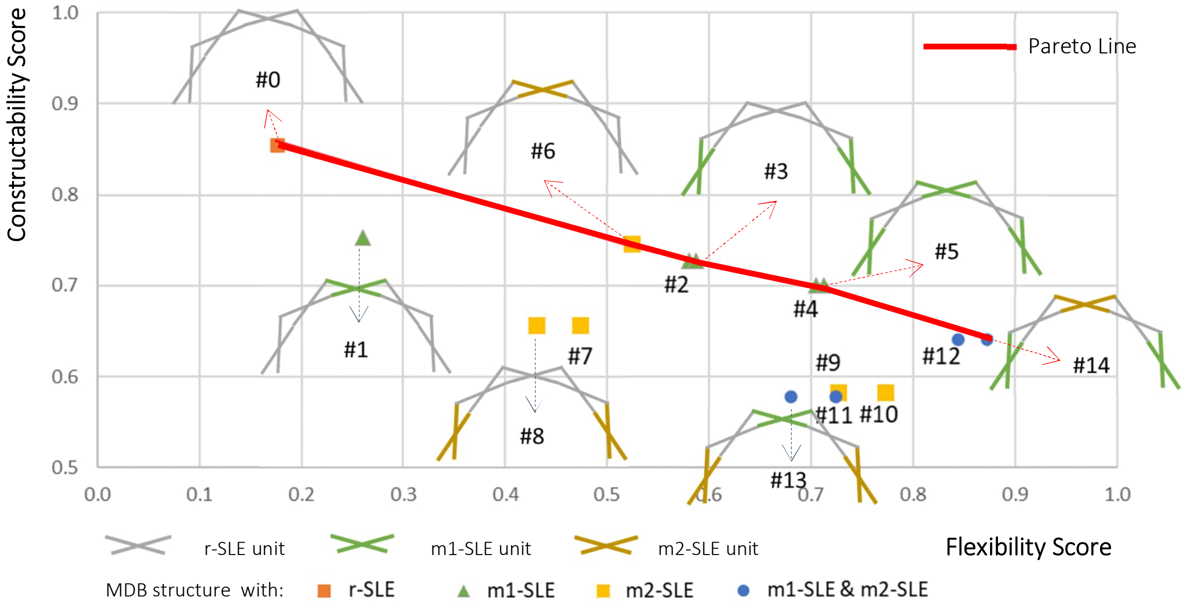


Figure 7. Pareto Analysis

4.3 Comparison of Highest-Flexibility Case to Reference Case

In the previous section, the non-dominated cases (on the Pareto line) #0, #6, #3, #5, and #14 were highlighted and considered as preferred designs. In this section, the case with the highest flexibility (case#14) is compared to the reference case (case#0) in more detail. Case #14 improves the flexibility by 0.70 points. Using a m2-SLE unit at the top of the structure splits the module into two identical and independent half-modules (see Figure 8) , which cannot be done with the r-SLE and m1-SLE units. Therefore, case #14 is significantly more flexible in arrangeability (F01). As a result and as shown in the row labelled F01 of Table 5, the structural modules can be arrayed in linear, centralized, and cantilever arrangements with case #14 as opposed to only the linear arrangement with case #0. Other significant improvements in flexibility include: shape-changeability (F03), which means that case #14 has more variants with symmetric and asymmetric configurations; reconfigurability (F04), which means that case #14 can create different shapes and space with the same pedestal position; and mezzanine possibility (F06). Interestingly, expandability (F02) and ground floor efficiency (F05) increase only slightly.

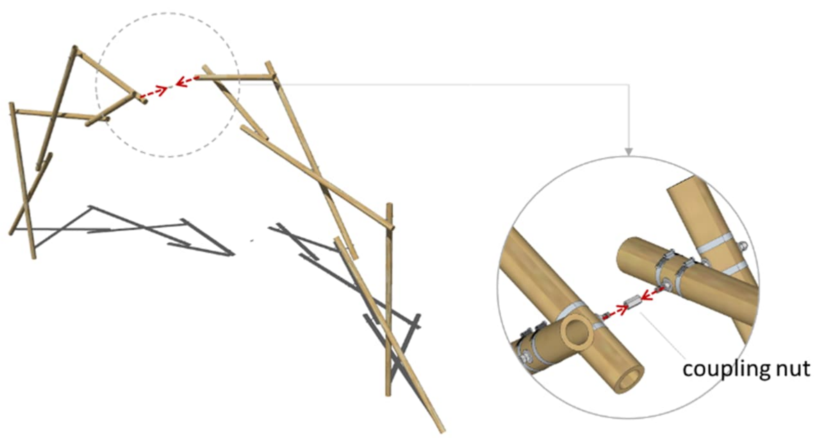
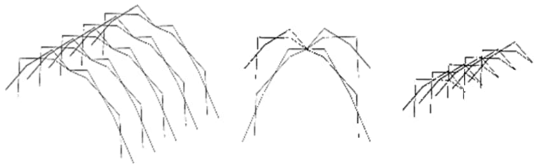
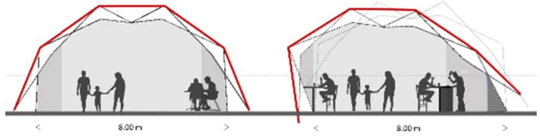
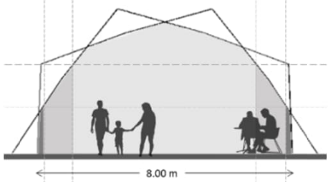
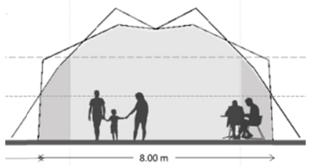
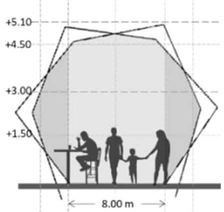
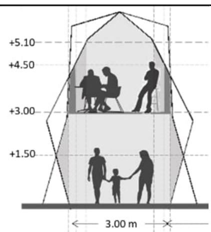


Figure 8. Splitting a structural module to two identical and independent half modules

Table 5: Comparison of the flexibility of Case#0 and Case#14

Code	**Case #0**	**Case #14**
F01	 Linear arrangement	 Linear, centralized, and cantilever arrangement
F02	 Span$_{max}$ = 9.50 m	 Span$_{max}$ = 10.00
F03	None	 Symmetry and asymmetry configuration
F04	None	 Two examples of different configurations without changing the pedestal
F05	 Ground floor efficiency = 68.06%	 Ground floor efficiency = 72.68%
F06	 No Mezzanine Possibility	 Have a mezzanine possibility Mezzanine floor efficiency= 89.90 %

The previous paragraph focused on the flexibility of case #14, which increased by 0.70 points compared to the reference case #0. This paragraph focuses on the constructability of case #14, which decreased by 0.21 points. As shown in Table 6, the most impacted measure is modularity (C03), which, as described in Table 3, quantifies the number of bar and connection variants in the structural module. Increasing from one bar variant and one connection variant (as in case #0) to four bar variants and three connection variants is a detriment since it requires signicantly more effort. Joinery complexity (C02), erection time (C08), and installation process (C09) worsen considerably as well. In terms of joinery complexity (C02), case #14 has two more connection variants: translatable pin connection with two degrees of freedom, and 4-bar pin connection with one degree of freedom, as listed in Table 6 and illustred in Figure 9. Installing a single case #14 structural module needs greater erection time (C08) and a more complex installation process (C09), as described in Table 6 and also illustrated in Figure 10. The other measures, i.e., bamboo efficiency (C01), fabrication time (C04), fabrication process (C05), weight (C06), and compactness (C07), worsen slightly.

Table 6: Comparison of the constructability of case #0 and case #14

Code	Case #0	Case #14
C01	Bamboo efficiency = 100% (bamboo length = 3.0 m)	Bamboo efficiency = 92.8% (bamboo lengths = 3.0 m, 1.5 m, 1.7 m)
C02	Joinery complexity = - 2-bar pin connection (2 bars, 1 DoF)	Joinery complexity = - 2-bar pin connection (2 bars, 1 DoF) - 4-bar pin connection (4 bars, 1 DoF) - Translatable pin connection (2 bars, 3 DoF)
C03	1 bar variant and 1 connection variant	4 bar variants and 3 connection variants
C04	Fabrication time = 210 minutes	Fabrication time = 229 minutes
C05	Groundwork with power tools	Groundwork with power tools
C06	Weight = 63.19 kg	Weight = 67.33 kg
C07	L + W + H = 441 cm	L + W + H = 463 cm
C08	Erection time = 25 minutes	Erection time = 65 minutes
C09	Installation process with only handy tools and three steps: - Set the two bamboo poles of one end of the structure to one pedestal - Deploy the structure - Set the other two bamboo poles of the other end to other pedestal	Installation process (see Figure 10) with only handy tools and five steps: - Set the two bamboo poles of one end of the structure to one pedestal - Set the other two bamboo poles of the other end to the other pedestal - Deploy the two half structural modules - Set the 4-bar pin connection at the top - Set the two translatable connections

Figure 9. Connections (from left to right): 2-bar pin connection, translatable pin connection, 4-bar pin connection with screw, 4-bars pin connection with plate (for linear arrangement), and 4-bars pin connection with plate (for centralized arrangement)

Figure 10. Installation (from left to right): setting pedestal, linking up 4-bar pin connection, setting translatable pin connection, and final configuration

5 Conclusion

Combining computational modeling and physical prototyping is advantageous to have a comprehensive understanding of the structure's performance, specifically for flexibility and constructability. Likewise, incorporating weighted sum analysis and Pareto analysis to optimize many variables can help explain the tradeoff between performances and to define the optimum use of modified SLE units. Conclusively, this study finds that modifying an SLE unit or more improves the flexibility of the MDB structure with relatively small loss in constructability. Two m1-SLE units at both bottom sides of the structure are preferred over one unit at the top of the structure; and one m2-SLE unit at the top of the structure has better performance than at other locations. Combining m1-SLE at both bottom sides and m2-SLE at the top of the structure has the greatest overall performance among all studied cases. This study reinforces the previous research on deployable structures for achieving flexibility and enriches it by contrasting with constructability. The research can be expanded by performing structural optimization, adding the number of SLE units in one structure, analyzing other SLE modifications, and varying the weights of all measures in the weighted-sum analysis.

The designer can use this finding and the performance scoring method to design and evaluate a modified modular deployable structure and apply it to vulnerable communities. This study broadens the opportunity of using deployable structures. Modular deployable bamboo structures also achieve sustainability at three level: material level by using local renewable materials, component level by developing reconfigurable elements, and structure level by providing flexible structures. Therefore, using modular deployable bamboo structures is valuable as they provide the ability to adapt to the needs and changes of various communities.

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FROM INDUSTRY TO INDUSTRIAL HERITAGE. QUALITATIVE INDICATORS IN SUSTAINABLE RENEWAL PROJECTS. RESEARCH STUDY IN SOUTHERN ITALY

Pasquale Cucco

Department of Civil Engineering, University of Salerno
Via Giovanni Paolo II, 84084 Fisciano (Sa), Italy; pcucco@unisa.it

Abstract

Southern Italy is rich in examples of industrial archaeology, that contribute to the creation of the industrial urban landscape emerged from the Eighteenth century and testify the process of transformation of both environment and society. The transition from industry to industrial heritage represents a breakpoint in appreciating the potential of these works, in the awareness of achieving sustainable development goals and reducing the consumption of resources. The recovery of abandoned factories represents a unique opportunity to rethink new and improved urban, social, economic, and cultural strategies. Certainly, it is not possible to pay the same attention to all the former industries of the Twentieth century, but there is a need for a primary selection by starting from a more comprehensive reflection. This paper intends to propose a methodology of analysis and action in any architectural and urban recovery and regeneration programs, evaluating all the aspects involved in recovery projects. This approach includes qualitative parameters of protection and development, to obtain more efficient and sustainable solutions. In this context, every project on the former factories allows both to rediscover the dynamic vocation of cities and to understand the historical-artistic value of such buildings crystallized in the not-too-distant past.

Keywords

Industrial Heritage, Sustainability, Reuse, Conservation.

1 Introduction

Southern Italy is rich in industrial architectural relics dating back to the period between the 19th and 20th centuries. These years were characterized by technological and scientific advances, by the important industrial innovations that have destroyed the craft world so dear to previous centuries; they are dominated by new economic systems and new centres of power [1]. Industrial Revolutions have radically changed people’s life and conditioned their relationships, desires, and landscape, by expressing the modern sense of industry capable of changing the community. The highest speed of this period leads to sudden changes of direction and to the gradual abandonment of the old factories, not capable of keeping up with progress. These buildings are evocative of an industrious community’s rhythms, sounds and

colours now disappeared. It's a social disintegration phenomenon, even before material, that invested many industrial settlements, with significant repercussions on the cities and territories. The concept of modern industry finds its roots in Western Europe, especially in the second half of the Nineteenth century, when Britain became the leader of the first industrial revolution. In the next century, with the decline and transformation of traditional industry, European countries entered the post-industrial era and began actions toward the protection of their industrial heritage. Europe's industries contribute substantially to the continent's prosperity. Some regions have had an industrial character for centuries, adapting themselves repeatedly to wider changes in industrial production patterns. From the second half of Twenty century, the industry underwent constant transformations induced by technical and organizational innovations such as new production systems, steam engines, electrification, mass production, automation, digital transformation. The transition from industry to industrial archaeology begins, recognizing in factories material and immaterial values to be protected and handed down, as well as the possibility of a rebirth of entire territories.
The term "industrial archaeology" was coined in England in the fifties and used in Italy for the first time during the work of the *International Meeting*, held in Milan in 1977 [2]. In the same years the "Italian Society for Industrial Archaeology" was formed. Over the years, there were several definitions: Kenneth Hudson wrote a solid starting definition for the following studies: «Industrial archaeology deals by discovering, cataloguing and studying the physical remains of the past industries» [3]; Buchanan described industrial archaeology as «a field of study that investigates, surveys, records and, in some cases, preserves industrial monuments; its objective, moreover, is to evaluate the significance of these monuments in the social and technological context» [4].
Today the terms "industry" and "industrial heritage" constitute the support of the so-called "industrial culture", made up of tangible and intangible assets: factories conceived as stately buildings, craftsmanship, and engineering skills, entrepreneurial masterminds, production processes, machinery, and know-how. Industry, industrial heritage, and industrial culture are truly European themes aimed at achieving SDGs; in fact, industrial culture supports integrated and sustainable development in the European regions by making them more creative places to live and work. Recovery and conservation, therefore, become an opportunity to rethink not only individual buildings but entire urban contexts, according to the social dynamics, economic characteristics, and cultural values of a city. It's necessary to analyze and preserve the signs of the industrial revolutions because of social, economic, and architectural experiments. Human work, from the 18th to the 21st century, radically changed producing a lot of "relicts", in need of protection, valorization, and recovery. In Italy, the debate about the reuse of disused areas dates back to the eighties and it developed in three phases: in the eighties, institutions and experts began to be interested in the vastness and complexity of the so-called "big urban gaps"; in the nineties, a new season begins in according to the idea that the degraded urban areas were a resource for renewing cities; in the new millennium, to the abandoned areas was assigned the definition of "action catalysts" for their central role in the overall urban revival. In recent decades, the deindustrialization phenomenon was very strong, and the voids left by factories became a problem rather than an opportunity [5-6].
The recovery of the abandoned buildings with the attribution of new functions useful to the contemporary community involves the creation of new communication paths, new areas of aggregation, new destinations, so the building can represent again a pole of attraction for the present and the future. The design of new squares, of modern green and urban routes, represents a fundamental step in the creative process. A greater projecting impulse is needed

to intervene courageously in historicized environments that risk remains clinging to a past that no longer exists, destined to crumble even materially. Regenerating buildings necessarily leads to rethinking the city, to guarantee the social welfare of its inhabitants and users. In fact, there is a close link between the quality of the town and its social, cultural, and economic development [7]. The European and Italian experiences show how these areas can become real “experimentation workshops" (social and cultural centers, poles for art and music, etc.). However, the success of the industrial area redevelopment is not ensured exclusively by a recovery project, but it strongly depends on their level of integration with the city and on their ability to create a tourist, cultural, economic, and social impact. In fact, the design basic principles are not only those relating to architectural and structural retraining but also those regarding economic sustainability, environmental impact, or integration with the surrounding urban areas [8]. However, the recovery and revitalization processes must be guided by prudent and compatible criteria that are able to reconcile the various aspects involved in a single methodological path.

In this scenario, the paper intends to define some qualitative indicators which, like quantitative data, can direct towards more compatible interventions on pre-existing structures. These indicators are generated in accordance with the Quality Principles drawn up by ICOMOS and EU, published in the doctrinal document ICOMOS “European Quality Principles for EU-funded Interventions with Potential Impact upon Cultural Heritage”, revised in 2020. These Q-Indicators must be taken into consideration during an industrial heritage restructuring project. In a first schematization, they can be divided into 2 levels and, therefore, two methodological phases:

1. Qualitative indicators useful in recognizing the importance of industrial buildings. If these indicators are satisfied, it means that the work represents a material asset to be protected and included in a renewed recovery program that should respect the second category of qualitative indicators.
2. Qualitative indicators that can guide the professional to consider the entire complexity of this type of heritage and, therefore, to propose projects compatible with the architectural, social, economic, and environmental values that the artifacts still maintain.

2 Qualitative Indicators

Since UNESCO and the Council of Europe are the most prominent international governmental organizations, this research fits in the framework of the doctrinaire documents by UNESCO, ICOMOS, and TICCIH.

The qualitative indicators are some of the parameters that mostly concern the industrial heritage worthy of being protected, preserved, and passed to future generations. These parameters correspond to some open questions on this heritage.

The qualitative indicators try to “measure” the performance of the renovation processes of buildings and sites and represent fundamental tools to understand if the operations on the built heritage reconcile quality principles so that the processes generate the expected results or if there is a need to improve. The set of indicators will be like focus on the performance of programs and projects compatible with the tangible and intangible characteristics of the artifacts and their systems. This set allows professionals and administrations or protection entities to ensure prudent projects and to identify those indicators that need more attention. The main difficulty is in measuring parameters that are difficult to quantify. However, it is necessary to organize a set of indicators useful for managing built-up processes that are also able to respond to the current needs of sustainable development (SDGs no. 11. Sustainable cities and communities, Target 11.4 “Strengthen efforts to protect and safeguard the world’s cultural and natural heritage”).

List of qualitative indicators of 1st Level (Figure 1):

1. *Example of technological, architectural, and structural innovation and creativity.* Styles, forms, construction technologies, daring engineering and architectural solutions, new construction methods, experimental materials, construction techniques, furnishings, and finishes, represent unique values in the history of buildings to be preserved and passed on to the future in their entirety.
2. *Example of economic or social developments.* Industrial buildings represent political, social, economic, and cultural development of each country, providing a precious contribution to the progress and well-being of cities and populations.
3. *Landmark* . The uniqueness and the exceptionality of the buildings, as well as their ability to survive over time, have produced real urban landmark full of “meanings”.

List of qualitative indicators of 1st Level *Is the industrial building a significant work to be protected, recovered and revitalized?*	Yes	Not
Is the industrial building a clear example of technological, architectural, and structural innovation and creativity?		
Is the industrial building an example of economic or social developments?		
Does the industrial building represent a clear and recognized landmark in the territory in which it is located?		
Specify		

Figure 1. Qualitative indicators of 1st Level.

List of qualitative indicators of 2nd Level (Figure 2):

1. *Location, territory, and social links.* Industrial structures tend to be concentrated in the more peripheral urban areas, giving a significant boost to the construction of road, railway, territorial infrastructures, etc., with the generation of new expanding production districts. Smaller industrial buildings in built-up areas are not uncommon.
2. *Architecture and Image*. The architecture and the structure represent essential data in the recovery project. Historic industrial buildings often do not have aesthetic appeal like other types of historic buildings, but their image must still be preserved and, if necessary, improved with compatible interventions.
3. *Flexibility and Adaptability.* Many former industrial buildings are flexible, by virtue of the large spaces that distinguish them. However, they often tend to be hardly adaptable to new uses, being built to a special shape and for a specific purpose that is no longer needed. The original functional destination makes it possible to operate simple solutions depending on the degree of complexity and the state of conservation: for example, textile plants tend to be more easily adaptable, while buildings for chemical works are particularly problematic.

List of qualitative indicators of 2nd Level *Does the recovery project take into account essential qualitative parameters?*	Yes	Not
Does the project pursue the preservation of authenticity of the industrial building?		
Does the project respect the dimensions, proportions, spaces, original characteristics?		
Does the project respect the original construction tradition?		
Does the project prefer repairs rather than heavy transformation?		
Does the project seek a balance and harmony between the existing and the new?		
Is the project well proportioned?		
Does the project generate flexible spaces?		
Is the new intended use compatible with the architecture and structure?		
Does the project generate new public benefits?		
Does the project respect and enhance the environment in which it is inserted?		
Specify		

Figure 2. Qualitative indicators of 2nd Level.

3 Research study in South Italy

In this section, 2 case studies belonging to the industrial heritage in southern Italy (in the Campania region) will be analyzed: ex Cirio factory, Paestum; former Marzotto factory, Salerno. These are disused industrial buildings, but which represent typical examples of a very fervent construction, economic and social season in Italy, contributing to the development of the resources and well-being of an entire territory.
The historical profiles of the two factories will be briefly presented, also thanks to historical graphics and images, then the analysis of the qualitative indicators will be applied and, finally, a possible recovery project will be proposed.

Case 1: Former food Factory Cirio, Paestum
The food Cirio factory was built in 1908 within the archaeological area of Paestum but it began production only in 1935. During the construction, some ancient structures came to light. In the fifties of the Twentieth century, other archaeological excavations were carried out on an expansion of the plant. The archaeological remains are of an ancient sanctuary dedicated to Venus [9]. However, despite the findings, the Cirio factory continued its work until the 1980s,

when it was definitively closed. The building, made up of several buildings side by side, is very close to the temples and Greco-Roman ruins and it is an example of “modern ruin” (Figure 3). During the Second World War, was occupied by American troops who landed on the shores of Paestum in 1944, and it was used as a military base, using the opposite area as a park for vehicles (Figure 4). The production resumed in 1946 and continued uninterrupted until 1987 when a profound economic crisis will lead to the permanent closure of the factory, almost simultaneously with the closing of the other Campania plants situated in Castellammare, Pontecagnano and Pagani. After its closedown in 1987 and the sale of the production machinery, the factory was bought by private and since that moment it was abandoned to a state of decay. Only in 2009 was bought by the Archaeological Superintendence of Salerno.
In this plant is clear how the functional distribution is derived from the typical production cycle of food. The entrance located on the main road introduces the inner square used for the unloading of goods [10]. The original structure of the factory, represented by the block on the street, consists of masonry in local limestone, typical of Paestum, of regular size, slightly hewn. Some subsequent inserts are in reinforced concrete. The vaulted and flat roofs show typical details of the construction tradition of the early Twentieth century. The main deterioration is due to the abandonment and consequently to the exposure and growth of the vegetation, to the static instability of the walls, to the breaking of the roofs. Also, for the two warehouses added in the 1960s consisting of two curved metal trusses, the main cause of degradation is represented by exposure to atmospheric agents that led to the oxidation of the iron and the loss of material.
The recovery proposal envisages assigning the Cirio factory to a building for art, music, and entertainment, retracing the common thread of the artistic value that has so characterized the previous centuries and of which Paestum is a tangible example. The Greek and Roman arts that are so celebrated in classical temples translate into contemporary arts within the industrial building. The function aims to allow you to admire the ancient ruins inside (Figures 5-6).

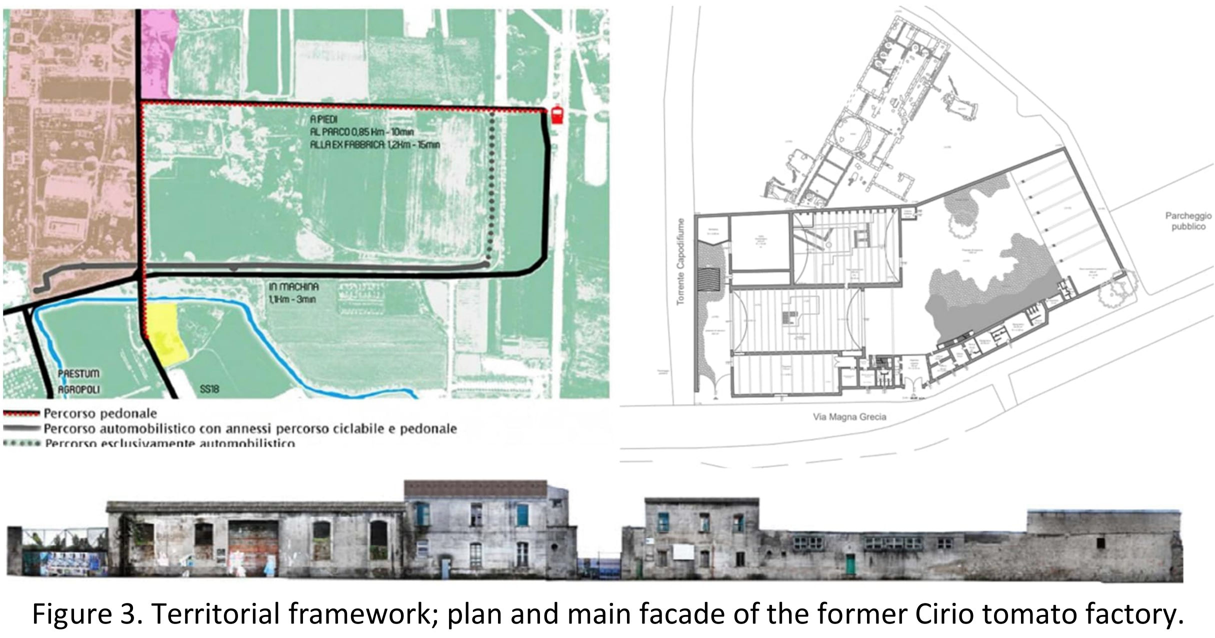

Figure 3. Territorial framework; plan and main facade of the former Cirio tomato factory.

Figure 4. Historical images of the Cirio factory Source: Association Agorà, Capaccio.

List of qualitative indicators of 1st Level *Is the industrial building a significant work to be protected, recovered and revitalized?*	Yes	Not
Is the industrial building a clear example of technological, architectural, and structural innovation and creativity?	✓	
Is the industrial building an example of economic or social developments?	✓	
Does the industrial building represent a clear and recognized landmark in the territory in which it is located?	✓	

List of qualitative indicators of 2nd Level *Does the recovery project take into account essential qualitative parameters?*	Yes	Not
Does the project pursue the preservation of authenticity of the industrial building?	✓	
Does the project respect the dimensions, proportions, spaces, original characteristics?	✓	
Does the project respect the original construction tradition?		✓
Does the project prefer repairs rather than heavy transformation?	✓	
Does the project seek a balance and harmony between the existing and the new?	✓	
Is the project well proportioned?	✓	
Does the project generate flexible spaces?		✓
Is the new intended use compatible with the architecture and structure?	✓	
Does the project generate new public benefits?	✓	
Does the project respect and enhance the environment in which it is inserted?	✓	

Figure 5. Check of Qualitative Indicators.

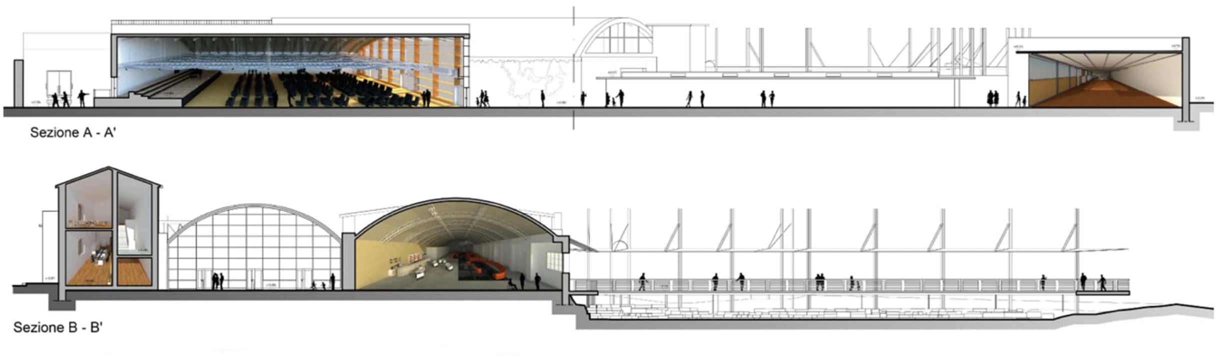

Figure 6. Project sections, Hall for arts and Theatre.

Case 2: *Former textile Factory Marzotto, Salerno*
Lanificio Marzotto was born in Valdagno in 1836 as a small wool company that, handed down from father to son, continued to grow thanks to constant investments, expansions, and technological renewals. In the 1950s the Marzotto company began investing in the South, encouraged by the benefits it could acquire. La Marzotto-Sud s.p.a. was established in January 1958 thanks to a loan from Isveimer and BIRS3, as part of the expansion program that the company started in those years [11]. The Salerno area had all the prerequisites for the development of a real industrialization pole: as part of the policy of extraordinary

intervention, Salerno was indicated as the pilot center for the birth of new plants, and a hinge city between the North and the South of the country [12] (Figure 7).
The architectural composition of the complex is divided into several buildings, connected to each other by a series of arcades: the main production shed; the office building; the thermal power plant; services reserved for workers, canteen, cafeteria, changing rooms, infirmary. In the Seventies, it suffered a serious economic crisis that led it to close definitively in 1983. The Marzotto-Sud plant is still today one of the thorniest issues for Salerno, so much so that in the governance of the territory it is almost neglected as a clear testimony of material and immaterial history for the city and the entire population. The plant has been in disuse since 1983, today the plant is in a state of total abandonment and some imprudent demolition works are underway (Figure 8).
However, it is still possible to recognize the main characteristic aspects of industrial buildings: the frameworks in reinforced concrete, the brick infill walls, the shed roofs, the typical oversized dimensions of the industrial space. The complex, which follows the typical scheme of the time, presents the main shed as the fulcrum of the entire work, in a central position within the lot, it is set on a regular plan with sides 140.00x156.00 m, with a front north-west back and facing towards the railway tracks, the north-east side is separated from the driveway with a difference in altitude of 9.30 m, while the south-east side is directly connected to the plant body and, through the portico, to the service building; finally, the south-west side overlooks the internal square where the crumbling canopies covering the workers' car park still stand [13].
The re-qualification proposal intends to recover the original destination of the textile industry with the aim of producing ecological fabrics starting from the recycling of plastic bottles. In Italy, there are very few industrial complexes dedicated to the production of fabrics deriving from recycled plastic material. The project, in addition to being attentive to environmental emergencies in progress, minimizes the impacts during the construction process and preserves the original compositional ideal of the factory, its constructive elements and its architectural intuitions (Figures 9-10).

Figure 7. Historical images of Marzotto factory and current state.

Figure 8. Current state of decay.

List of qualitative indicators of 1st Level *Is the industrial building a significant work to be protected, recovered and revitalized?*	Yes	Not
Is the industrial building a clear example of technological, architectural, and structural innovation and creativity?	✓	
Is the industrial building an example of economic or social developments?	✓	
Does the industrial building represent a clear and recognized landmark in the territory in which it is located?	✓	

List of qualitative indicators of 2nd Level *Does the recovery project take into account essential qualitative parameters?*	Yes	Not
Does the project pursue the preservation of authenticity of the industrial building?	✓	
Does the project respect the dimensions, proportions, spaces, original characteristics?	✓	
Does the project respect the original construction tradition?	✓	
Does the project prefer repairs rather than heavy transformation?	✓	
Does the project seek a balance and harmony between the existing and the new?	✓	
Is the project well proportioned?	✓	
Does the project generate flexible spaces?		✓
Is the new intended use compatible with the architecture and structure?	✓	
Does the project generate new public benefits?	✓	
Does the project respect and enhance the environment in which it is inserted?	✓	

Figure 9. Check of Qualitative Indicators.

4 Conclusions

Industrial Culture is relevant for the performance and progress of local territory. Any recovery project of disused valuable industrial buildings contributes to achieving several goals such as conserve the material work and its architectural, technological, and compositional innovation; highlight the connection from the early industrial founders in the 18th and 19th century up to today’s success stories; revive the local entrepreneurial spirit and encourages people to care own history; create new spaces for creative pioneers and promote new cultural activities.
The recovery and reuse projects of the ancient buildings allow us to rediscover the dynamic vocation of the city and, at the same time, its ancient traditions, thanks to the regeneration of the artifacts with functions useful for the contemporary community. The recovery of abandoned buildings is a solid response to the revitalization of the whole city, avoiding that cultural heritage gradually dies with the decay of its architectural complexes.
Industrial culture offers the possibility of better coping with the economic and ecological transition, combining new opportunities with existing traditions, and it provides the right opportunities to support the architectural production of the past according to compatible and quality contemporary programs.

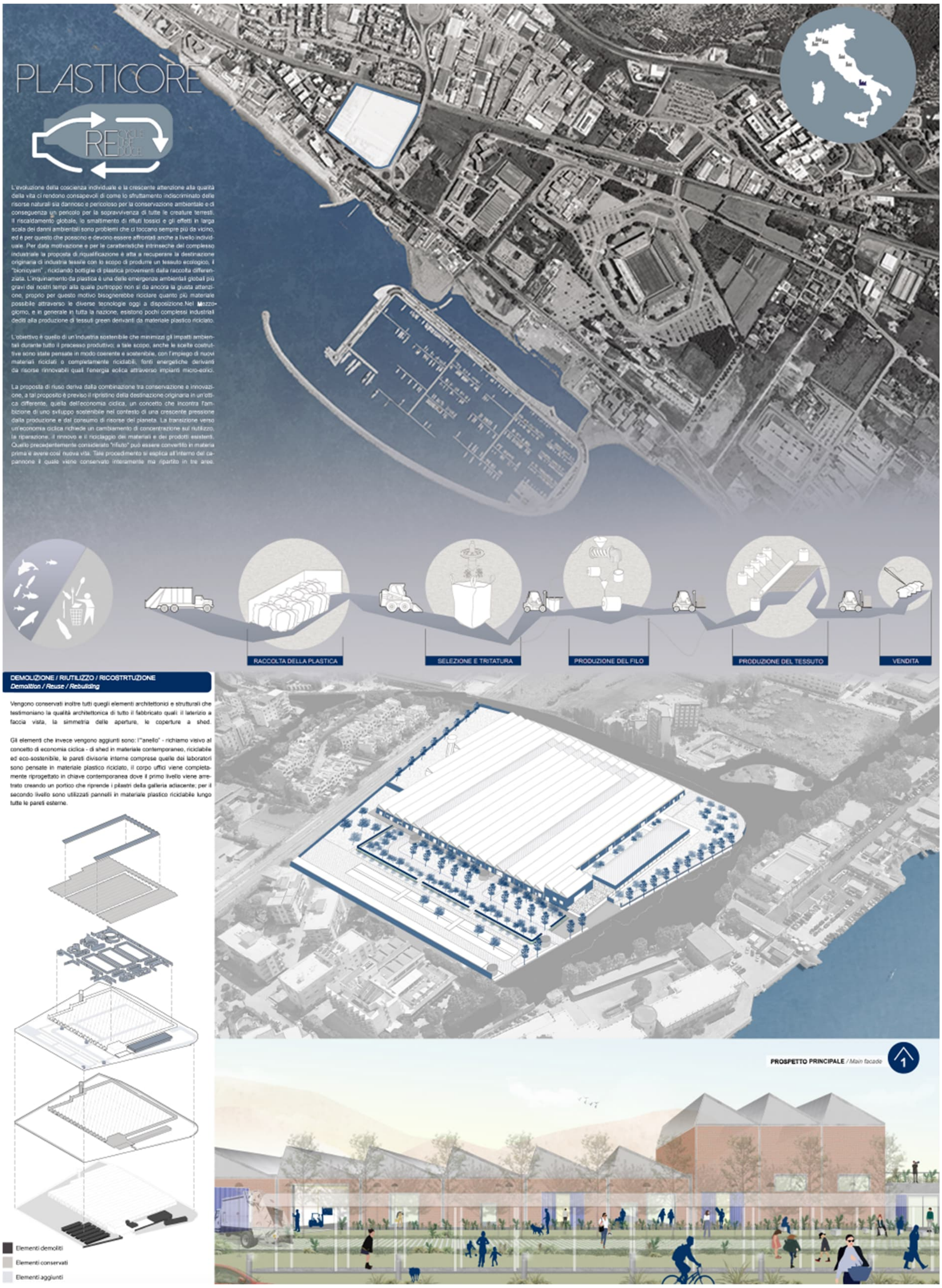

Figure 10. Recovery project proposal.

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A DATA-DRIVEN HYBRID LANDSCAPE INFRASTRUCTURE

*Sara Pezeshk, Shahin Vassigh
Florida International University College of Communication, Architecture + the Arts
11200 SW 8th Street, PCA, Miami, FL 33199, USA; * speze001@fiu.edu, svassigh@fiu.edu

Abstract

This paper describes a solution to protect the coastal areas from the impacts of climate change, including rising sea levels, extensive coastal erosion, frequent flooding, and depopulation of marine species. The paper presents a nature-based approach for designing a protective modular tile system to create resilient shorelines using digital technology, sustainable material, and innovative manufacturing techniques. Aside from preventing coastal erosion, the project aims to gather sediment, filter stormwater runoff, and promote biodiversity.

The methodology used for developing the tiles in the data-driven hybrid landscape infrastructure was a generative process that used an algorithmic workflow to incorporate multilayer environmental data sets, including solar radiation, water turbidity levels, and solar radiation. During the project development, several prototypes were produced using additive and subtractive manufacturing methods. Over time, these prototypes will be evaluated for long period of time for their resistance to wind and water pressures and their ability to reduce erosion rates and sediment collection while also improving the current microhabitat and supporting biodiversity in the current ecosystem.

Figure 1. Prototypes placed on the site.

Keywords

Data-driven Landscape, Nature-based Solution, Generative Design, Coastal Resilient Infrastructure, Biodiversity

1 Introduction

Climate change and sea-level rise are affecting marine life in coastal areas. Intense wave action caused by sea-level rise has increased coastal erosion, resulting in increased sedimentation, reduced water quality, elevated water acidity, and turbidity levels. Furthermore, increasing ocean temperatures have resulted in decreased oxygen levels in the water. All of this has resulted in habitat loss of numerous marine species and even the wading birds[1].

As coastlines are fundamental to human habitation, architects, landscape architects, eco-engineers, and biologists have been actively seeking to develop practical solutions to protect the shoreline, mitigate the impact of climate change on the ecosystem and contribute to environmental quality and experience. Thus, there are growing examples of interdisciplinary approaches that address coastal erosion. Hybrid infrastructures, which are a combination of built and natural systems, are considered one of the most innovative approaches for coastal protection and improvement of ecological resilience [2].

This paper describes a project designed to protect the coastal areas from the impacts of climate change, including rising sea levels, extensive erosion, frequent flooding, and depopulation of marine species. The project offers a sustainable approach for developing a protective modular system to create resilient shorelines using digital technology, sustainable material, and innovative manufacturing techniques. The paper will first discuss example projects with novel design approaches to infrastructure development that mitigate coastal erosion and increase the abundance and diversity of coastal ecosystems. It will then explain the project's primary objectives, followed by a description of the project and how environmental data has informed the design and the optimization process.

2 Nature Based Hybrid Infrastructure Systems

Hybrid infrastructure is a nature-based solution that integrates artificial (gray) infrastructure, such as riprap, and natural (green) infrastructure, such as salt marsh, mangrove, and seagrass. The International Union for Conservation of Nature defines nature-based solutions as measures that adaptively maintain, restore, and govern natural or altered ecological systems. NBS nature-based solutions promote sustainability values by providing positive environmental externalities such as increased biodiversity [3]. In addition, nature-based solutions are considered a resilient option for dealing with the environmental impact of extreme events such as floods, droughts, heatwaves, landslides, storm surges, coastal erosion, and other hydrometeorological hazards [4]. Furthermore, they facilitate the connection of city inhabitants to nature, which offers physical and psychological benefits and increased social connections and communal interrelation [5].
However, the majority of our existing coastal infrastructure and engineering solutions are considered ecologically unsustainable. They are mainly constructed with synthetic materials that discourage diverse biological assembly causing undesired and invasive species to predominate [6]. Eco-friendly solutions find a way to incorporate nature-based solutions that make the infrastructures more resilient and cost-effective [7]. The following paragraphs present an example of a nature-based project and a research report focused on enhancing biodiversity and preventing coastal erosion. These illustrate a framework and proof-of-concept for ecologically sensitive expansion and development of coastal areas.

The Seattle Waterfront, an eco-engineered project, was completed by James Corner Field Operations, a leading landscape architectural firm collaborating with several other design firms. This project is an excellent example of how infrastructure can bring back marine wildlife to the shoreline using a hybrid approach. Prior to the seawall construction, a pilot study was carried out to investigate how the material used for its construction impacted marine wildlife. The study examined the relationship between texture alteration and the expansion of microhabitats. For four years, a sequence of panels with two different textures of cobbled and smooth and three shapes of finned stepped, and flat one serving as control was set in the old seawall[8]. As expected, the preliminary findings showed that the textured treatment of the concrete seawall promoted microhabitats on the vertical surface. At the bottom, the sea-mattress provided additional habitat for marine wildlife [9]. In addition, researchers from the School of Aquatic and Fishery Sciences at the University of Washington located juvenile salmon swimming under the wooden piers along the shoreline after the wall was built in the year of 2017[10].

A comprehensive research project titled "Biodiversity: Which Interventions Provide the Most Ecological Benefit?" examines the efficacy of traditional eco-engineering methods and the environmental impacts of adding microhabitats into urban infrastructure. In this report, O'Shaughnessy et al. compared published studies between 1946 and 2016 using a quantitative meta-analysis and a qualitative review of 109 global projects [11]. The research focused on projects that introduced microhabitats to urban infrastructure during building or retrofitting in intertidal and subtidal coastal ecosystems marine areas. The results were catalogs and data analysis charts that showed the impact of various interventions on the abundance of habitat-forming species. These interventions included texture, crevices, pits, subtidal holes, low and high elevations, and soft structures that led to increasing species such as Barnacles, Bivalves, Branching Coralline, Sissle, Canopy Algae, and Coral [12]. Even while this study's findings showed that eco-engineering interventions increased the quantity and diversity of urban ecological communities, it is uncertain how much they offset the impact of replacing natural habitats with artificial ones. This project's information demonstrates how to develop a taxonomy of interventions and their impact on the abundance of flora and fauna.

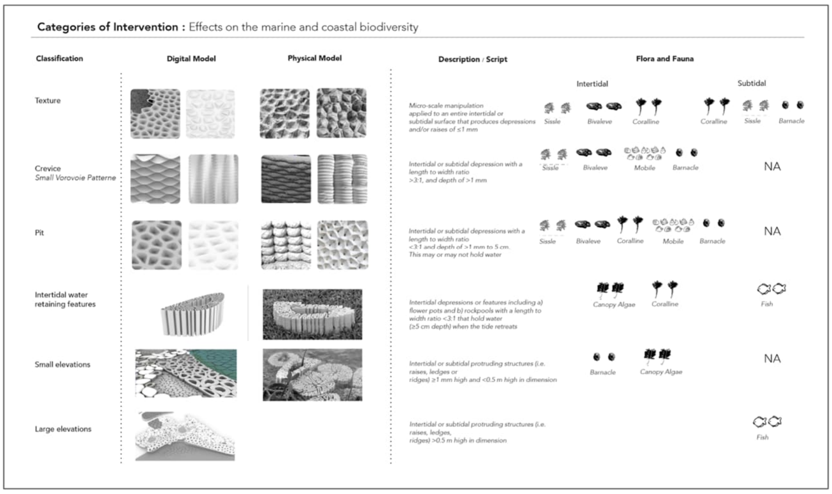

Figure 2. Categories of Intervention and effects on the marine and coastal biodiversity. The diagram is created the case study [13]

3 Project Description

Our project was an artificial landscape that consists of a series of modular components called bio-tiles that have structural and ecological. The following modular aimed to provide a nature-based solution to reduce coastal erosion in Miami's Biscayne Bay. The project's ultimate goal was to create a data-driven infrastructure using a responsive design to the environmental conditions. Another goal of the project was to develop a microhabitat for marine species to boost biodiversity in the coastal area. The project's design methodology was based on a generative algorithmic process that produced four different types of tiles listed below and shown in Figure 3:

1) Bio-rip tile, a solid textured concrete tile that works similarly to the riprap to slow erosion while encouraging the growth of microorganisms.

2) Bio-Pool tile, a hollow textured concrete tile, can control surface runoff and collect sediment comparable to a rockpool. In addition, this tile is designed to promote the abundance of intertidal species.

3) Bio-Pod tile, a hollow textured ceramic tile, with a pod in the center that houses mangrove seeds aiding their growth.

4) Seagrass blanket, an interlocking planter that accommodates seagrass to support restoration.

The first two types of tiles were developed with the primary goal of controlling erosion. We used optimization design methods that utilize microclimatic data such as solar radiation, storm surge depth, and turbidity level to design the tiles. The third and fourth tiles were designed to house living infrastructures such as mangroves, saltmarsh, and seagrass. The design of these tiles used topographical, hydrological, and geological information such as water flow, catchment area, and soil condition as described below.

Figure 3. All four bio-tile types -Bio-rip, Bio-Pool Bio-Pod tiles, Seagrass blanket, and the microhabitat associated with each tile.

Site Information: The project was initiated with a site visit. The site offered numerous levels of information which were incorporated into a multi-layered map. The map layers included information such as solar radiation, wind speed, water direction, water level, coastal erosion from U.S Geological Survey (USGS), Aeronautical Reconnaissance Coverage Geographic Information System (ArcGIS), and local Buoys (see figure 4). This map was imported into Rhino, a 3D modeling software to generate design algorithms for developing the bio tile's form and texture.

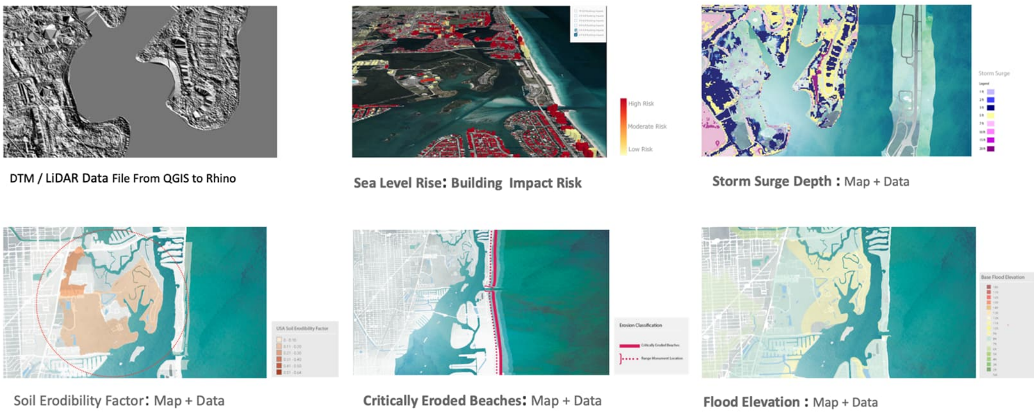

Figure 4. Data and map collection

3.1 Topography modelling

To generate a topography model, we used the LiDAR (Light detection and ranging) to transfer point cloud data into a 3D mesh surface in the rhino model (see figure 5). When compared to every other method we examined, this procedure created the best accurate contour 3D model. The vegetation and tree information were georeferenced to the topography using Land Design, a Rhino plugin. At the same time, the catchment boundaries were identified with a "Groundhog" Grasshopper plugin that helps to analyze landscape features. This analysis was driven by a topographic model of the site that identified spots on the land where water would most likely gather after rain to incorporate vegetation for water management strategies (see figure 5). This visualization helped us to designate and incorporate the mangroves, saltmarsh, and seagrass location within the Bio-Pods and seagrass blanket along with the site. This methodology aided in creating a hybrid solution by incorporating the natural features to mitigate and control surface runoff.

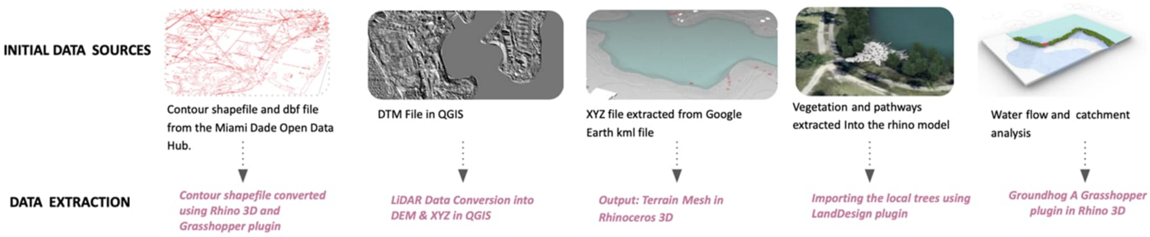

Figure 5. Workflows for terrain modeling through data extraction

3.2 Solar Radiation Data

We used solar radiation data to design and optimize an ecologically informed design for the Bio-rip tile. An important consideration was to increase thermal comfort for marine habitat along the intertidal zone. This process involved translating the solar radiation values found in the local weather (EPW climate) files into the project's algorithm using optimization plugins in Grasshopper (Wallacei combined with Ladybug) to maximize shading by optimizing the height of Bio-rap. In addition, the process included simulations that resulted in the height variation of tiles across the landscape to maximize the shading. The self-shading of the tiles lowers the temperature of the surface exposed to direct sunlight. Therefore, increasing the height of each tile to generate shading for the adjacent tile led to lowering the temperature at site and water and providing thermal comfort for the marine ecosystem.

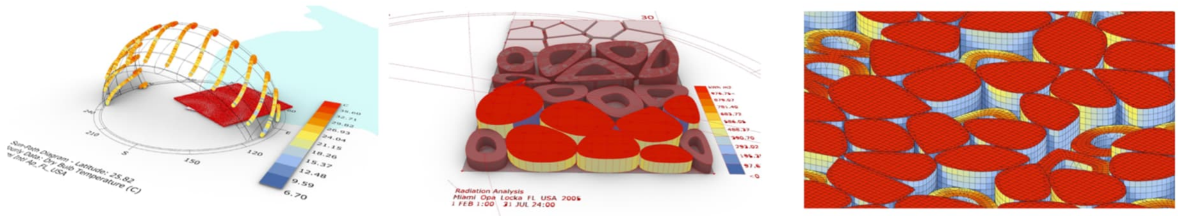

Figure 6. Using Multi-objective Evolutionary Algorithm to reduce the solar radiation

3.3 Storm surge data

Bio-tile's maximum height was governed by the storm surge data to reduce the impact of waves. We used maps from the Storm Surge Simulator developed by the National Oceanic and Atmospheric and Administration (NOAA) to determine the maximum height. These maps have color-coded overlays that represent the storm surge depths. The color-coded maps were then transferred into a 3D model for identifying high-risk zones in three dimensions (shown in figure 6). The color-coded overlay model allowed us to decide where to place various types of bio-tiles across the designated site.

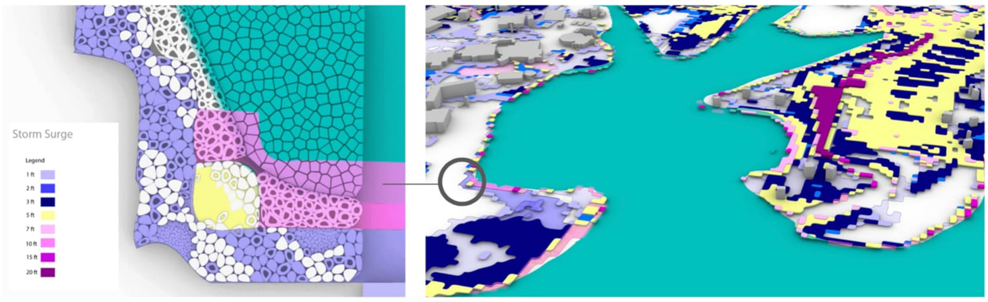

Figure 6. Bio-tile placement base on the Storm Surge 3D Diagram

3.4 Water turbidity level

Turbidity is a measure of water clarity. High turbidity indicates that many particles are suspended in the water, and light cannot get through. The turbidity of the coastal region contributes to sediment accumulation, leading the turbidity level to rise, posing severe challenges for aquatic ecosystems. In some cases, coastal turbidity occurs with the resuspension of fine sediments deposited in nearshore coastal waters following floods (Bartley et al., 2014)14.

We used turbidity data to develop the Bio-pool tile slope to control surface runoff and collect additional sediment. This approach lowers the turbidity level by filtering out the water and keeping the particles inside the bio-pool. In addition, turbidity data allowed us to optimize the design of the tile. The design algorithm optimized the form of the tile with slants ranging from

10 to 20 degrees. As a result, tiles with more slants would be placed in locations closer to the water edge (shown in figure 7).

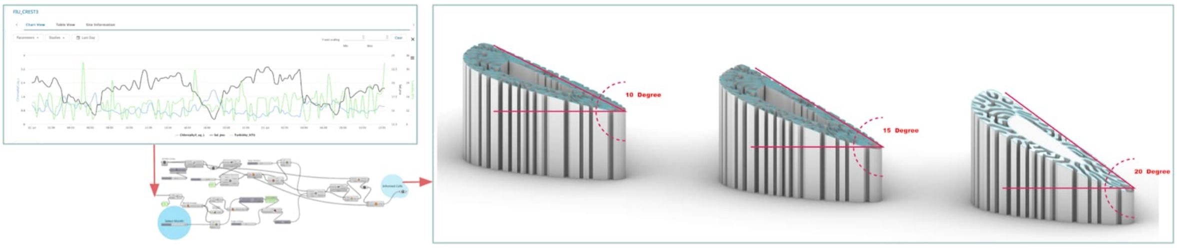

Figure 7. Bio-pool formation and optimization

3.5 Texture formation

This project's surface creation and texture dimension were based on the findings and data analyses from the research report described earlier. The two main patterns used for the surface development of the tiles were inspired by the fossil patterns of native corals, including the Voronoi pattern inspired by honeycomb coral and the reaction-diffusion pattern inspired by brain coral (shown in figure 8).

These two patterns were decoded into a surface deformation algorithm developed in Grasshopper. However, first, the Voronoi pattern algorithm was implemented into the bio-tile flat surface to create a rough and bumpy texture called "Pit," an intervention technique to create a microhabitat for marine organisms. The information about the intervention size and shape was based on what we learned from the example described earlier, promoting Sissle, Bivalves, Barnacles, Coralline, and Mobile habitat in the intertidal zone (see figure2). Second, the reaction-diffusion algorithm pattern was applied to the surface to create deeper grooves to promote a specific marine species, and the intervention is called "Crevice." The Crevice texture intervention could promote Sissle, Bivalves, Barnacles, and Mobile habitat. Finally, these texture deformations were cut with a CNC machine into the formwork of tiles to make a series of textured tiles and a flat one for future comparison. Following the study, six tiles with two different textures were created for further investigation.

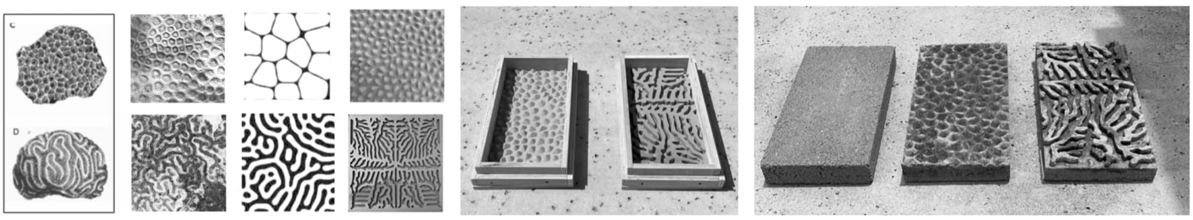

Figure 8. Decoding texture from nature, Reaction Diffusion and Voronoi patterns

4 Conclusion

Increased urbanization along coastlines, more extreme weather events, and rising sea levels will continue to strain the shoreline ecology. The experiment presented here highlighted how integrating environmental data into the design process can mitigate coastal erosion and contribute to biodiversity. Bio-tile, a data-driven hybrid infrastructure, presents an example of ecological design by demonstrating efficient solutions for reducing erosion, increasing biodiversity, and building a better coastal environment that can also be embraced, connected, and learned.

Bio-tile prototypes have been built and are currently being tested near bodies of water to determine their impact on ecosystems and whether they can create a suitable microhabitat. If these experiments are deemed successful, this methodology can be expanded and used on different ecosystems that need protection and restoration, allowing for a more comprehensive approach to ecosystem preservation and restoration.

Figure 9. Rendered view of the proposed design

Acknowledgements

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NEGLECTED SPACES: URBAN FRONT GARDENS AND THE SUSTAINABLE BUILT ENVIRONMENT

Niamh MURTAGH*, Rachael FROST

University College London (UCL), Gower Street, London WC1E 6BT, UK

n.murtagh@ucl.ac.uk

Abstract

A thriving natural ecosystem is essential for a sustainable built environment. Private urban gardens can offer multiple ecosystems services, in addition to health, well-being and social benefits. Front gardens offer particular value with respect to reduction of flooding and improvement of air quality. However, urban trends globally are towards less garden space and reduced vegetation. In terms of design for enhancement of ecological services, front gardens are relatively neglected spaces. An essential input to the design process is knowledge of the needs and behavioural tendencies of users. The current study explored how people relate to their front garden space and its potential for planting. Five focus groups were conducted with a total of 20 urban working-age adults from across the United Kingdom, and were thematically analysed. There was a sharp contrast between meanings and uses of front versus back gardens. People expected to spend time in their back gardens and this provided a rationale of why they planted more, and spent more time, effort and money on the back garden. Back gardens were perceived as more private and although front gardens were the site of social interactions, these were expected to be casual and transient. For most participants, their main objective for the front garden space was space for car parking with a neat and tidy appearance, requiring low effort for maintenance. Conclusions that may be drawn are that people seek individual benefits from their gardens, and are unaware of the potential for ecological services and social benefits from front garden spaces. There is a need for design leadership: to demonstrate possibilities, to incorporate multi-functionality, some privacy and low maintenance, and to allow people to perceive front garden spaces as critical elements in ecologically and socially sustainable urban settings.

Keywords

Urban private gardens, occupant behaviour, aesthetics, urban greening

1 Introduction

The most critical urban network for sustainability is the natural ecosystem. The multiple services provided by vegetated spaces protect the built environment and its occupants, enhance the quality of human life, and support other resources and processes essential to society such as clean water, healthy soil and pollination. While urban parks can offer green spaces, ecological systems require connectivity: urban gardens can provide connectivity as well as benefits in their own right. These interstitial spaces can be overlooked in discussions of green infrastructure but must be understood and utilised for a sustainable built environment. The design of spaces can facilitate or thwart activities within them and successful design starts with knowledge of the needs, desires and behaviours of users. This study aimed to understand how people relate to their front garden space and its potential for planting, in order to consider how to design front gardens to optimise their ecosystem roles.

The benefits offered by planting and soils, termed ecosystem services, are well-established: greenery can cool the local environment through shading, evapo-transpiration and reflection of solar radiation (albedo effect) [1]. Carbon is sequestered not only in plants but also in the soil [2], reducing the accumulation of greenhouse gases in the atmosphere. Permeable surfaces capture rainwater and slow its percolation into drainage systems, protecting them from becoming overwhelmed [3], and can filter out pollutants in the process [1]. Vegetation, particularly hedging and some types of trees, is effective at improving air quality [4] and planting supports biodiversity [1]. Beyond services in the domain of nature, greenery has significant impact on people, reducing stress [5] and its physiological correlates such as blood pressure [6], improving attention [7], enhancing well-being [8], and encouraging pro-environmental behaviour [9].

In the UK, 88% of homes have garden space and the aggregated land coverage is over 7000 sq km [10], more than twice that of two of the largest national parks. However urban front garden space is increasingly being converted from lawns and flower beds to hardstanding for car parking [11, 12]. A global tendency towards smaller gardens has been noted [8]. Car parking can occupy as much as 40 per cent of urban land [13]. The dominance of car and the accompanying desire for convenience [14] provides a partial explanation for the loss of front garden planting but cultural shifts typically result from multiple factors.

Previous research on attitudes to gardens (as distinct from gardening) is limited. A detailed study from 1968 mapped changing perspectives in the UK, from utilitarian attitudes after the policy of domestic food growing during World War II and its aftermath, to mid-century norms of front gardens for display purposes only [15]. Fencing, particularly hedging, was common. Multiple uses of back gardens were described, as was a tendency to perceive the garden as an extension of indoor space. The typical design of low fences between back gardens was assumed to indicate a limited desire for physical and visual privacy. Cook [15] commented on the lack of systematic research on what people want, and in their research showed a general, though not universal, desire for greater privacy. In late 20th century California, a typology of meanings attributed to gardens, acknowledged as non-comprehensive, was proposed. This included: the garden as extension of the house; the garden as a project; and idiosyncratic or individualistic approaches [16]. Perceptions of gardens as continuation of indoor living spaces appeared to transcend location and time, but the individualistic tendency in the California study may also indicate cultural differences.

In her work on landscapes and ecology, Nassauer explored how societal culture influences what people pay attention to and how they understand what they see [17]. An ‘aesthetic of beauty’ then is a commonly-held view of what constitutes an attractive garden. An ‘aesthetic of care’ comprises signals that a space is maintained or looked after – neatness can be a strong indicator of care. This understanding led to the critical insights that (i) the value of ecosystem services in a location may not align with prevailing aesthetics – for example, an unmown strip of land may be rich in biodiversity but look unkempt – and (ii) that spaces which do not comply with aesthetic values may succumb to cultural pressures for change.

Tending a garden can be a source of pride, signalling care for place and community [18]. The signalling function of front gardens can be used to communicate social status and values [19]. In US suburbs, a close-cut front lawn has been interpreted as demonstrating people's desire for control over their environment but also as a display of community spirit [20].

Despite a substantial body of research on gardening, much has focused on older people, on gardening as therapy and on gardening for urban food production. There has been relatively little on understanding gardens as spaces to which people may relate in different ways, and what may motivate people to tend plants other than for food.

The literature then provides evidence of the critical role of gardens for urban sustainability and indicates a diversity of meanings and socially constructed norms relating to front gardens. Unlike landscapes, in front gardens, individual householders wield the power to make changes. The aesthetics of front gardens do not reside simply in the perception of the viewers but are actively created by their occupiers, who both absorb and create cultural norms. The loss of front gardens discussed above indicates that norms are shifting. In order to protect the ecosystem services that gardens can provide, research is necessary on current perceptions of meanings, desired and required functions of front garden spaces and the study aimed to address this gap.

2 Method

Applying a method well-established in environmental, health and social psychology, the study conducted a series of small focus groups with a mix of participants. A pre-prepared topic guide included questions on each participant's front garden space, the functions of front gardens generally, and motivations for, and barriers to, gardening at the front. Five focus groups were conducted, with a total of 20 urban/suburban working age adult residents. The participants were from across the United Kingdom (UK) and were recruited via a commercial research agency to achieve a mix of sociodemographic characteristics. All participants had a front garden space of at least 3m^2. A half-and-half mix was achieved for: gender; income under/over £30,000 (€35,000, approximately the UK median income) and gardening in their front garden. There was a spread of age (20-34 years: 2 participants; 30-49 years: 11; 50-64 years: 7). Six rented their home and 14 owned it. Sixteen described their ethnicity as White British and four as Asian/British Asian/Black African/Black British.

The research was approved by the university ethics committee and the focus groups were conducted on Zoom in January to March 2021. The sessions followed the same protocol and were audio-recorded with permission from participants. The recordings were transcribed verbatim and a thematic analysis was conducted [21].

Qualitative exploration is intended to collect a range of perspectives, through hearing the participants' own voices on their experiences, feelings, attitudes and beliefs, unmediated by prior assumptions by the researchers. The intention is not to seek statistical representativeness. Validity is achieved through commitment to rigour, coherence between research question and method, and transparency [22].

The analysis resulted in a rich set of themes which included motivations, capability, and external enablers or constraints for gardening in the front garden. We have selected one theme for focus in this paper, in keeping with the themes of the S.Arch conference: meanings of front gardens.

3 Findings

To ground the discussion, each focus group began by asking participants to describe their front garden. The most common elements were a driveway (paving or gravel), followed by grass/lawn and shrubs/trees. Flowers in beds and planted pots were also described. A few participants mentioned hedges and hanging baskets. Around a third of participants mentioned front garden space enclosed with a fence or wall.

In thematic analysis, themes may emerge as patterns of responses, rather than a simple response to a question [21]. In the analysis, the researcher can draw out latent ideas underlying articulated answers. In our data, we noted a pattern of comparison and contrast between front and back gardens, which offered illuminating insights into meanings associated with front garden spaces.

The participants thought differently about the front versus back garden spaces, with different uses, concerns and objectives. A key theme was a perception of difference in privacy, with front gardens seen as more public: "*The back garden's just so much more private…you know no one can necessarily be watching you…where the front garden's more exposed to anyone from anywhere*". Most urban and suburban back gardens in the UK are overlooked and, in that sense, are visually semi-private but participants did not acknowledge the limitations of privacy in back gardens. For the participants, back gardens felt much more private than front gardens. As the quotation shows, there was a sense of increased exposure to strangers ("*anyone from anywhere*") at the front, positioning the front garden as a semi-public space.

Attributed in part to better privacy, sitting and enjoying the space was an expected use of the back garden but perspectives on the use of the front garden as a social space were diverse and nuanced. Some participants articulated strong social norms against simply sitting in a front garden:

> *There's just that stigma around being in your front garden. I don't know why or where it comes from. For some reason, it just seems that the front garden …is not the place to be seen relaxing or enjoying.*

Other participants agreed that sitting the front garden would bring social disapproval. Another participant, again using the term 'stigma', related relaxing in front gardens to "*social standing*" or class. These were clear, shared, and strongly worded perspectives on sitting in front gardens. While the practice may be common in other cultures, for the participants' streets in modern, suburban Britain, it was explicitly positioned as not socially desirable.

But the norms discussed were not quite so simple. Several participants mentioned the street parties which took place in May 2020 to commemorate Victory in Europe (VE) Day: these were very popular across the country, including streets where sitting the front garden would not be acceptable normally: "*My parents' area wouldn't do it [sitting in the front garden] but then if it's something like the Jubilee or D-Day, it's like, 'Ooh, tea party', but they wouldn't do it in general*".

The popularity of VE Day socially-distanced street parties may have offered a welcome social release during pandemic restrictions. Lockdown had an effect on how people used and thought about the social function of their gardens. Some used their front garden as a socialising space in somewhat formal ways, putting out tables for a birthday, but for most, it was casual chatting at the gate. Several talked about the value of their front garden which "*has become a good social meeting place*" and they appreciated the social interactions that were possible there, within the lockdown constraints. The wording "*has become*" suggests a shift in perception of the potential benefits of a front garden space.

But some participants also acknowledged their front garden as a social space within particular constraints prior to the pandemic lockdowns. The social opportunities they described were unplanned and centred around activities: "*Not through choice, it would have to be ad hoc, like accidental social space, it would never be planned as the right space".*

Participants generally enjoyed a chat with some, but not necessarily all, of their neighbours. Washing the car, having their children or dog in the front worked as prompts for social interactions. Gardening was particularly valuable because of the time spent and shared pleasure in the outcome:

> *For example, my magnolia tree, when it blooms it looks lovely and people walking past, and especially if we're in the front garden, they'll comment on it. It's just nice, you get to know your neighbours that way as well and people walking past as well, and they'll ask about it or whatever.*

So while sitting and enjoying the front garden was not acceptable, people generally enjoyed the unplanned social interactions that the front garden allowed, and gardening in particular offered a time-consuming activity which enable more interaction.

Beyond these activities, while the back garden was a space in which to spend time, the front was to be traversed or visited as quickly as possible: "*the back garden … that's where you sit and spend all your time…We don't really see the front garden. We drive up, go in and forget about it often*". The supremacy of the car was explicitly acknowledged: "*it's all about the car, isn't it really? …car into the house, into the car, into the shops*". Spending time in the back garden was used as a justification for putting more time and work into the back compared to the front, and this extended to money spent:

> *"I think probably most people are more inclined to spend more money on their back gardens because that's where they spend most of their time than their front gardens and probably more time making them look nice…So I think if you're on a tight budget, you're more inclined to spend less money I would say in the front garden than the back".*

In this extract, the participant appears to draw on cultural norms ("*most people*") as did other participants in setting out their rationale that more time spent in the back garden was a logical reason for expending more effort, time and money in the back.

The aims for the front space were notably limited. While back gardens included exotic plants, experimental and profuse planting, fruit and vegetables, space for socialising and for children to play, or a sanctuary, the front was "*just a practical place at the front of your house*". For some, the orientation or proximity to a busy road were constraining factors for planting there. With the exception of one participant with an interest in topiary, the clearest ambitions were a space to park and/or some colour: "*as long as it's presentable and tidy, maybe a bit of* *colour*". The desire for a "*nice and tidy*" space was echoed by many of the participants. This spoke to cultural norms of meeting the expectations of others: "*I feel it's got to look presentable when people are walking past because it does look, you know, nice, nice and clean then, you know, just trying to keep it tidy*". The front mattered as the first view of the home, and passers-by would judge not only the home but also the occupants based on its condition. However, for some, keeping it tidy was the height of their ambition for the space and they wanted to achieve that with minimal effort. One participant had fully paved front and back gardens to that end. For those that gardened, their aims acknowledged the gaze, and judgement, of others: "*I'll do front gardening, mainly for my own benefit, but also what others think, I think. You know, you want the front of your house to look nice. So kind of keeping up appearances*". There was a sense that, whereas the aim of tidiness could be more for others than oneself, the aim of a 'nice' garden could be more for oneself than others, although the multiple motivations were overlapping and not distinct. Their responses resonate with Nassauer's aesthetics of care, particularly with respect to neatness, and of beauty ("look nice") [17].

A few participants acknowledged that they did not know how to use the space: "*We're still waiting for the big light bulb moment of what to actually do with it*". The participants did not find value in large, complex 'make-overs' on TV programmes. Beyond parking and perhaps some planting in pots for colour, the participants appeared to struggle with what functions the front garden space could offer: "*It doesn't really serve a purpose. Just tons of grass, not using it. We don't go on it"*. Another said about their front garden "*it's not much use really*". In the absence of other meanings, the space defaulted to a simple boundary or transitional area that did not merit attention or effort.

4 Discussion

The study analysed five focus groups of four participants from around the UK with a mix of sociodemographic characteristics, including people who gardened in their front garden and those who did not. We analysed comments comparing front to back gardens, which showed differing attitudes, beliefs and practices between the two, and provided insights into cultural perceptions, norms and meanings of front garden spaces.

The participants described strong social norms against simply sitting in the front garden. Nevertheless, most enjoyed the casual social encounters that could occur if they were at the front. While relaxing in the front garden was not socially desirable, activities there could be acceptable and could enable social interaction: gardening was particularly good as it meant spending time and providing a focus for a conversation. Less planting in front gardens then leads to reduced social encounters with neighbours. It is possible to suggest that this in turn reduces identification with the local community, and less salient place and community identities. This indicates another way in which the space demanded by the private car can loosen social bonds. Weaker place and community identities may mean less pride in the locality and a loss of a sense of community. In contrast, working in front gardens offers the potential to strengthen social bonds and to build social capital. Evidence has demonstrated the importance of social relationships in recovery from disasters, and in community resilience more generally [23]. A connection from front gardening to improved urban social resilience can be proposed.

The contrasting perceptions of privacy between front and back gardens carry implications of a less clear sense of ownership at the front. Back gardens were seen as private, rather than semi-private, in contrast to front gardens, which were seen as not private, that is to say, semi-public. The loss of hedging and fences from UK gardens, noted as long as 50 years ago [15], could be a factor. In a semi-public space, a sense of ownership and responsibility may be more ambiguous.

For those who did not garden at the front, their comments could be seen as inward-looking or individualistic, offering a self-centred rationale for not having planting. They proposed a logical argument that the back garden merited time, effort and money because that was where they would spend time. The back garden was the priority because the householder got to benefit from it. Because the front garden was not seen as a social space, except in an ad hoc manner, and because little time was spent there by the householder, it was not worth much effort. Some participants were explicit in stating that they did not work on the front since they did not see the results from inside the house and did not get the benefit. The argument draws on utility theory and, on one hand, appears rational. On the other hand, however, several important factors are omitted from the line of reasoning. In this approach, there is no consideration of the beauty of what could be produced, and no mention of emotions such as joy or contentment as possible outcomes of the activity of gardening. The potential benefit to others such as passers-by or neighbours is overlooked. More generally, neither positive outcomes for the community or society nor invisible gains, including most ecosystem services, were counted. The householders were exercising their rights as an occupier of land, but not their reciprocal responsibilities to society [24].

However, although the rationale was logical, people do not rely on utilitarian reasoning in their decision-making [25]. Social norms are powerful drivers of behaviour [26]. The discussions around more social interactions with neighbours, both informal and planned, during pandemic restrictions showed how previous norms had changed and this may have contributed to stronger coping [23]. Their responses referred to the aesthetic of care, particularly of neatness, and, to a lesser extent, an aesthetic of beauty. These aesthetics will have guided what is attended to and what is perceived, and thus will have influenced behavioural choices. If such aesthetics can be explicitly addressed to incorporate desired ecological outcomes, perception, expectations and behaviour could change.

5 Conclusions

What are the implications of the findings for architects and others who design and shape the built environment? Given their value to ecosystem services and social connection, and the casual loss of vegetation in recent decades, urban front gardens can be described as neglected spaces. There is a critical role for leadership through design to protect the role of front gardens for a sustainable built environment. The findings demonstrate complex attitudes to the uses of front garden spaces. However, cultural norms and affordances can guide people on how to respond to a space [27]. Because norms have increasingly moved towards the front space as car parking, and with limited ideas on what a front garden can be, creative ideas are required. There is urgent need for design examples of front garden spaces which incorporate multiple functions beyond car parking. Integrating practical functions such as parking and bin storage with planting can show the potential for multi-functionality. The creation of semi-private space could help to challenge the rationale of not spending time at the front and the use of boundary indicators such as fences could enhance a sense of ownership. Design support for casual social interactions could strengthen local community relationships and identities. The findings suggested a strong desire for low maintenance features.

The objective should be to develop aesthetics of care and of beauty, to move beyond the perspective of garden space as simply an extension of indoor living, and in particular to lead on how ecosystem services can be read through design. In sum, the essential role of design for front gardens is to enable them to be interpreted as spaces worth caring for, which offer pleasure to their owners in tending to them and in the outcome, and benefits to passers-by and society more broadly through the ecosystem services they offer.

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MOVING POPULATIONS IN FLUID TERRITORIES

Efthymia Dimitrakopoulou*[a], Elina Letsiou*[b], Phoebe Giannisi[c], Zissis Kotionis[d]

Department of Architecture, University of Thessaly
Pedion Areos, 38334, Volos, Greece

* [a] PhD candidate, efthymia.dim@gmail.com, * [b] PhD candidate, eletsiou.arch@gmail.com
[c] Professor, fogianni@arch.uth.gr, [d] Professor, kotionis@gmail.com

Abstract

Through a critique of metropolitan life, the living rhythms of the modern subject, and his technological household apparatus, this research investigates what could be the expanded, even hybrid ways of living in the modern city. In a condition of negotiating the dipole of urban work and countryside pleasure, we reverse the terms and examine the practices of working in the countryside and leisure practices in the city. We study how practices of the rural world could penetrate and colonize cities by developing new hybrid practices that serve the modern way of living of the urban moving subject, and which incorporate necessary practices for the performance of everyday life. Through the connection with the natural landscape and the countryside, living practices and laborious methods were produced, accompanied by a set of objects that contributed to the performance of multiple activities. These methods, combined with the intensification of technology and the deterritorialization of work, push us to reposition ourselves in the question of the modern mobile subject and to redesign the accommodation unit and household apparatus, in terms of time fluidity, which is not divided into working time and vacation time, natural and artificial environment. Uninterrupted work and uninterrupted vacations reconstitute the structure of the living space, creating a new hybrid identity for the city.

Keywords

Metropolis; Rurality; Practices; Hybrid; Household apparatus.
Topic: T6 Urban Ecology and Climate.

1 Introduction

The modern city through the possibility that it offers to provide jobs, leisure, education, and social development functions, has become the place where societies reproduce and the built and open spaces are multiplied, constantly expanding its boundaries. Thus, the city became the pock of human habitation creating multiple typologies of habitation of both public and private space. As Sennet describes in the "Tyranny of intimacy", the city-machine transforms from a field of urbanization and urban culture with clear divisions and roles into a field of culture of intimacy [1]. Urbanization brought into a symbiotic condition heterogeneous

identities through negotiations and claims. The arrival of the diverse crowd transforms the urban culture into a network condition in which we find accumulations and dilutions.
The need to move is even more pronounced as the human in the modern globalized and interconnected world renegotiates concepts that were so far established and fixed. So even the relationship with space is changing. Modern human ceases to live exclusively at one point on the map but the residences are a multitude of points on a new network. Habitat is not a fixed point but diffuses between nodes on the map. The concept of housing is increasingly being followed by the concept of residence. Habitation is characterized by a continuum from node to node without commitments. According to Deleuze in "the life of the nomad is the intermezzo" [2], the nomad at each node does not stop, it just pauses, and the route/journey/movement is a continuous flow between these points.
Familiarity with mobility, the ability to keep pace with the most sudden upheavals, adaptability, flexibility to move from one set of rules to another. From what we call "nomadic mobility" to what is respectively called "traveling" in a post-industrial era, uninterrupted work and rest reorganize the structure of the living space into the uncertainty and instability of metropolitan life, thus normalizing the habit of not acquiring habits, the practice of the uncertain and the changeable are derivatives of the remote work and they adapt not only a way of life but also the material world around us and consequently the spatial condition examined by the science of architecture.
A typical example of this reflection is the intertemporal example of the architect Takis Zenetos (1926-1977) with “Electronic Urbanism” (Figure 1) project who already 60 years ago talked about another way of life in terms of sustainability and use of technological achievements new forms of habitation and sociability are emerging. Takis Zenetos, realizing this transition, since the 1960s, proposes Electronic Urban Planning, a three-dimensional spatial structure over existing cities and the natural landscape, which is made possible thanks to the automation of "telecommuting" applications and in the evolution of technology on the micro-scale, housing "cells" are attached to the urban fabric and mutated parametrically according to the needs and desires of residents. Nature at ground level is left intact to be "transported" to the suspended levels and to be integrated and cultivated in the "neighborhood". Nomad and farmer are the two human characters that meet in the suspended urban planning.

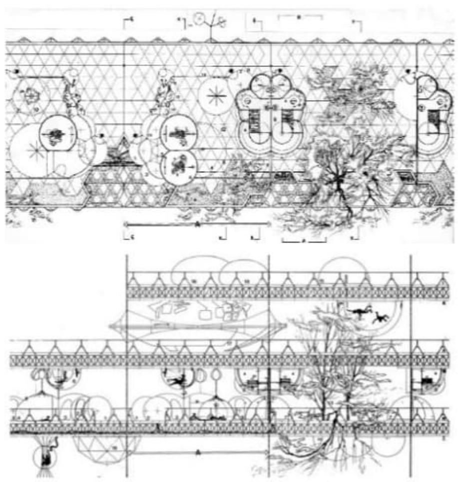

Figure 1. Electronic Uranism, Takis Zenetos, 1960, exhibition *Tommorrows*

2 The Metropolis and the Countryside

2.1 Rural and idyllic

The previous agricultural way of treating the countryside as an area that is not directly related to the urban fabric made it seem foreign. In general, the industrial revolution and urbanization that followed, gradually transformed rural areas into unattractive areas, difficult to inhabit and associated with regression and lack of progress (as opposed to the city) [3]. Then both the pressure of urbanization and the density of cities and the technological development that allowed the networks to be established even in fraudulent lands made it possible to inhabit the countryside in another way. The degradation of life and the environment in cities on the one hand and the fact that the countryside is marked by a high cultural potential involving socially symbolic representations such as landscapes, national, regional, or local identities [4] re-examine attractiveness of the countryside in other terms.

Two rural trends are emerging:

-Urban countryside: nostalgia for the countryside, multifunctionality, tourism

-Rural actors: post-productive countryside, overproduction, contribution to the environmental crisis

The restoration of the relationship with nature and the countryside, we could say, arises through principles introduced by sustainable development that avoid the anthropocentric view of land and natural resources and favor an approach where ‘nature’ or ‘environment’ has its own existence and must be treated with respect by human societies, practically that nature does not 'belong' to the human species, but is 'by itself' a separate entity [5]. According to this view, human's relationship with nature has been disrupted by the modern way of life, and the restoration of the relationship between should be sought, that is, the discovery of the essential, endogenous value of nature and its preservation. This approach is in direct contrast to the approaches of nature as a resource, wherewith typically anthropocentric logic, nature is treated as a means of production. To achieve this restoration, alternative tourism comes to shape this gathering through another approach and another form of landscape consumption. "Authenticity" and "nostalgia", the two dominant rhetorical forms of tourism, in the case of agro- and eco-tourism typologies are combined with much greater emphasis on the concept of preserving an authentic rural, natural past [6].

Thus, the countryside has changed from a productive field to a place where ‘authentic’ life takes place and where urban dwellers spend part of their time as visitors or temporary residents on holiday playing the role of a potentially outdoor resident.

In the frame of the countryside as a productive landscape, we approach the Vlach semi nomads’ assemblages, performing long-distance transhumance pastoralism in Northern Greece. Nomadic pastoralism is a complex subsistence system in which herder decisions regarding pasture access and mobility are key to their survival. Transhumant pastoralism may be defined as animal production and land use strategy involving the movement of herds of domestic herbivores between altitudinally differentiated and complementary seasonal pastures (Geddes 1982) [7]. Base characteristic is the fact that it is an integral part of a more broadly based agricultural system which includes sedentary cultivation and animal pastoralism by members of the same community. Pastoral mobility is a direct product of the long-term adaptation of pastoralists to the unpredictable ecological dynamics facing their seasonal long-distance movement with their flocks between lowland winter pastures and mountain summer pastures. Through seasonal movements between ecological zones, pastoralists move on several different spatial and temporal scales. Research on their mobility behavior can highlight interactions between humans and environments, with the recognition of the planet’s transition into a possible new geological epoch, the Anthropocene.

Postindustrial aspects of livestock production, such as modern pastoral technology and veterinary practices, the twentieth-century transformation of the peasant's landscape, and market orientation for livestock husbandry have altered dramatically traditional pastoral production practices. Yet, we can still find some remaining cases of nomadic pastorals that combine old traditional techniques with the modern ways of living and technologically advanced apparatuses (Figure 2). According to Claudia Chang (1999: 135), what does remain a useful analogy between past and present, is the adjustment and adaptation pastoralists today make to a given topographic, environmental, and climatic setting.

Chang suggests that, among Greek pastoralists, the commitment to sheep and goats must be seen in a historic context. In that way, even when modernization appears to have taken its toll on "traditional" practices of livestock husbandry, pastoralism is preserved on the landscape and as part of people's daily lives. This is highlighted and maintained through various vernacular types of ephemeral architecture on the terrestrial surface, such as the construction of *mandria* or animal folds, used to house flocks of sheep and goats. Animal folds are now constructed of concrete blocks, as well as more traditional methods of dry-laid stone masonry, thatched straw, and brush, mud-brick, or wattle and daub. These enclosures are used as stock holding areas and also may be associated with kalivas or konaki, herder's huts constructed of tin, wood, brush, and plastic sheeting (Chang 1999) [8]. Vlach nomads have the ability to disassemble, move and reassemble their hut in a matter of hours without any tools. Constructed out of wood, ferns (characteristic plant of forest vegetation), and animals' dung, it is one of the most natural dwellings on Earth (Figure 3).

In all these cases, site abandonment practices result in thin artifact scatters, rock alignments, stones marking the *mati,* or eye of the milking pen where herders sit to milk sheep/goats, and very thick manure deposits, leaving almost zero imprint on the landscape and the wider ecosystem.

Figure 2. nikoskellas / Instagram
Available at:
https://www.lifo.gr/now/greece/apithano-instagram-enos-ellina-boskoy

Figure 3. View of konaki

Studying at the same time cases of forms of tourism, we find for example, in the study area of Pelion in Central Greece, the historic youth camp located in Pelion, Magnesia (Xanth Camp), which not only redesigned the way of approaching the countryside but also created a new habitat in nature and a bourgeois-visitor culture that redefines its relationship with nature through an educational process of landscape management and introduction of living and survival practices out there while maintaining the archetypal accommodation unit, the hut, until today (Figure 4). On the other hand, we find more modern agritourism hospitality units (Karaiskos Farm, Portaria, Pelion) (Figure 5) which imitate an older rural way of life making the atmosphere of the traditional by using older practices of daily life (traditional cooking methods, animal husbandry, farming, gardening). This reversal of functionality and 'aesthetics' and the transformation of the village into a setting is clearly seen in the use of 'traditional' materials in modern constructions intended to meet modern needs (addition of stone and/or wood in buildings, etc.), the effort to highlight the 'traditional' character of spaces and landscapes and in environmental conservation in the way a museum is treated.

A prerequisite for the representations that shape fantasies of the countryside, nature, and agriculture as consumer goods is the perception of their value as "endangered species". This biological metaphor is consistent with the naturalization of past ways of life since historicity is perceived through the opposite dipole past/present, where the present is dynamic while the past is eternal. In conjunction with the discussion of the tourist's gaze, Bauman (1996: 26) approached the tourist as a "stroller" who hires strangers (hosts) as "surfaces" which are exhausted by seeing them as rows, episodes without a past and without consequences [9].

Figure 4. Accommodation hut in the fores, YMCA, Xanth Camp, 90 years YMCA, p. 84

Figure 5. Agritourism facility n Portaria, Pelion, https://www.karaiskosfarm.gr/

2.2 Hybridity

Through the modern look at the land of the urban and suburban territory, it is ascertained the redefinition of the dipoles that want the urban periphery and the rural land to be characterized by homogeneity and shaped typologies of living of everyday life. Places cease to take on contradictory functional roles between work time and leisure time in correspondence with life in the city and life in the countryside. The modern way of life and the climatic conditions activate on the one hand new territories that can be called semi-outdoor or semi-urban but also to shape old territories to create post-modern functional space defined by multi-identifiable subjects that can move between the local and global. Thus, a hybrid way of life takes the place of strict typologies of living in the countryside and in the city. The difficulty of creating spaces of purely local specificity or globalized universality is therefore increasing. The symbiotic condition leads to “universality” (glocalization), which causes heterogeneous phenomena and gives rise to hybridization.

For Donna Haraway's hybrid term "nature/ culture" implies the ambiguity of the dividing line between nature and culture, the view of physical and human production as something intertwined or even as one, and the belief that the concept of nature is a constantly reinventing artificial construction [10]. For Haraway, both the postmodern subject and nature

are approached as an interactive holistic system, which is in constant exchange and sharing in the environment.
In this direction, the project HOT_CAGE (Figure 6) tries to integrate the concerns of the era for a sustainable stay in the context of the oscillation between the city and the countryside, in mobility and stability, the locality of the use of materials in combination with the use of new technologies trying to build a unit of residence/work/leisure, metaphorically a cage. The HOT_CAGE project describes the possibility of urban and at the same time rural living with increased energy and food autonomy. HOT_CAGE interprets current farming practices urban activity, which special means under conditions of deprivation they develop on the borders of Greek cities. THE untested term bio-cultivate (bio-culturalism) describes urban residences within a controlled, greenhouse framework, procedures residence, work, and production. THE framing-fencing-cage humans, plants and animals together is a kind of voluntary confinement in a state of autonomy. It is at the same time transport but also a practical example organization of accommodation in the established emergency social conditions but also its geological conditions human-made and climate change.

Figure 6. *H O T _ C A G E Apparatus for The "En-Cagement" Of Autonomy, Zissis Kotionis, (collaborator Efthymia Dimitrakopoulou) 2017*

For Stuard Hall, hybridism defines the concept of "dispersion", where strangers from different places fill the void of a place. Hybridity as a concept is defined through heterogeneity and diversity. Denial of purity and acceptance of mixing. It means multiple identities of the subjects, their mixing. The terms hybrid identities and heterogeneity are now considered intertwined with action. Hybridization has a spatial dimension as subjects shape places and makes heterogeneity a legal state, as movement and displacement create hybrid subjects [11]. With this thought, the project Hot Camp project (Figure 7) comes to incorporate the ideas of hybridization not only at the unit level but manages the building block that could act as a hub.

Figure 7. H O T _ C A M P A Trans Urban Block, T O M O R R O W S Urban Fictions for Possible Futures Proposal for a project by Zissis Kotioni, *(collaborator Efthymia Dimitrakopoulou), 2016*

A Hothouse is an artificial environment providing a controlled, warm environment for cultivating plants. On the other side, a Concentration Camp is a gated settlement for people excepted from law protection, usually under the condition of obligatory labor. Connecting the two terms in the new term Hot_Camp we introduce a program for collective living and working in the margin or in-between cities. It intends to provide a spatial and performative condition under which suburban life melts into rural life and vice versa. Life for moving people in a state of emergency is asked to be integrated in this form of open community. The project refers to the precarious conditions of contemporary (future) life, in political relevance to the South, into the Mediterranean climatic conditions. A semi-temporary, prefabricated structure is proposed, to be set on a 3600 s.m. open area. The 60x60m land is covered by a light, transparent structure functioning as a shell of outdoor space and a bioclimatic apparatus (passive system, solar electricity, water reuse apparatus, etc.). Postindustrial home production is combined with gardening in a sense of a common-household industry.

2.3 Un-Territorial Household Assembly

The territorial reserve of the rural geography allows us to inhabit it with all the necessary equipment for urban living. The countryside from a place of scarcity could be turned into a field of abundance, work, enjoyment, and daily exoticism. Nevertheless, the climatic conditions of the seasons, the dimension between summer and winter living still make life in the countryside seasonal. It is precise because work, through network technologies, has been de-territorialized, that we are allowed to think of living in relative independence from work, the ground from the activity performed on it. This independence of the land from the activity allows us to think of new activities, new communities, and new daily life in old lands as if a beginning settlement is going to move permanently here or there. This ambiguous state of the generalization and localization of the domicile turns the countryside and the city into the potential field of reception for new, dispersed settlements.

We are generally going through a period of heterogeneous crossbreeding and hybridization in the structured environment, which is the result of the abundance of movements and multicultural contacts. Hybridism is a concept that interprets the process that "builds" cultural identities. The dubious structured environment, which is constructed in fluid territories, will possibly define the future identity of the places. The modern overlaps and effects are numerous and instantaneous, guiding the modern movements between places and creating a heterogeneous crowd that resides more than settles, takes root in one place.

The pressures of the dense metropolis create a potential community that operates in terms of solidarity without missing the physical confrontations, claims, or otherwise cultural discussions about how resources are shared and how the commons are managed. The modern hybrid form of subject combines work and leisure in a temporary residence structure, within the context of de-territorialization from the metropolis and the search for a semi-outdoor facility. The result of this multi-layered daily life is the relative autonomy and self-sufficiency that makes the modern subject flow between rural landscape and urban practices, the primitive and the technologically advanced. The residence unit could transform into a small facility of metabolism of organic and inorganic materials of multi-identity processes (Figure 8).

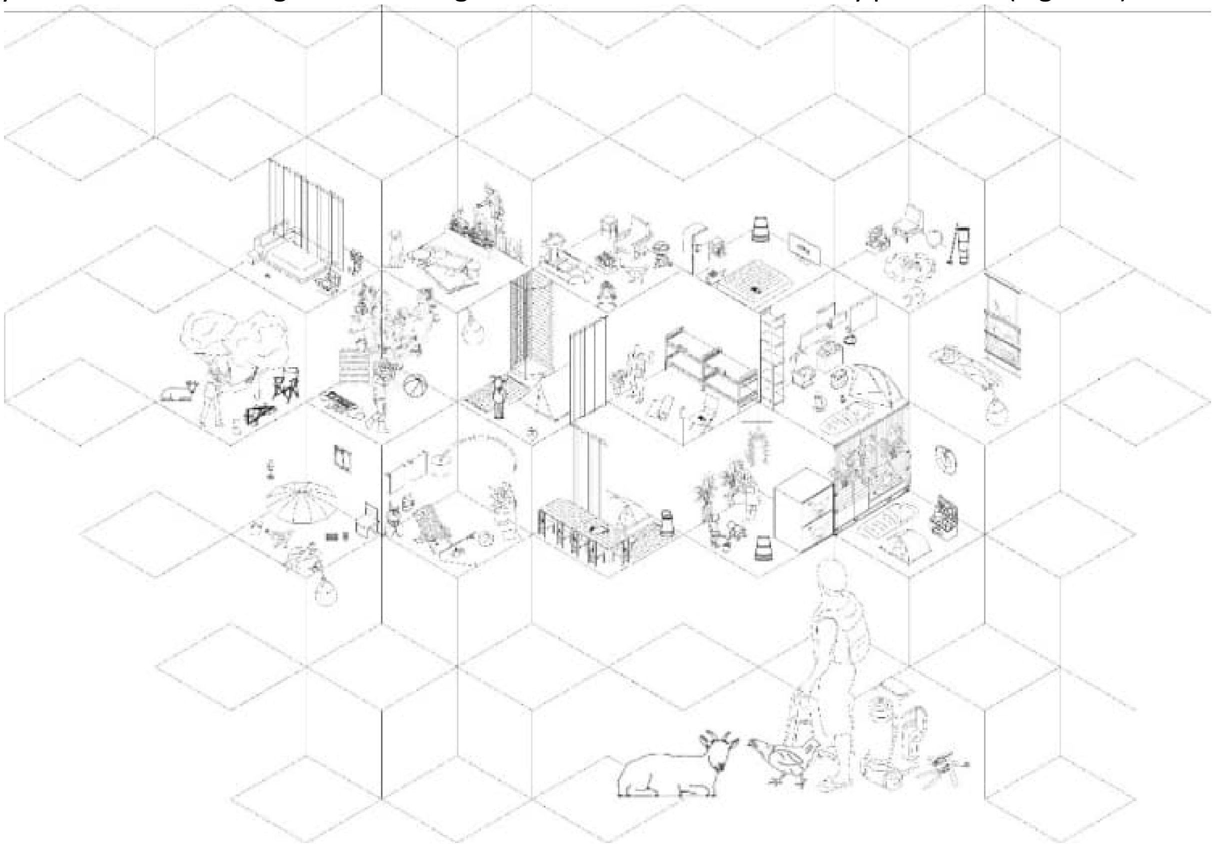

Figure 8. Assembly of material objects and multiple subjects in new territories

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INCREASING RISK OF FLOODING IN CITIES: RISK MAPPING USING GIS IN BURSA, TURKEY

Ayşe Sena ÇILDIR*, Didem Güneş YILMAZ

Bursa Technical University Yildirim Bayezid Campus
16330, Bursa, Turkey; aysesenacildir@gmail.com, didem.yilmaz@btu.edu.tr

Abstract

One of the effects of climate change in cities is the increasing rainfall and flood risks. Unplanned urbanization, unplanned areas, unplanned green areas, and impermeable surfaces increase the risk in cities. Especially in urban vulnerable areas, flood risk increases with the effect of climate change.

Bursa is one of the most populated cities in Turkey. Bursa has sloping areas, whereas water resources are abundant, and the amount of precipitation is high. The selected area includes neighbourhoods built on mountain slopes. It also contains stream beds. Due to these factors, the flood risk of the area increases.

Figure 1. Flood disaster Fidyekizik neighbourhood, Bursa

This study aims to calculate flood risk for a rapid and unplanned developing urban area in Bursa. Flood risk will be calculated by using ArcGIS software for an area deemed vulnerable. Analytical Hierarchy Process (AHP) and Geographical Information System (GIS) analysis techniques will be used.

Keywords

Climate Change, Flood Risk, Cities, Urban Vulnerability, Unplanned Urbanization

1 Introduction

Climate change is the general name for long-term changes in weather conditions and earth temperatures. Until this century, the changes were slow and in harmony with the ecological balance. After the industrial revolution, climate change accelerated with the increase in the use of fossil fuels, the increase in the emission of greenhouse gases into the atmosphere, and the change in land uses. These changes in climatic conditions occur in the form of large differences in average temperatures, as well as changes in precipitation amount and shape.

Floods and overflows are experienced severely in some regions due to sudden and heavy rains caused by the climate change. In some regions, in contrast, natural disasters such as drought and desertification are taking place in a speed way due to the decrease in the total amount of precipitation.

Due to the global climate change, there has been a continuous and significant increase in the number of large-scale natural disasters with hydrometeorological character since 1980 in the world.[1] Hydrometeorological disasters cause more than 300,000 deaths and 325 million people are seriously affected, and also averagely 125 billion dollars economic losses worldwide every year.[2] Extreme weather and climatic conditions such as floods, storms, drought, and heat waves are directly responsible for 64% of disasters in Europe since 1980.[2] In Turkey, natural disasters, which are predicted to increase in future due to climate change, are listed as extreme weather events, wildfires, storms, floods, hailstorms, heat waves, landslides and avalanches.[3]

Cities will encounter different risks in terms of climatic, spatial, geographical, and socioeconomic aspects with the effect of climate change. As a result, the ecosystem, inhabitants, economy, and infrastructure of the cities will be adversely affected. The multifaceted effects of climate change differ according to the development levels of countries and the vulnerability levels of cities. In this context, it should be determined what the physical, morphological, and socioeconomic characteristics of each city are on a local scale. In other words, it is necessary to know what threats a city is likely to encounter due to the climate change and the level of resilience it has to cope with it.

Changing climate, increasing population, and unavoidable urban expansion make cities more vulnerable. It is necessary and urgent to manage environmental hazards in cities to prevent the great destruction that may occur in the physical and social dimensions in the future. It has become crucial for resilient cities to mitigate the effects of climate change, such as extreme weather, heat waves and floods. New approaches and methodologies are required for the future effective management of urban environments. Recent research in particular highlights the need to manage flood hazards. Accordingly, in this study, heavy rains and flood effects caused by climate change are emphasized. Flood risk analyses were conducted in a vulnerable urban area in Bursa using the ArcGIS software with the analytical hierarchy method (AHP).

2 Floods

The most common cause of flood, which is one of the hydrometeorological disasters, is heavy and prolonged rainfall. Floods can also occur because of strong flows from snow melting or due to the blocked drainage channels. The most common reason encountered today is that when the main river beds are completely full as a result of during heavy rainstorms. This happens where riverbed is narrowed or is left with insufficient embankment or is supported with insufficient drainage systems due to overpopulation and rapid urbanisation..

Damages caused by urban floods are increasing due to the destruction of natural vegetation, unplanned urbanization, and human settlements in and around stream beds. The phenomenon of rapid increase in the amount of water in a stream bed due to more than normal rainfall in the basin or the melting of the existing snow cover in the basin and damaging the living creatures, lands, and property around the bed is called flood [4]. After long-term excessive and heavy rainfall, flooding occurs especially on highly sloped and impermeable surfaces. [5]

Urban depression areas, which are geographically disadvantaged in general and are not suitable for settlement in terms of physical and geological aspects, are seen as sensitive areas against the effects of climate change such as floods, increase in air temperature, drought, storms, and hurricanes, and increase in sea level.

2.1 Floods In the World

Floods caused by overflowing rivers as a result of excessive rainfall are among the most widely seen natural disasters. As the global warming increases, disasters also increase. Indonesia, India, and Africa lead the list of regions where it is necessary to take serious protective measures, followed by the USA and the Central European countries. The most flood-prone countries in Europe are England, Germany, and France. According to the European Environment Agency, annual flood losses are expected to increase for fivetimes by 2050 and 17times by 2080.[6]

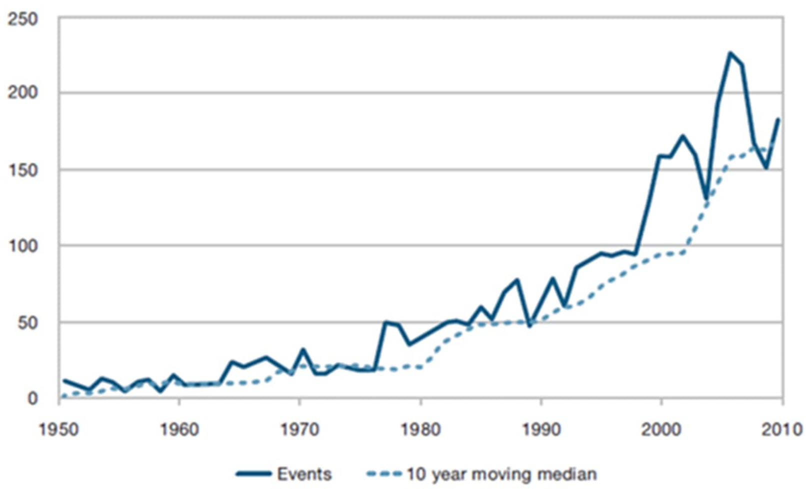

Figure 1: Number of reported flood events. [7]

2.2 Floods in Turkey

Floods are the second most destructive natural disaster types in Turkey after earthquakes. Almost 30% of all natural disasters in the country are caused by flood events. According to

EM-DAT (The International Disaster Database), 34 flood events occurred in Turkey between 1950 and 2007, 1,016 people lost their lives and approximately 1.5 million people were affected. [8]

Today, human activities such as industrialization, wrongly chosen settlements, destruction of nature can increase the effects of such disasters or cause new ones to emerge. Due to the global climate change and increasing unplanned urbanization in Turkey in the coming years, significant increases are expected in hydro-meteorological disasters (such as droughts, landslides, flash floods and sea level rise) and secondary hazards that threat our urban settlements. [9]

The number and severity of floods in cities also increases, due to the severe thunderstorms in countries outside the tropical climate, such as Turkey. Earthquake, flood, etc. hazards can turn into more disastrous in rapidly increasing distorted residential areas. [9] As in many parts of the world, frequent floods can be seen in Turkey as a result of successive heavy downpours or long-term rainfalls, resulting in great loss of life and economic losses.

2.3 Floods in Bursa City

The urban settlement in Bursa was formed on the Bursa plain and partially extends on the slopes of Uludag, which is a mountainous area and also a national park. If it is evaluated in terms of flood risk, floods are usually experienced after extreme rains due to the fact that there are stream beds on the slopes of Uludag, as the slope is high, and the infrastructure is insufficient. There is unplanned urbanization on the slopes, especially in the east of the city. Slum-type dwellings are largely exist which are more vulnerable to flood risk. The risk is increasing with the effects of climate change.

Looking at the history of Bursa, it is seen that there were floods in various periods. Floods and swamps were a part of life for the inhabitants of Bursa city and its surrounding villages. Throughout the 18th and 19th centuries, the inhabitants of the cities and villages were subject to floods at various intervals. [10]

3 Study Area

The site is located on the Uludag slope in the east of Bursa province in Turkey. (Figure 2) There is one river in the region and the slope is high. For this reason, floods are likely to occur in extreme rainfall. In addition, due to the high slope, the surface flow from the mountain slope to the lower regions is high.

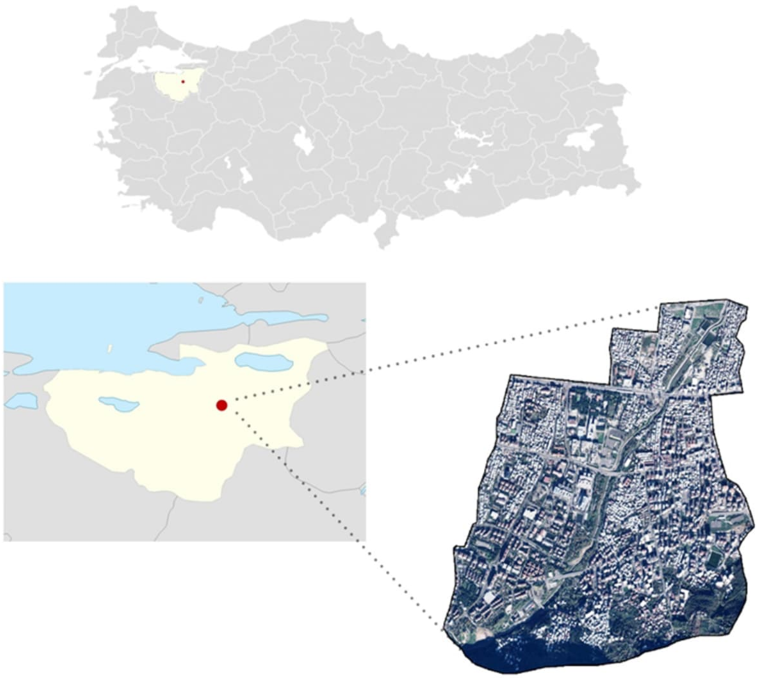

Figure 2. Study area in Bursa, Turkey

The selected region consists of 7 neighborhoods. (Figure 3). In the 1980s, rapid urbanization and squatting started in the region. For this reason, there is no planned urbanization in the area. Unplanned housing structures are dense. There are also new constructions in Mimar Sinan neighbourhood and Bağlaraltı - Erikli neighborhoods where public buildings and health facilities are seen. As a result, it can be said that there are structures of 10-50 years throughout the area.

Figure 3. Neighborhoods in study area

Located in the south of the area, at the point where the slope is the highest, the neighborhood of Fidyekızık is exposed to flood disaster from time to time. It is adversely affected by floods due to its inadequate infrastructure and unplanned settlement.

Figure 4. Flood disaster Fidyekizik neighborhood, Bursa [11]

In 2015, after heavy rains in Fidyekızık neighborhood, a flood disaster occurred when the stream overflowed.(Figure 4) 3-meter retaining wall of the school in the neighborhood collapsed with the impact of extreme rainfall. About 100 people at the school were stranded. The collapsing retaining wall damaged 20 vehicles. Citizens trapped at the scene were rescued by rescue teams. [11]

4 Research Method

In this study, flood risk analysis was performed in the vulnerable area of Bursa city using Analytical Hierarchy Process (AHP) and Geographical Information System (GIS) analysis techniques.

AHP is used to deal with this complex problem, since flood probabilities and consequences involve complex and interrelated factors. AHP is a framework based on mathematics and psychology. [12] Developed by Thomas L. Saaty in 1977, AHP is a mathematical theory and a method used for measurement and decision making. The scoring system used in this method is as in Table 1.

AHP includes the following steps:

1) structuring the possible factors for the problem in a hierarchy;

2) arranging factors for each alternative;

3) develop criteria for alternatives;

4) assessing the importance of alternatives; and

5) analyzing the weight of each factor.

In fact, this method is a technique for determining the priority status of multi-criteria elements of a problem in a hierarchy. Because flood probabilities and consequences involve many factors, AHP is used to evaluate complex problems. In this study, weight values were found by applying the scoring system in the table according to the risk priority of the criteria.

Table 1. Saaty's 1-9 fundamental scale

Importance level	Definition	Explanation
1	Equal importance	The two elements have an equal contribution to the objectives.
3	Moderate importance	One element has slightly more importance than the other element.
5	Strong importance	Experience and judgment strongly favor one element over the other.
7	Very strong or demonstrated importance	One element is favored very strongly (has dominance) over the other.
9	Extreme importance	One element has the highest dominance or is the most important compared to the other element.

The criteria of flood risk were determined by using the studies conducted in the literature on this subject. Oguz et al. (2016) determined the flood risk areas through multi-criteria decision making method by creating precipitation, geology, slope, aspect and land use maps in ArcGIS software. Samantha et al. (2016) created a risk map based on a multi-criteria decision approach using different data sets such as elevation, slope, distance to the river and land use. Kourgialas N. and Karatzas G. (2011) created separate risk maps for factors such as slope, aspect, distance to stream, precipitation using GIS. Then, a flood risk map was created based on the weighted calculation of these risk factors.

5 Flood Risk Analysis

In the flood risk analysis, differently from the literature, an urban area with dense built environment was chosen. For this reason, hard ground, soft ground, undesigned areas and buildings in the urban area were processed in ArcGIS environment by using satellite imagery. The stages of the analysis are as follows:

1) Physically digitizing the selected area in the ArcGIS environment: Required geographic information (slope, precipitation, ground feature, distance to the stream and aspect) was collected and the built environment was processed into the ArcGIS environment. The slope, aspect, precipitation, distance to the stream, etc. maps were created. (Figure 5)

2) Carrying out multi-criteria risk analysis within the framework of the collected data: Using the analytical hierarchy method, the risk criteria in the field and the sub-criteria of these criteria were determined and their weights were calculated. The weight values of factors such as slope, aspect, distance to stream, precipitation were entered into ArcGIS software and a risk map was created.

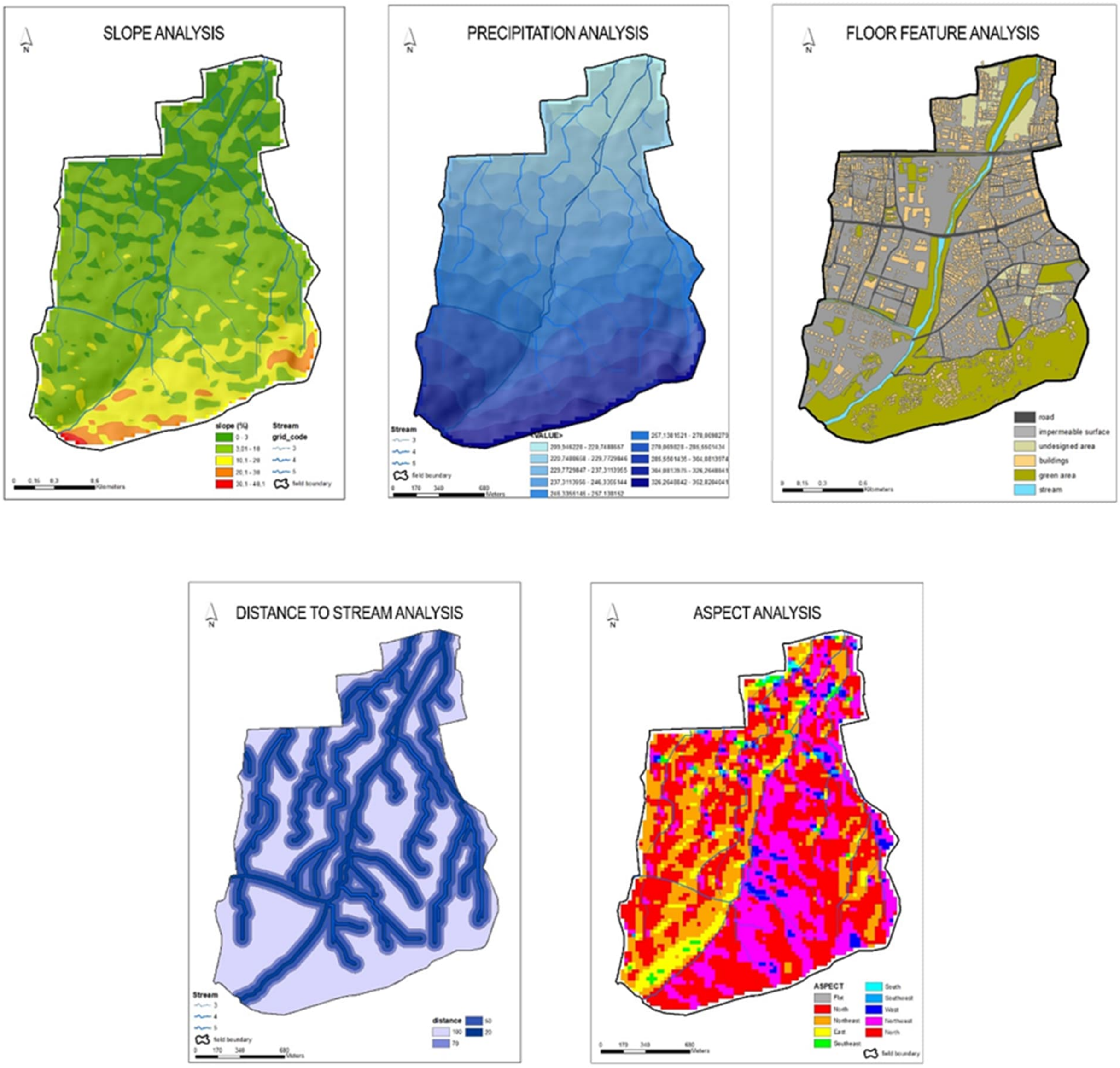

Figure 5: Field analyzes in ArcGIS

The slope, precipitation, urban ground feature, distance to the stream and aspect layers that constitute the flood risk were created in ArcGIS software using DEM (Digital Elevation Model) data. (Figure 5) For the precipitation layer, the data of 200.9 mm, which is the highest total daily precipitation that Bursa experienced in 1942, was used. For the urban surface feature layer, roads, buildings, impermeable surface, undesigned area and green areas were drawn on the satellite image and included in the calculation.

Using the data in the literature and considering the geographical-physical characteristics of the area, the hierarchy of the criteria is as follows: slope, precipitation, ground feature, distance to the stream and aspect. The weight values of these main criteria were found by scoring with the AHP method. The weight values of the main criteria and the sub-criteria belonging to these criteria are as in Table 2.

Table 2. Weight Values of Criteria and Sub-Criteria

Criteria	Weight	Sub-Criteria	Weight
Slope	0,503	30,1-40,1% slope	0,503
		20,1-30% slope	0,260
		10,1-20% slope	0,134
		3,01-10% slope	0,068
		0-3% slope	0,035
Precipitation	0,260	326-352mm	0,288
		304-326mm	0,210
		285-304mm	0,152
		270-285mm	0,110
		257-270mm	0,079
		246-257mm	0,057
		237-246mm	0,040
		229-237mm	0,029
		220-229mm	0,019
		209-220mm	0,017
Floor Feature	0,134	Road	0,377
		Impermeable surface	0,297
		Undesigned area	0,165
		Buildings	0,088
		Green area	0,047
		Stream	0,026
Distance to Stream	0,068	20 m distance	0,558
		50 m distance	0,263
		70 m distance	0,122
		100 m distance	0,057
Aspect	0,035	North	0,633
		South	0,260
		East-West	0,106

The weight values of the criteria and sub-criteria were found using the AHP (Analytic hierarchy process) method. The weight values were transferred to the ArcGIS program and the risk analysis was completed using the 'weighted sum' tool. The flood risk analysis finalised at the end of this process is as in Figure 6.

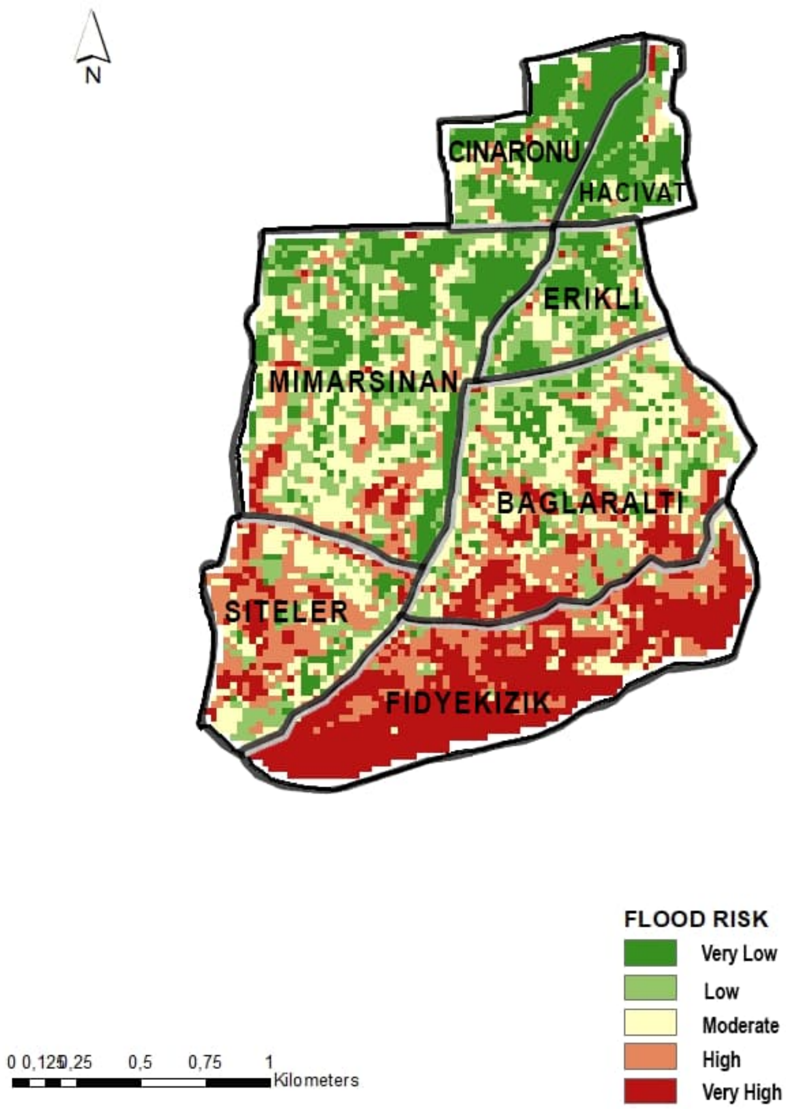

Figure 6. Flood risk analysis

6 Results and Conclusion

As a result of the analysis, it was seen that the risk is highest in Fidyekizik neighborhood on the mountain slope, where the slope is the highest, and in its immediate surroundings. (Figure 6) In Mimar Sinan and Baglaralti neighborhoods, the risk is high in areas where roads and hard ground are dense. (Figure 7) The parts where the risk is moderate are generally the garden areas consisting of buildings and impermeable ground. The locations where the risk is low and very low are the points where the slope is low and the green area is high. For example, in Hacivat and Cinaronu neighborhoods, the risk is low due to the low slope. However, it cannot be said that there is no risk for these points. Since the surface flow will move from the point where the slope is high to the point where it is less, it is possible to experience water accumulation in these two neighborhoods.

Fidyekızık neighborhood, which has a very high risk according to the analysis, is also the neighborhood where flood disasters occur most frequently. As a result, flood disasters confirm the analysis result. From the south to the north of the area, there is a general order from high risk to low risk. If the characteristics of the neighborhoods are taken into account here, the most flood-prone neighborhood, the Fidyekizik neighborhood, is the most vulnerable area because it largely contains slums and unplanned settlements. In addition, the Hacivat neighborhood is vulnerable due to the risk of water accumulation and slum type building stock. (Figure 7)

Figure 7. High-risk areas in neighborhoods

The gradual increase in the effects of heavy rains triggered by climate change in the city is the result of wrong urban policies. It is inevitable to experience disasters caused by floods due to the destruction of green cover, deforestation, wrong zoning plans, unplanned urbanization, non-compliance with the characteristics of the topography, and failure to improve the stream beds. The increase in impermeable surfaces by destroying the green texture and nature in cities and the unplanned increase in building density increase the risk of flooding. The uncontrolled increase in impermeable surfaces increases the surface flow rate of rainwater and negatively affects the natural drainage form. The water that cannot be absorbed by the soil increases the risk by passing to the surface flow.

As a result, necessary measures should be taken urgently in cities. It cannot be said that there is no flood risk for any region due to climate change. Especially in vulnerable parts of cities, the rate of being affected by disasters is increasing. Cities face these risks but have many capacities to mitigate risks. This capacity should be evaluated for each region and necessary measures should be taken before it is too late.

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URBAN REGENERATION: THE DATA FOR A PROJECT FOR THE CITIES IN TRANSITION.

Veronica Strippoli

University of Rome "Tor Vergata"
Via del Politecnico 1, 00133 Roma, Italy; vero.strippoli@gmail.com

Abstract

The representative scenario of today's city shows an urban condition studded with episodes of degradation that requires an improved transition. Urban regeneration fits into this context as a promoter of a substantial change, that lead it to become an actor of the "city in transition". The transition to the city of the future, intended as a sustainable organism in environmental terms, economics terms and social terms, requests the multidisciplinary analysis of urban space. This process appears to be a preliminary passage to the realization of the urban project programme, that it provides information about the state of the art of the city concerning its different components. Therefore, the sectorial investigations allow to identify the specific data pertinent to disciplines that establish a relationship with the territory. The research, aimed at obtaining preparatory knowledge, critical processing of analytical data emerged, thus becomes the precondition for the action of the architect. The goal is to make research converge toward the identification of concrete actions in the area, supported by specific and innovative methods. Therefore, the result of this work is summarized in the description of an analytical starting framework enriched by the empirical approach typical of the project design. A starting point that becomes a tool for the designer and for planning actions on the city. Actions aimed at the extrapolation of data connected to each other in a multidisciplinary network, able to address the project design choices. Good practices that fit into the scenario of the city in transition and that become the manifesto of an action aimed at improving the quality of life and of the open space of cities.

Keywords

Urban regeneration, urban design, social data, economics data, environmental data.

1 Introduction

Urban space is now a stage for renewal actions. The city is the tangible expression of architecture and the representation of the designer's work only when it preserves the compositional rules that have generated it. The lack of rules leads the urban space into a condition of deprivation of order which in turn flows into the loss of quality of the open and shared space. In this scenario, the place is therefore configured as a container of shortcomings.

A condition that anticipates the fate of a defaulting landscape, neglected in its formal and functional role, proliferating opportunities for decay. Such a scenario demands for repairing actions that move within a complex and articulated framework where the designer is called to operate; his task is to provide for the condition of lack that punctually covers the neighbourhoods of the city.
The expectations of the research are directed towards identifying ways of rehabilitating the "negative" fragments scattered around the city, with the eventuality of reviving places so that they become living arteries in the sleeping city.
To achieve the goal, a coordinated action is required between several sectors of scientific knowledge, relevant to the characterizations of the urban area. Therefore, the analysis of the city must be implemented through a multidisciplinary approach able to identify the territorial, social and economic peculiarities that have led to the deterioration of the urban scenario. With this aim, the survey is addressed to identify ways of researching urban data, which become a prerequisite for planning action on the city in transition. [1]

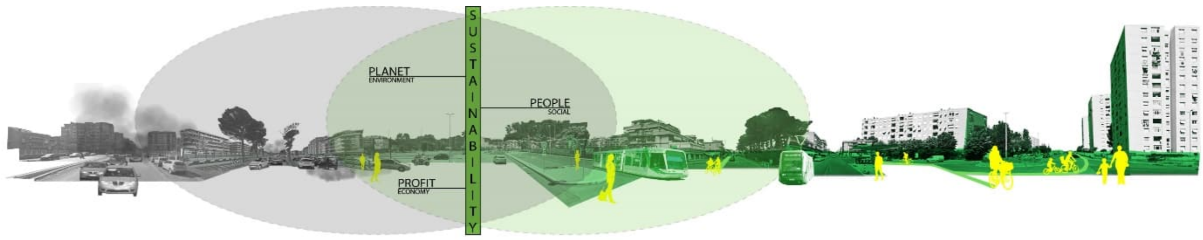

Figure 1. Urban Regeneration: a sustainable conversion process to urban high quality.

2 Urban regeneration of the city in transition

In an increasingly complex, articulated and fragmented reality of opposing urban scenarios in which the forms of the built space produce an alternation of solids and voids apparently lacking a regulating principle, the designer is called to operate.

As already stated, the preliminary urban analysis of the design concept is no longer just entrusted to the awareness of the architect but is enriched with analytical components result of the work of professionals. [2] In this scenario, the designer is supported by novice professional figures in the planning of urban interventions and keeps the role of main coordinator of the transformation of the city. As a wise observer, he is the conscious expert of the starting urban status. This awareness is the result of his acute observation, validated by scientific results of multidisciplinary urban analysis.

A scenario in which several actors operate, in which the regulatory rule can establish a line to follow for coordinated action. It is known that the regulatory instrument can give specific indications for the planning of the territory, providing a unitary starting point for the planning of urban intervention.

"Promoting, encouraging and fulfilling, to improve the quality of life of citizens, urban regeneration is understood in a broad and integrated sense, therefore, it includes social,

economic, urban planning and construction aspects, also to promote or relaunch territories subject to situations of social and economic disadvantage or degradation" [3]

As, for example, mentioned in the L.R. 7/2017 of the Lazio Region, the environmental, economic and social components are a starting prerequisite, without which there is no regeneration project for the city. The multidisciplinary nature of urban regeneration processes, in fact, is one of the prerogatives required by the regulatory instrument. It therefore represents a change with respect to the practice of urban design, so far carried out by means of territorial redevelopment interventions with mainly design characteristics.

Having said the premises, the urban project understood as a formal act result of the intellect and experience of the architect, if used exclusively, becomes an insufficient tool to respond to the multifaceted needs of the new urbanity.

The transition is an evident consequence of the exclusively theoretical and empirical approach carried by the designer. It is necessary to support the scientific analysis of environmental, economic and social data that identify and quantify the "problems" of the degraded urban space. Fundamental data for the development of a made-to-measure design of the urban place in which it is inserted. Therefore, the scientific data is an element of value introduced with the aim of avoiding new repercussions in urban decay and abandonment.

2.1 Environmental data

The metropolises are the place where the effects of climate change are manifested. The risk is evident based on the data relating to the concentration of fine dust present in the air, which is too high compared to the limits set by the WHO[1]. In the face of this evidence, air pollution is therefore one of the main problems that the city in transition must face and for this reason it is included among the Sustainable Development Goals in the 2030 Agenda of the United Nations.

"A struggle that starts from the cities, as announced by the goal number 11 of the United Nations 2030 Agenda: it is necessary to make cities and settlements lasting and sustainable. It is inevitable to think of a close relationship between environment, sustainability and the city. The urban environment plays the leading role for the consequences on the climate; cities are among the most responsible for the emission of pollutants into the atmosphere, mainly due to urban mobility, buildings and factories. To change the direction, it is necessary to start from the cities, converting them from pollution generators to urban lungs". [4]

To achieve urban quality in cities, it is necessary to improve air quality.

Cities therefore represent the most important problematic junction for climate change. The concentration of the population living there, the amount of energy that is consumed for the functioning of their economy and the very high levels of emissions make it the potentially most effective setting for all technological and organizational innovations able to proceed towards a low-carbon development perspective. With this reading key, the urban regeneration, of which the green component is a fundamental element, becomes a significant element for mitigation policies able to avoid climate-changing gasses emissions and to limit the global warming.

The analysis thus carried out on the city highlights the presence of a specific data relating to the lack of "breathable" air, indicating the high concentration of pollutants. This constitutes the basic data to be processed to propose specially made design solutions. Sustainable solutions for transport management, the increase of sustainable and shared mobility, the reforestation of cities, the recovery of abandoned casings, the recycling of resources for 70% - 80%, the energetic improvement of existing buildings as well as the adoption of policies that favour interventions in green building, use of renewable energy, represent only some of the design solutions available for the designer. [5]

A determinist approach, based on the numerical survey of quantities, which produces specific solutions and is combined with the architectural design idea, which is anything but determinist. A fruitful combination that marks only a part of the process, put in place to be enriched with further data, the result of economic and social analysis.

2.2 Economic data

Regeneration programs are a means used today for the urban economic relaunch, offering new opportunities for investment, development and work.

The path of the urban redemption was already announced in the 1980s with the programs of the territory redevelopment for the recovery of post-industrial buildings. The goal of these programs was to salvage unused artifacts and therefore the economic relaunch became a consequence of the project. Today, however, the local economic development of urban space becomes a requirement for the city regeneration programs. The centralization of the economic issue consequently leads to functional and functionalist choices that bring to the relocation of urban and commercial services in a widespread manner throughout the territory.

The transition today takes place according to the principles of circular economy, directing urban policies towards building recovery and the reuse of available resources, thus overcoming the linear vision that has accompanied the era of development of the last century. The RESOURCE-USE-WASTE system is abandoned in favour of the RESOURCE-USE-REUSE system, in which waste becomes a resource. It is therefore clear that the economic choices are closely related to the design and environmental issues, highlighting the need for a decrease/cancellation of the use of resources in favour of a policy focused on sustainability.

We therefore speak of sustainable economy, the result of the combination of solutions aimed at solving multidisciplinary problems. A new vision of economy that goes beyond the concept of ownership and places the "sharing" at the centre of its development policy. A system that responds to the need to find innovative solutions to today's urban challenges, in contexts marked by congestion, overcrowding and incorrect management of spaces and resources. The choice of a sustainable economic policy is articulated by the mandatory problem in cities linked to the waste of resources. Hence, these conditions necessarily represent a data to be included within the regeneration process of cities.

The project design of urban places is therefore called upon to act according to these new economic-environmental guidelines. The designer's task, hence, is to rework the economic data and provide design solutions aimed at introducing activities and services for the reactivation of the local economy. For this purpose, investments must be directed to cities, for the enhancement of the urban environment and the historical and cultural heritage in an economic-financial key.

Through this process the city is converted into an attractive place and becomes the product to be "sold" to investors. Therefore, the urban project, from a competitive perspective, is expressed as place identity and place branding[2]: the urban areas have their own recognizable identity. The more the identity of the place and the characterization of the urban area will be defined, the greater the interest from investors will be. In addition, the project idea must be supported by an economic plan that guarantees the self-management of the project intervention over time. Therefore, the interest shown by the investors in such complex programs is evident as they present themselves as complete and economically self-sufficient programs for the upswing of the local economy of the city. [6]

Following these assessments, it is therefore possible to identify a double potential in the city: on the one hand, fertile ground is being prepared for public-private investments in the urban area in view of sustainable economic development; on the other, the possibility to activate the place through the induction of attractive functional and commercial activities is realized.

2.3 Social data

The shared open space reflects the public social life of the citizens who gravitate around there. The urban regeneration of physical space is also social regeneration. It is in fact known the importance of including city users in the urban programs and how sharing and participation can activate processes of reappropriation of public space.

The use of urban space allows to convert the phenomena of abandonment into functional opportunities for public activities, thus contrasting the opportunities for urban and social decay. The tool available to the designer, to respond to the requests of the city users, is provided by the administrations and associations that operate in the territory in these terms. Governance processes are therefore adopted, which move away from the purely urban planning issue and become coordinators of a multidisciplinary scenario. [7] An urban policy in which government and administrations cooperate with the private sector, through forms of active citizenship[3] in which new public and private stakeholders are directly involved. A collaborative model among institutions results of the citizen's participation[4] process in the transformation of the city.

According to the researcher Archon Fung[5], the participation processes must be pondered on different phases, which allow to identify the right segment of citizens able to give specific directions to approach the design choices towards the real expectations of the users. The characteristics of the “typical citizen” can’t be codified, as their definition is affected by variables linked to the peculiarities of an urban space intrinsic to it or associated with it; they change according to the identified problems, to the goals to be achieved and to the recipients of the intervention. This method of identification and selection allows to carry out a mapping of stakeholders divided by subgroups, according to age, gender, interest and usage methods of the open space. The aimed choice of the subjects of participation is directed to extrapolate the empirical data, the result of the experience of typical citizens. Hence, the representatives of the different indicated subgroups permits to identify the problem of the use in its several hints and therefore to be able to offer a complete solution.

Figure 2. “Typical citizens” giving direct or indirect information for city transformation.

The interaction between designer and city users takes place in two main ways, distinguishable in direct participation models, in which the stakeholders actively participate in the decision-making processes and in the indirect participation methods, where the city user provides his own contribution in an implicit form.

In the direct participation processes, we mainly identify two categories of face-to-face meetings:

- one-off, considering only one meeting with stakeholders, generally at the beginning of the program. This methodology includes assembly meetings, in which city users offer input for the development of the program according to the expressed goals; or through an extended meeting, including workshops lasting several days, in which stakeholders offer their contribution for the development of an interdisciplinary program together with experts and administrations;
- repeated in conjunction with the co-governance process. This category includes the assembly meetings organized in the preliminary, intermediate and final stages of the implementation of the program, in which city users are informed of developments and offer their contribution for any improvements; meetings that can also be addressed to different stakeholder groups for the different phases. [8]

The methods of indirect participation are added to the assembly methodologies seen, which can be achieved by means of:

- questionnaires and tests aimed at selected groups of city users, in which citizens as beneficiaries of the urban space offer their contribution in relation to functional and service issues, offering a complete framework of the knowledge of any needs and problems of public space.
- targeted cognitive processes, adopted by industry experts such as architects or sociologists, who observe the activities of the city user by investigating for the search for relational information between the user and the urban space.

The adoption of a direct participatory process does not exclude the possibility of following an indirect process, the two methods do not cancel but complement each other and coexist. [9]

The elaboration of the empirical data is carried out by the designer, the person in charge of reading and re-elaborating it in a critical and investigative key. Through a process of identifying and synthesizing of the instances revealed by the data, the designer can extrapolate a formal solution. A practice that develops for each single data and traces back to a network of interconnected solutions, which will all be included in the proposed urban project.

The process is therefore identifiable and it is divided into three levels: a first phase of collecting information from the typical citizens, which allows the identification of the main empirical data; a second step, which, as seen, is carried out by the designer, involves an analytical process and an investigation of this data, which leads to the synthesis in precise solutions to the requests that have emerged; the last phase, again by the designer, considers the collection and inclusion of the solutions identified in the project design. For the last step, a sensitive approach is required, full of compositional regulatory precepts of the urban project. It is necessary to consider the risk, the design product must prevent it from becoming the outcome of a determinist process, keeping the emotional attitude typical of the design process. [10]

3 Conclusion or starting point?

The executed study has produced results deriving from the environmental, economic and social analysis of the urban space which, as announced, constitute the starting point for the development of the program. The revealed data are the pieces of a puzzle that, combined, give rise to an intervention scheme that acts on the city and for the city, capable of filling the specific gaps that the exclusive design vision risks not to consider. Therefore, the analytical data represents an added value for the urban project and its critical and empirical elaboration by the designer allows to produce a complete design product in several disciplinary variations.

In this sense, the project becomes the container of formal solutions to the information derived. It is evident, in fact, how the urban project can respond to critical issues, as a manifestation of binding wounds, formalized in the lack of supporting architectures, transferring the problem from function to form.

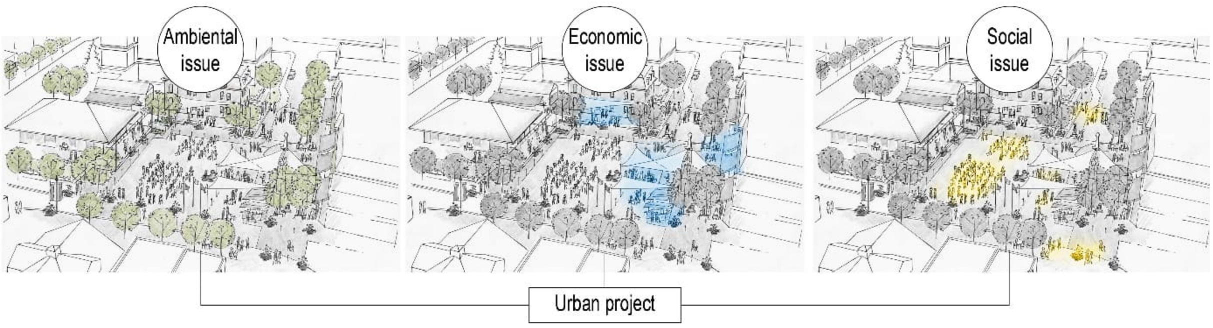

Figure 3. The urban project is like a container of multidisciplinary issues.

The process for its early-stage alternates between purely analytical phases, relating to the study of the status of the city, up to the conclusion with the critical evaluation, purely empirical and full of sensitive meanings, resulting from the design experience. A non-determinist process that underlines the traditional craftsmanship of the urban project.

In the examined process, the urban regeneration project, therefore, promotes a holistic vision of the intervention, which avoids specialist prevalence in favour of a policy of interaction between knowledge. The urban project, which has always been adopted as a means for the formal transformation of the city, now finds itself covered with a new role, flanked by new protagonists.

The prerequisites for intervention, shared by the city regeneration programs adopted today, therefore seem to have their roots on a ground made up of multidisciplinary requests and interdisciplinary connections. The evaluated factors become the starting point for the urban research because they allow to offer a design project that aims at solving the real problems of the city. This represents the starting point of the design research as the main trigger of transformations for the city in transition, aspiring to create new resilient urban scenarios.

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[1] The World Health Organization define the limit for the fine dust to PM 2.5.

[2] Guy Julier defines the city as place identity and place branding. The city is "sold" through marketing actions to investors; with this aim, it's necessary to adopt development policies and branding programs to make the city attractive for the investors.

[3] "Active citizenship means the ability of citizens to organise themselves, to mobilise human, technical and financial resources, to act in public policies in different ways and strategies, to protect rights and to take care of the common goods, exercising powers and responsibilities to that end." [11]

[4] "The participation process is a powerful monitoring tool as it establishes a channel of communication between those who carry out the transformation and those who suffer the effects. Through this link, the administrator can pick up the signs of conflict, ineffectiveness and redirect his action." [12]

[5] Archon Fung is an expert on citizen participation in architectural projects. He defines the characteristics of a "typical citizen" through three phases: finding the features of the typical citizen for the participatory process, choice of criteria for the selection of participants and identification of the modalities of interaction between citizens and administrative bodies.

CREATING A HEALTHY & PRODUCTIVE ENVIRONMENT FOR TRADITIONAL CRAFTS: A CASE OF SAHARANPUR WOODCARVERS

Vaibhav Kumar BANSAL, Parul

Aayojan School Of Architecture
Poornima Marg, Sitapura, Jaipur, Rajasthan 303905; info@aayojan.edu.in

Abstract

In this era of technology, a high-quality working environment is imperative in all fields. However, providing quantity rather than the quality of work environments is very common in most of the developing countries. The same goes for indigenous and traditional crafts workspaces across India. Such is the case in Saharanpur city, popularly known as the '*Sheesham wood village'*, which is home to some of the country's finest woodcarvers. Internationally renowned, the city is synonymous with intricate and fine workmanship-oriented craft and its artisans have been creating magic with wood since the Mughal era. Nevertheless, the conditions under which they work are of poor quality and impact their health in later years. Hence, this study was undertaken to analyse the effects of lighting on their work performance and enhance the quality of spaces under optimal conditions to improve their productivity via creation of a healthy work environment.

Multiple workspaces were investigated for existing lighting conditions of their working period and activities with regards to anthropometry and ergonomics. Customized questionnaire surveys along with on-site observations and illuminance distribution measurements were also conducted in these workspaces. The findings indicated poorly lit spaces and the observed illumination values were even below the recommendations by the country's national lighting code.

This research by both qualitative and quantitative methods validated that an abysmally articulated work environment negatively affects artisans' work efficiency and wellbeing by exposing them to occupational diseases. Henceforth, design solutions were given for optimal lighting for a healthy and productive work environment.

Keywords

Traditional woodcraft, Saharanpur, Work Efficiency, Illumination, Design guidelines

1 Introduction

Saharanpur, a city in India, popularly known as the '*Sheesham wood village*', is home to some of the country's finest woodcarvers. The city is internationally renowned for this intricate and fine workmanship-oriented craft as the way artisans tell the customers and show their work is about bringing dead logs alive. The vine-leaf patterns are a specialty besides the geometric and figurative carving and brass inlay work. Materials like iron, ceramic, and glass are used along with wood as a contemporary addition to this traditional craft. Originally, this craft was practiced in Kashmir where abundance of walnut trees allowed for intricate carving. Subsequently, during the Mughal rule, this craft travelled to Saharanpur, where now complete neighbourhoods (*Mohallas)* accommodate wood carvers' clusters (refer figure 1).

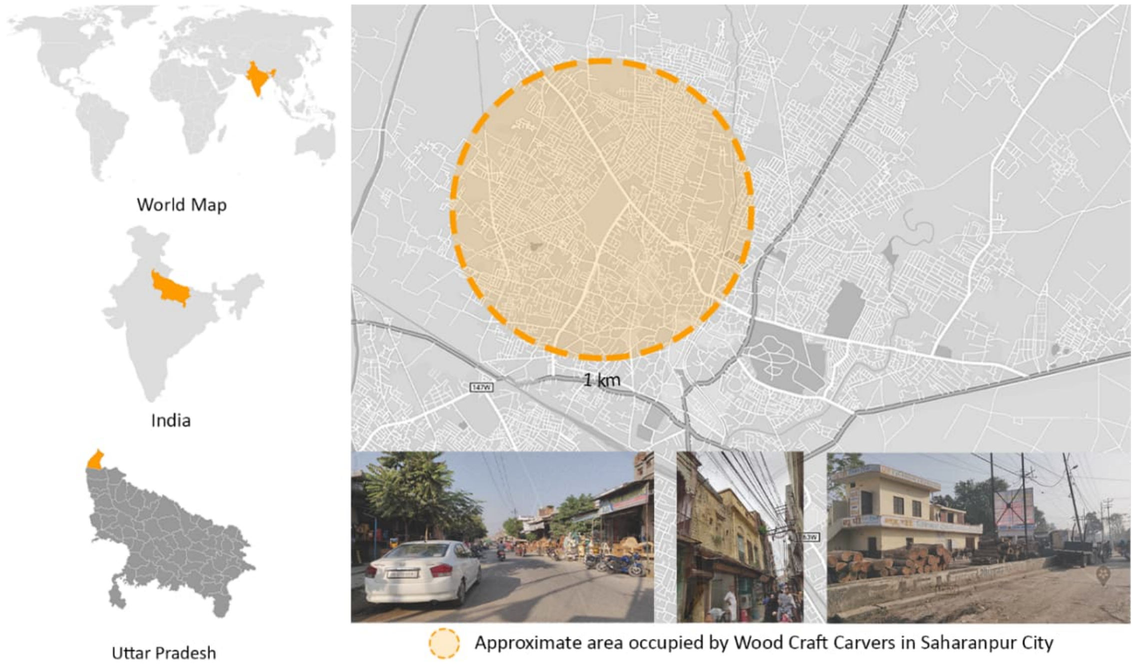

Figure 1. Location of Saharanpur City & the Wood carvers cluster therein (Source: Author)

This study was undertaken to study the craft, related artisans' workspaces and thereafter analyse the lighting quality's effects on their work performance. Furthermore, design solutions were devised to enhance the spatial quality under optimal lighting conditions to improve the woodcarvers' productivity. Hence, the objectives formulated for the research were (1) to document and understand Saharanpur's wood carving craft process. This was followed by (2) analysis of lighting conditions of carvers' workspaces, work hours with regards to anthropometry and ergonomics; around the year (refer figure 2). In addition (3) the observed data was compared against optimal lighting standards and details with regards to wood carvers. Ultimately, (4) Design solutions and strategies were formulated to create optimal lighting environments to enhance the artisans' efficiency and productivity.

Figure 2: Workspaces showing craft process & the working conditions (Source: Author)

2 Saharanpur Craft process

Saharanpur wood craft products are widely exported to European countries such as Spain, Germany, France, U.K and the USA. The range of products are furniture, home decor, lifestyle accessories, toys, and sculptures, etc. Essentially the wood used for this traditional craft is sourced from Mango, Sheesham, Teak and it involves five work categories namely Carpentry, Engraving, Polishing, Inlaying, and Assembly. The artisans under these categories have been termed as the primary work category as shown in the figure 3. All the three initial steps are time intensive and require intricate and fine workmanship which in turn is also dependent on the type of product, design, materials to be used besides wood, and degree of detail.

Figure 3: Saharanpur Wood Carving process (Source: Author)

3 Methodology

In line with the stated objectives, multiple workspaces around Saharanpur were identified and investigated to study the existing lighting conditions in the artisans' workspaces. Alongside the craft itself, associated work practices, processes, persons engaged, their working hours, were also studied to determine the allocated spaces' footprint and quality. Physical observations and illuminance distribution measurements were also conducted in workspaces to understand the existing lighting condition. Customized questionnaire survey for a sample of 104 artisans was conducted to find out their perceptions about lighting standards in the workplace and its influence on their health and work productivity. The same has been tabulated with parameters and data sources as given in the Table 1.

Table 1: Analytical Data Framework (Source: Author)

S. No.	Objective	Data Required	Data Source
1	To document & understand Saharanpur's wood carving craft.	1. Historical Background. 2. Process of carving.	Primary: Interviews Secondary: Books, Films, etc.
2	To analyse lighting conditions of carvers' workspaces, work hours with regards to anthropometry & ergonomics.	1. Working hours in natural & artificial light in various seasons. 2. Working conditions within the workspace. 3.User experience	Primary: Case studies, Survey, Interviews of Carvers Secondary: BIS, NBC, NLC, Books, Research papers.
3	To compare the observed data against optimal lighting standards and details with regards to wood carvers	1.Lighting & furniture standards 2.Modeling and simulation 3. Building Details w.r.t lighting	Primary: onsite surveys and visual documentation of different workspaces & Artisans' Interviews.
4	To explore and recommend design solutions and strategies for optimal lighting environments to enhance the efficiency and productivity of wood carvers.	1.Data Interpretation of the observed dataset and findings	Author

4 Results

Through the study it was found that the Saharanpur Wood craft involves five work categories as stated previously. Additionally, there are other small processes such as buffing, sanding & nailing, and many other smaller worker categories who are engaged on a product to product basis. Artisans under these categories either work individually or on a contract basis or they work under manufacturers or exporters. Further, details have been discussed for parameters related to workspace, work hours, lighting conditions and its impact on the artisans, etc.

4.1 Work hours

The average working hours for the primary work category are 8-10 hours, usually from 09 am to 07 pm in summers and 09am to 05pm in winters. Artisans working individually work around 10-12 hours per day or depending upon the workload, however they work mostly on a contract basis. Manufacturers and exporters work about 10-12 hours per day and at a time of high demand, it gets extended up to 14-15 hours. Artisans working under manufactures and exporters work around 8-10 hours per day and are either paid on a monthly or contract or daily basis. (refer figure 4)

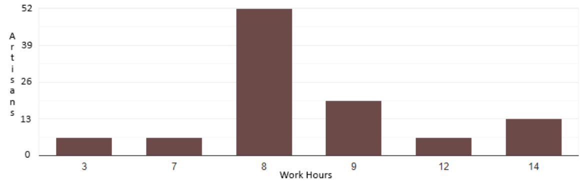

Figure 4: Graph showing the work hours for Artisans (Source: Author)

4.2 Artisans’ Working Efficiency

As observed around the year, during various seasons, pre-festival periods, and supplemented with the survey findings, it was found that the artisans are generally not physically affected by the aforementioned. Rather they have a psychological impact on the artisans’ psyche thus leading to low or high work productivity (refer figure 5). Via survey it was also found that the best working period for the carvers is 3-5 pm when they get off the work and are thus motivated to speed up the assigned task for the day.

Figure 5: Pie Chart showing the impact of seasons & pre-festival periods (Source: Author)

4.3 Natural & Artificial Lighting conditions

According to the interviews, 68.8 % of the artisans face major issues regarding the amount of natural or artificial lighting. In contrast to this, the manufacturers or exporters have no issues regarding lighting conditions. However, despite being the owners of these workshops, they are least interested in addressing the issues faced by the artisans, as it will be an expensive affair from which they will not be directly impacted.

4.4 Impact on Health due Lighting Conditions

According to the interviews and surveys, it was found that continuously working for 12-14 hours in low lighting caused eyesight related issues such as a slight decline in vision or diseases like ophthalmoplegia, double vision, etc. Other problems consisted of irritation, poor concentration, repeated need of breaks, etc. Survey results also indicated that lack of awareness related to the impact of lighting on working environments had young or semi-skilled artisans respond that they do not have a problem as they are from the labour force and their problems will not be resolved. In opposition to this the experienced and skilled artisans (majorly aged 45+ years) (13%) wanted to get these issues resolved as they either had been suffering or had started to see the negative impact of the poorly lit workshops.

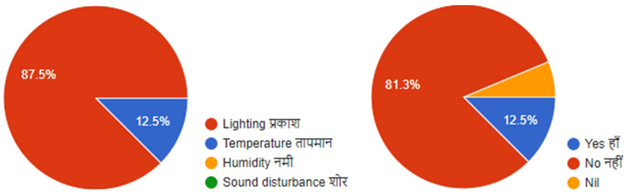

Figure 6: Pie Chart showing Impact of Lighting, Temperature, Humidity, Noise on Artisans' Productivity & Efficiency (Source: Author)

4.5 Lighting Conditions & Artisans' Productivity & Efficiency

Part of the survey also focussed on artisans' working efficiency and productivity with regards to lighting? The results showed that 87.5% of the artisans are severely affected by poor lighting conditions in their workspaces. Over the period of time their vision is impaired and they suffer from various diseases as well. The poor lighting conditions were due to apathy of the owners, regular power cut and improper or insufficient lighting provisions. However, they are accustomed to changes in temperature, humidity and noise during working hours, for which it was also observed that their workspaces had little or no provisions such as lack of dehumidifiers or noise blockers etc., as indicated in the figure 6.

5 Conclusions and Recommendations

5.1 Conclusion

Based on the above results, the research can conclude that the involved artisans or wood carvers usually work continuously for 8-10 hours a day in low or poor lighting conditions. Workspaces are in bad condition as they are either rented properties or if they are self-owned then the manufacturers/ owners are disinterested in providing a good working environment to the carvers. Beside lighting and ventilation, the space allocated was also inadequate with regards to the number of artisans' in the workshop as illustrated in the figure 7. Either it was on the grounds of space for the process to be performed and the number of people involved, machinery and equipment, storage of both raw material and finished product, etc. in few cases artisans were even performing the task on the sidewalks thus encroaching the public street space. The spaces were thus also affected by the seasonal changes and had an impact on artisans' working efficiency.

Although the intricate Saharanpur wood craft requires a good lighting approach the workshops were also found to not have any specific luminaire and light typologies. The owners had equipped the workspaces with either candescent bulbs hanging from naked wires or simple LED tubes just above where the task is to be performed. All the same it was done with no prior knowledge of light intensity or by roping help from an architect or lighting consultant. The arrangement was purely on the need and easy on pocket basis. Poorly lit workshops had sharp contrast in light levels, because of which artisans had been suffering with eye strains, blurred vision, stress, fatigue and other permanent health issues. These concerns were further supplemented with regular power cuts during the working hours and lack of power back forced the artisans to work in adverse environments.

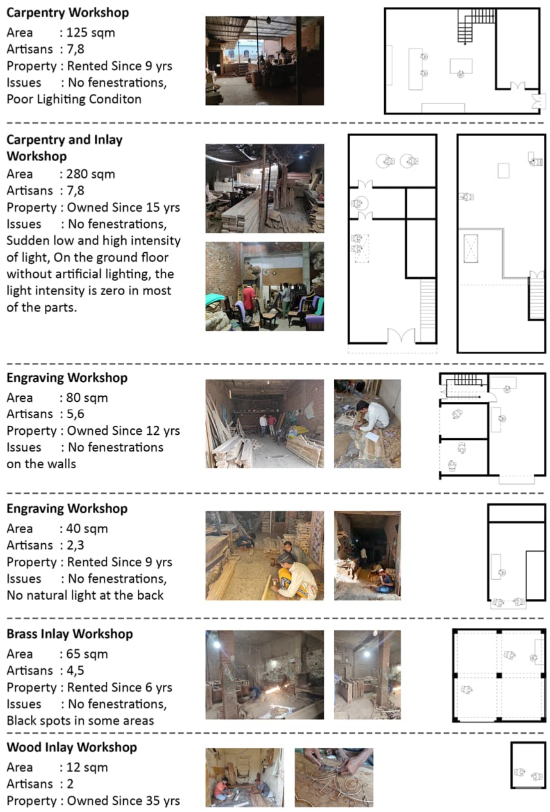

Figure 7: Workspaces showing spatial extent, layout, and issues (Source: Author)

5.2 Design Recommendations for Existing Workspaces

5.2.1 Light Well

After studying the workspaces, it was deduced that there is very less scope of fenestrations in walls due to compact neighbourhood fabric. Hence, as shown through figure 8, in existing structures, light wells can be incorporated to get natural light and eliminate sharp contrast of extreme high-low lighting levels. Light wells when used in a combination of natural and artificial lighting can increase the workers' productivity.

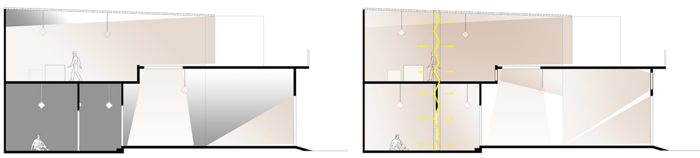

Figure 8: Light wells in existing workshops for Saharanpur Woodcarvers (Source: Author)

5.2.2 Skylights

In existing workshops, skylights can be a good design solution if used with double glazing at a certain distance with a combination of artificial lighting. In addition, small light punctures in a grid can act as LED lights and create an optimal lighting solution. (refer figure 9)

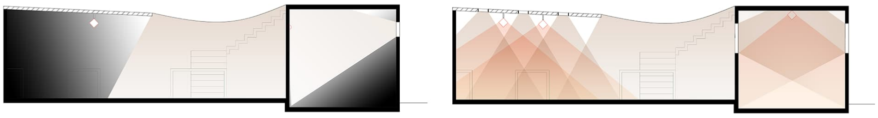

Figure 9: Incorporation of Skylights in existing workshops for Woodcarvers (Source: Author)

5.2.3 Blinds

As per the survey results, some of the artisans quoted that they face glare issues because of the orientation of the workspace as their area is very small so they cannot avoid this problem. Thus, excessive amounts of natural light and glare in small spaces can be controlled via blinds and these will be beneficial for different weather and sky conditions to control light levels for the artisans as indicated in the figure 10.

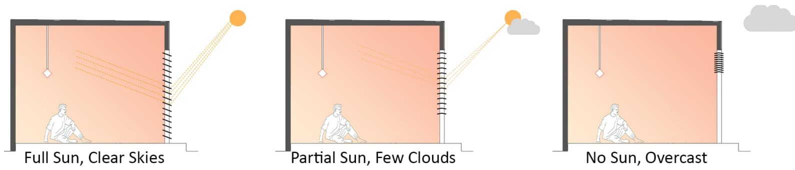

Figure 10: Usage of Blinds in existing Saharanpur Woodcarvers' workshops (Source: Author)

5.3 Design Recommendations for Potential Workspaces

5.3.1 Location & Orientation

It is critical that a building be designed in such a way that it blends in with the site's location and natural as well as built context. The orientation of the workspaces has to keep in mind following considerations:

South Facade: Light distribution on building's southern side is generally uniform and is thus the most appropriate surface for admitting light especially in high altitude areas. In the case of Saharanpur, the issue of surplus solar gain in the summer can be resolved by usage of overhangs which in turn can help maximise the potential of fenestration on the southern facade. Therefore, this direction is recommended for admitting light in workshops where intricate work has to be done such as engraving and inlay work as these processes need around 1000 lux for working. [4]

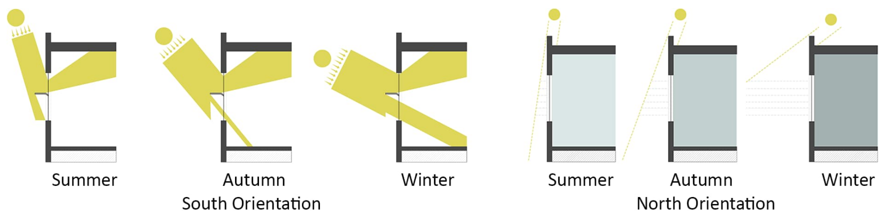

Figure 11: Fenestration designs on South & North facades for potential Saharanpur Woodcarvers' workshops (Source: Author)

North Facade: The northern facades receive uniform diffused and low amounts of natural light. For Saharanpur wood carvers' workspaces wherein carpentry, assembling, or polishing are to be performed, openings in this direction are ideal. In the workshops on the northern facade, maximum fenestrations could be provided for allowing diffused or ambient lighting in the space. These tasks require 300-500 lux and can be combined with ambient lighting as well for accurate light levels. [4]

East & West Facades: These facades receive only half-day sunshine exposure, and the light changes throughout the day. As a result, optimum fenestration design here is more complex, and the facades will also have to endure undesired summer heat gains while giving little passive solar contribution in the winter. Consequently, the size and number of openings should be kept to a minimum along with controlling light ingress with vertical screens. This approach is suggested for assembly and storage processes where minimum light is needed.

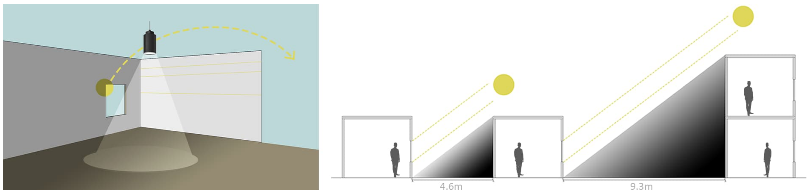

Figure 12: Orientation & Built Block Organisation for potential Saharanpur Woodcarvers' workshops (Source: Author)

Built Block organization: In winter solstice angle is 37.5 degrees, so according to calculations length to height ratio should be 1.3. To gain direct sunlight, if a one-story building is 3.5m then the distance between these two blocks should be 4.5m and if a two-storey building is 7m then distance should be 9.3m as illustrated in figure 12. The organization also depends on other factors like sill and lintel level and orientation of the block etc. which can be calculated through sun study.

5.3.2 Spatial Dimensions

Size and shape of the space to be lit influences how many skylights or windows are to be incorporated and where. This is in order to achieve the desired illumination as some lighting systems are impractical in small spaces, while others may not function well in large spaces. (refer figure 13). These can be mitigated via designing windows with shading devices (fixed or operable) thus rendering optimal lighting solutions for workspaces. For the same, windows depend upon the orientation of the space as well as Window to Wall ratio. This can be calculated by using the following formula [5]:

$$WWR = \Sigma \text{ Glazing area} / \Sigma \text{ Gross exterior wall area}$$

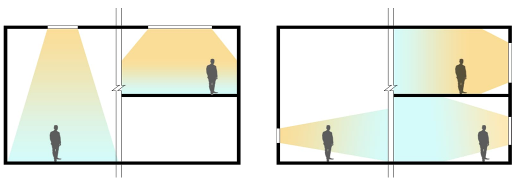

Figure 13: Skylights & Windows in Woodcarvers' workspaces (Source: Author)

5.3.3 Illumination Level

Adequate or optimum lighting is another imperative parameter in a space as it allows the user to clearly see the immediate context and efficiently perform various activities. Thus, it is necessary to create a space with the best possible lighting solutions. As Saharanpur lies in a composite climate, having all types of weather patterns, it is difficult to maintain the desired average value of lux levels but it can be calculated and simulated to achieve the best possible solution. Table 2 can be referred for desired lux levels for the woodcarvers' workshops.[4]

Table 2: Illumination Requirements as per National Lighting Code, India

Area	Average Illumination (Lux)	Limiting Glare Index
Engraving	1000	19
Rough Sawing and Bench Work	150	22
Rough sanding, Sizing, buffing	200	22
Fine bench work, finishing	300	22

5.3.4 Colour of Light:

As known, the appearance of the vertical and horizontal surface colour entirely depends upon the colour of the incident light. For woodcarvers' workspaces the light composition should be such that the colour appears natural and is same, under both natural and artificial light. Daylight fluorescent luminaires allow for pocket friendly illumination even for large spaces with artificial daylight giving good colour render at a sufficiently high level. The natural white light of 4000K as indicated in the figure 14, is recommended for working and it is recommended that the source of natural and artificial lighting should be the same.

Figure 14: Colour of Light for Woodcarvers' workspaces (Source: Author)

5.3.5 Colour of Enclosing Surfaces:

The light reflected from the walls and ceilings provide illumination in any space. White walls and ceilings reflect more light as compared to coloured ones (refer figure 15) hence, white walls are recommended for better concentration of work in woodcarvers' workshops.

Figure 15: Colour of Enclosing Surfaces in Woodcarvers' workspaces (Source: Author)

6 Discussion

Scores of the literature have reported that poor indoor environmental quality such as lighting has a harmful effect on human health, and in the case of wood-carvers, it has adverse effects on their work performance as well. This study has examined the effects of lighting quality on the working efficiency of workers in different workspaces of different categories of artisans in

Saharanpur, Uttar Pradesh, India. Primary survey results, on-site measurements, and the authors' observations have indicated that artisans are not satisfied with their workspaces' lighting environment and its quality was insufficient for healthy work conditions. Visual destructions such as glare discomfort, lighting flicker, sharp contrast, etc. and the occupationally induced health issues such as eyestrain, headache, teary eyes, back pain, etc. were widely reported.

Furthermore, the research identified that poor lighting design techniques, use of outdated lighting fixtures and makeshift lighting, not adhering to different task lighting requirements, absence of local lighting codes and governing regulations, poor use of the concept of room index ratio, no scope for natural lighting, and poor choice of lighting luminaires were the factors which contributed to inadequate lighting in the surveyed woodcarvers' workspaces. Other factors were lack of public awareness about the ill-effects of inadequate lighting on working efficiency and human health, poor periodic maintenance, and services of the lighting systems, which resulted in accumulated dirtiness around the luminaries and dilapidation of the lighting infrastructures.

Therefore, this research recommends further investigations about the appropriate working environment of the workspaces in Saharanpur's wood carving industry. Lastly, besides the given remedial measures for the observed lighting environment defects in the study area, this study also suggests that the Indian Union Government's Ministry of Culture and the respective state government should foster the process of setting up and enacting local construction codes to govern and regulate the construction industry to safeguard its citizens and help them emerging from poor built environments and unhealthy work surroundings.

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A NEW READING OF THERAPEUTIC ENVIRONMENTS: BIOPHILIC ELEMENTS IN MAGGIE'S CENTRES

Bekir Huseyin TEKIN*, Rhiannon CORCORAN, Rosa URBANO GUTIÉRREZ

University of Liverpool
L69 7ZN, Liverpool, United Kingdom; B.Tekin@liverpool.ac.uk

Abstract

This paper discusses a meta-synthesis conducted to identify, compare and synthesize the published qualitative literature on a paradigmatic example of non-institutional cancer support centres, Maggie's centres. These centres are well known for their uniquely designed buildings and curated spaces, where architecture and gardens have been at the heart of the centres' philosophy since their inception, with the aim to provide a clear agenda that supports bespoke healing environments. Previous research has thoroughly analysed this unique approach to therapeutic environments, not only confirming the importance of designed space as originally conceived by Maggie's but also identifying precise values associated with specific elements within their design. The compilation and examination of all these data through the lens of biophilia contributes to our understanding of the role of nature in cancer patients' lives. The comprehensive representation of cancer patients' nature experiences, permitted the identification of critical values and design opportunities, crucial to guide future research and therapeutic environment development.

Keywords

Biophilic design, Therapeutic environment, Maggie's centres

1 Introduction

The World Health Organization (WHO) defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" [1]. The concept of therapeutic environments implies that the atmosphere of healthcare facilities can affect the patient's recovery period or adaptation to particular acute and chronic conditions [2]. Healing environments are not only places where patients are treated with the most advanced medicine and technology, these should also be places that support their users (staff and patients and their families), in psychological, emotional and social terms [3].

The importance of these environments was widely accepted after Florence Nightingale, a trained nurse, asserted her observations during the Crimean War in the mid-19th century. Nightingale's principles outlining the design of wards included considerations in relation to the natural elements, quantity of windows and daylight quality, bed placement and space layout, atmosphere and spatial quality, comfort related to heating and ventilation systems and materials and colour [4].

Nightingale’s principles were followed in the late 19th and early 20th centuries, however, with the advent of the germ theory, the environmental approach to health became exclusively focused on healing with medical interventions and surgery [5]. Today’s “mega hospitals” [4]or “mall hospitals” [6] have centred their efforts on achieveing efficiency and satisfactory hygiene standards and controlling the emergence and spread of infections, disregarding other considerations, such as the inclusion of nature in the built environment, which was historically present in the typology [5], [7]. Charles Jencks, architect and co-founder of Maggie’s Centres, described this type of health facility as a factory-hospital, where the relevant medical and technical resources are dedicated to mass health, and expressed the need for non-clinical, human-centred therapeutic centres [8]. The success of these centres together with recent research on the field, have brought to the forefront the need to include other parameters in our design briefs, where the role of nature, and with it the application of biophilic design, seems paramount.

The emergence of biophilic design as a discipline refers to the innate human connection to nature and natural processes to promote health and well-being in the spaces we inhabit [9]–[11]. The principles that define biophilic design can be examined from three different perspectives: as established in building regulations and standards, as used in design practice and as investigated in research practice. When examining each of these areas, we can find several issues and disconnections. In practice and regulatory frameworks, we can observe the use of an unbounded design framework that is not underpinned by scientific facts, do not prioritise principles or parameters, and even considers as a design intervention the use of disparate evocations of nature that do not hold a meaningful sustained connection. In scientific academic environments, there is abundant research on many of the different aspects of biophilic design, but all of this in-depth research providing scientific facts about the importance of nature on humans has happened separately or for a specific design parameter, and not in a holistic way. Thus, the ultimate goal of this research study is the redefinition of a holistic and scientifically underpinned biophilic design framework, with a focus on therapeutic environments. This research also aims to hierarchise the parameters included in the new framework in a way that can more efficiently guide designers, revealing which are the most critical for promoting and supporting human health and wellbeing in therapeutic environments.

The work presented in this paper was developed within this general framework, and will specifically discuss the role of biophilic design in therapeutic environments in the case of Maggie’s centres, as paradigmatic examples of non-institutional therapeutic centres for those who are affected by cancer. In particular, it will focus on the role of biophilia to satisfactorily affect two of the most prominent characteristics of these centres, as ‘welcoming’ and ‘relaxing’ environments.

These centres are well known for their uniquely designed buildings and curated spaces. Architecture and gardens have been at the heart of the centres’ philosophy since their inception, with the aim to provide bespoke healing environments. This original belief led to the creation of a distinctive architectural brief [12], and the careful consideration of designers, to develop an extensive national and international network of centres. Previous research has thoroughly analysed this unique approach to therapeutic environments, not only confirming the importance of designed space as originally conceived by Maggie’s, but also identifying precise values associated with specific elements within their design [12]–[18].

2 Methodology

This research aimed to investigate Maggie's centres architecture from the users' and the designers' perspectives, assessing their experiences of the building and their design intentions. There is previous research on these centres which included ethnographic studies (interviews, focus groups, observations, questionnaires) but had been done from different standpoints. Thus, a great amount of qualitative data was lying in all these publications which had not been analysed through a biophilic lens. Particularly, direct quotation speeches of users and architects, obtained via interviews and focus groups, may be considered as primary data as they have not been processed by other researchers. Although this methodology examined all the architectural and biophilic design parameters, this paper mainly focuses on the welcoming and relaxing effect of Maggie's centre architecture on patients and their families.
The meta-synthesis methodology followed a systematic search strategy, an analytical data extraction and classification, and an interpretive result analysis. Initially, scoping searches were conducted in December 2020 to provide an overview of relevant literature and insight into the framed draft of databases. The review protocol was designed in the light of the scoping searches (Table 1).

Table 1: Searching protocol.

	Inclusion Criteria	**Exclusion Criteria**
Population	The patients, staff, visitors who used these therapeutic spaces on a regular basis, and designers of any Maggie's centres	Others
Nature of the Intervention	Maggie's Centres	Others
Comparators	Architectural and biophilic design parameters	Others
Outcomes	Direct quotations for Maggie's architecture	Studies that examine only one or inadequate number of patterns.
Cultural / Linguistic	English	Non-English
Time Period	1996 to current	Pre-1996
Study Design	Qualitative Any primary comparative study	Reviews
Types of Documents	Academic journals, conference material, theses, and architectural magazines and books	Architectural news
Databases	Scopus, Web of Science, JSTOR, ProQuest, ScienceDirect and Ebscohost	
Searching Syntax	"Maggie's centre" AND (architecture OR building OR design OR environment).	

The main search was conducted on 14th December 2020 on six databases decided. The language was limited only to English, and the searching period goes from 1996 (when the first Maggie's Centre was opened in Edinburgh) to the searching date (14th December 2020). A total of 97 publications were exported to Rayyan QCRI, a systematic review software, developed by Qatar Computing Research Institute, that helps accelerate the initial screening of abstracts and titles using a semi-automatised process [19].
After removing 10 duplicates via this software, an initial screening was done by reading abstracts and checking full-texts in some particular cases. Thus, 18 studies were employed for the full-text reading stage, while 69 papers were excluded, meanwhile, five more publications were included externally for full-text reading in this stage. During the full-text reading of 23 publications, 13 documents were included: one PhD thesis, one conference poster, three conference proceedings, one book chapter, three architectural magazine papers and four academic journal papers (Figure 1). These 13 resulting documents were imported to Nvivo 12 software for qualitative analysis.
All 13 documents were analysed in the NVIVO 12 software by creating codes. Codes were created regarding the content of the data by considering biophilic design elements that were framed by previous researchers [9], [20], [21] and their outcomes on human health and wellbeing. However, this paper mainly focused on the welcoming and relaxing impact of biophilic design elements of centres, which is the most important characteristic outcome of nature-based design approaches of Maggie's architecture.

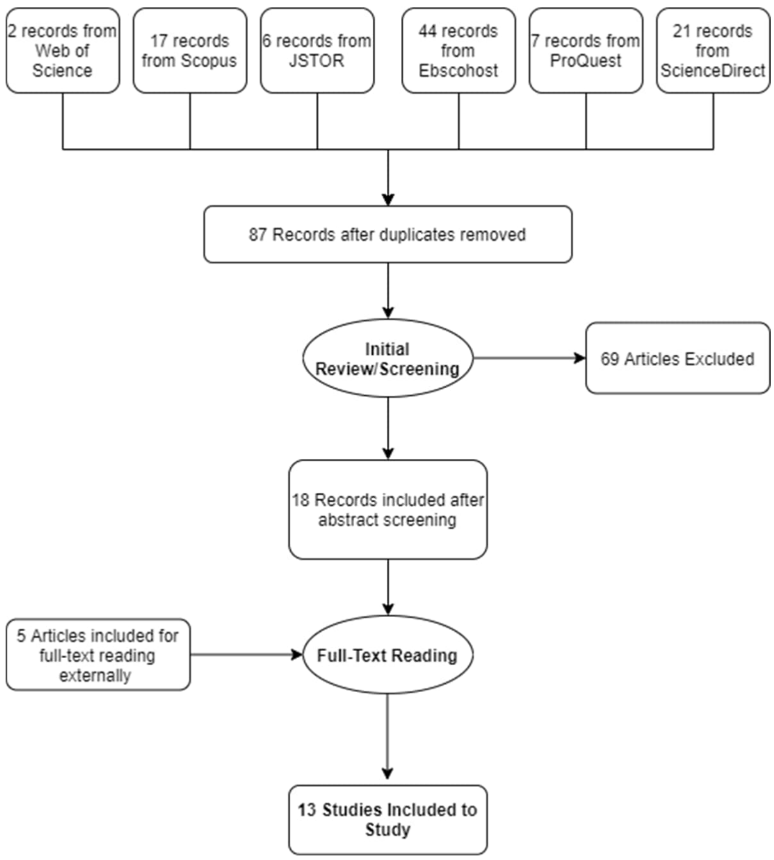
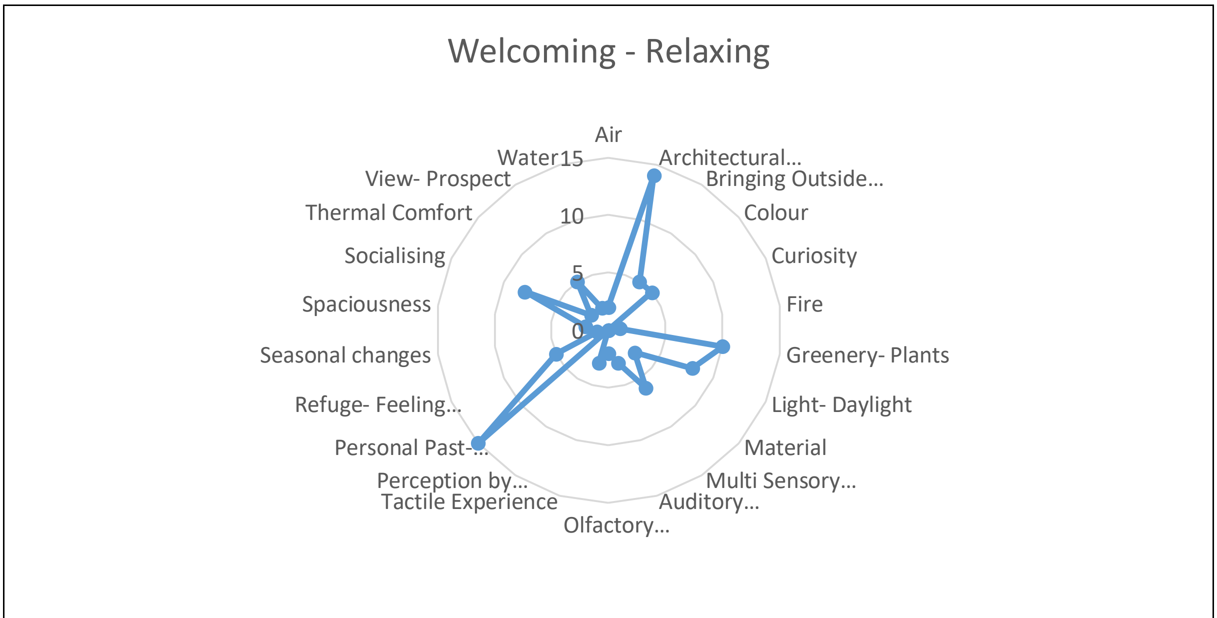


Figure **Fehler! Kein Text mit angegebener Formatvorlage im Dokument.**.
Identification of included articles in the review

3 ANALYSIS

In order to guide the commissioned architects to design the centres, Maggie's published the Architectural Brief [12], a document that describes emotional and design requirements based on cancer patients' needs. Apart from the technical space requirements, the brief strongly emphasises that the centres should have a welcoming homely atmosphere where the users can benefit from natural elements. On the other hand, the architects aimed to create a homely welcoming and relaxing atmosphere based on their own research, since the main issues of people with cancer experience are related to stress, depression, and anxiety [18]. Thus, this analysis mainly focused on how the welcoming and relaxing feelings of biophilic design elements helped to deal with stress, depression and anxiety while users taking part in random activities in Maggie's centres, such as classes (healthy lifestyle, nutrition, yoga, etc.), one by one therapy delivery, or socialising.

Table 2: References to the Welcoming-Relaxing spaces, and interrelation with the other codes referred together.



First of all, the analysis showed that there was a very strong connection between the personal past of the users and their welcoming and relaxing perceptions of the space (Table 2). The interviewees expressed very frequently that they felt like 'coming home', therefore they had a feeling of being welcome and safe when they entered the centres [17], [18], [22]–[24]. One of the reasons why they associate the Maggie's centres as a homey environment was their actual personal and cultural perception of what home means to them and their families. Therefore, there was a strong connection between the sense of belonging, a biophilic design attribute, and the feeling of welcome and relaxation.

In terms of architectural planning, the most mentioned welcoming characteristic was the entrance of the buildings. People found Maggie's centres as non-clinical and quite welcoming since there was no reception desk, they just felt relaxed to enter the buildings without hesitation or feeling intimidated. The reassuring small entrances were considered as relaxation places that helped people to prepare themselves before entering the centre, and it slowed people down with a homely feeling [13], [16], [17], [22]. People criticized the layouts of centres a lot in a positive way, mostly associating them with relaxing safe places due to the distinguishing plan from clinical settings.

One of the most important biophilic design elements that enhanced the welcoming atmosphere was the greenery (Table 2). Plants and landscape greenery were perceived as "healing" [13], "admirable", "fantastic", "feels like home" [22], "peaceful", "relaxing", "protected space", "feeling safe" [25], "alive and changing", "sense of welcome", "barrier with the outside world", "buffer zone", "threshold", "place of relaxation" and "calming" [18], [26]. The garden and plants slowed people down and conforted them when they approached the buildings, and encouraged them to enter [26] It was widely accepted by the interviewees that the gardens and greenery had a powerful relaxing effect on them, even in a very short distance walk in the gardens before arriving at the entrance, it made them feel calm and relaxed.

The daylighting design was also an important factor, which aroused a homely feeling by relaxing the patients. Together with the greenery, air, and colour, the daylight engendered pleasant thoughts in the visitors. The welcoming and relaxing effect of light in the centres was indicated frequently [26].

The results also showed that bringing the outside to the inside, either through views or physically, was highly associated with the welcoming and relaxing feeling (Table 2). According to the interviewees, the inside-outside relationship made the centres 'calming, peaceful [17], welcoming, inviting, a safe place, house-like [26], relaxing, uplifting and healing' [27]. Viewing out, particularly to the vegetation of the gardens or the blue sky, encouraged the feeling of relaxation and a sense of comfort [16], [18], [22], [26], [28].

As cancer patients, the visitors stressed their sensitivity to the cold, thus thermal comfort was one of the important parameters, and the inclusion of the fireplace was successful at providing a welcoming feeling [22]. In some centres with interior gardens, this feature was appreciated, especially as it provided thermal comfort while allowing people to enjoy the feeling of being outside and encouraged the connection with green elements in cold weather [22]. Also, manually opening windows and sliding doors helped people to feel relaxed, since they can easily step into or incorporate an environment with different temperature and air quality [22].

Maggie's architecture uses different natural materials to create welcoming, warm and safe places, which were also employed to attract attention and curiosity in some cases. The materials, in general, were seen as a greeting part of the centres with their texture and tactile features [16]. The wood was welcomed by many of the patients and commonly mentioned with its 'warmth' and 'natural feeling', which settled their minds [26]. The wood and timber trusses were also associated with the quality of architecture, as they attracted the people's attraction and created a refuge space where they felt safe and relaxed [16], [26]. Even though the interviews did not specify any other particular material, the choice of material, and their textures and tactile qualities were widely appreciated, and as shown in Table 2, they created a welcoming and safe atmosphere with warmth and greeting [16].

Some responses referred to the interior paintings and natural colours too. The splash of warm colours and tactile texture of materials at the entrance were also stated as engendering elements of feeling welcome and the warmth of the greeting [16], [26]. A response indicated that colourful decoration had a sense of family and immersed them with feelings of welcoming and relaxing.

The multisensory experience offered by natural elements was one of the most effective ways to create a welcoming and relaxing environment. The gardens enabled the users to experience a variety of fragrances, sounds and textures, stimulating all their senses, which enhanced the feelings of relaxation, greeting, safety and encouraged them to stay there and fight death. In the building, the visitors were smelling the spiritually rising natural fragrances of plants or the wood-burning fireplace rather than the smell of medicine, so this olfactory experience triggered again a sense of being relaxed or a sense of belonging by recalling memories from personal past [26].

The sounds had a similar impact as the smells in terms of recalling memories back, which helped to improve feelings of welcome and relaxation. The most mentioned sounds were originated from the gardens: the moving and rustling tree leaves, branches, and plants [15], [26]; patterns of rain on the huge leaves [29], the joyful singing and chirping of birds [15], the bumble of bees [26] or chickens crowing [18]. The gardens were "never dead" with all these movements and sounds, this aliveness made the cancer patients feelings go up while they were endeavouring to survive [26]. Also, the people enjoyed the sound of water elements, which gave them relaxation and welcomed them by calming down. The water elements also had a visually welcoming impact by slowing down the visitors [15].
According to all these examined studies, the architects were substantially successful about the auditory experience and they created a welcoming, changing and alive atmospheres in Maggie's centres.

Prospect and refuge, another of the space parameters of biophilic design [20], successfully encouraged welcoming and relaxing feelings in Maggie's centres as well. The centres provided safe environments where the users had the impression of refuge while allowing them a strong visual connection with the outside. This balance triggered the relaxing and welcoming feelings [16], [17], [22], [26], [28], [30]. Thus, the staff stressed the importance of the welcoming and safe atmosphere that comes from the possibility of using the centre privately but without being isolated [17]. The kitchen table and the atmosphere of the kitchen had a powerful effect on the feeling of safety and refuge on patients,. It was claimed that this space was very successful at immediately calming down most angry and worried patients, as the place was safe enough to socialise with the mind at peace [22]ocialising opportunities enabled in the centre also enhanced the feelings of welcome and relaxed, since people became more open for socialising with each other when they felt relaxed and welcomed.

4 Conclusion

The results showed that creating a welcoming and relaxing environment was the most important of all architectural features of the therapeutic environment in the context of Maggie's centres. The welcoming-relaxing code was referred to in 71 responses, not only reflected in the interventional elements but also in the outcome elements referred to this code.

Analysis of welcoming and relaxing characteristics of biophilic design elements in therapeutic environments revealed that some biophilic design parameters had a powerful effect on dealing with stress and anxiety by creating this welcoming and relaxing atmosphere that can not be ignored. Sense of belonging, as a biophilic design attribute [21], was the most outstanding parameter for creating a welcoming and relaxing atmosphere, followed by other biophilic design elements: greenery, light, multi-sensory experience, inside-outside effect, view, prospect and refuge, colour, material, thermal comfort, and water consecutively.

Apart from biophilic design elements, the architectural form, layout, furnishing and fittings were the main tool that the designers used for creating a welcoming and relaxing place as the ultimate design goal. Although all the other codes had their specific aims and outcomes, almost all of them either supported welcoming and relaxing impact or were supported by this feature. Also, design features that supported the generation of socialising spaces had a great impact on relaxing and greeting people to fight stress and anxiety.

Overall, it is stated that the buildings were clever with their design, colours, fittings and natural features, all together made the visitors feel safe and welcomed [16]. Particularly, the biophilic elements clearly successfully supported the welcoming and relaxing perceptions of the space while dealing with cancer.

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EVALUATION OF BIM TOOLS AND ENERPHIT STANDARDS FOR THE ENERGY-EFFICIENT REFURBISHMENT OF HOUSING STOCK IN THE UK

Sinan Celal DADAĞILIOĞLU*, Haniyeh MOHAMMADPOURKARBASI, Steve SHARPLES

University of Liverpool
School of Architecture, Abercromby Square, L69 7ZN, Liverpool, United Kingdom;
S.Dadagilioglu@liverpool.ac.uk

Abstract

Globally, the construction industry has been linked to several key environmental issues: increasing energy consumption, resource depletion, and greenhouse gas emissions. Existing buildings make a major contribution to these issues, and this is especially true in the UK, which has the oldest residential building stock amongst developed countries. This, in turn, creates poor building thermal performance. As a sustainable solution for these global issues, there has been an increasing interest in energy-efficient housing refurbishment as a way for the UK to meet its 2050 net-zero targets. Despite awareness in the architectural, engineering and construction (AEC) industry, there has been a low uptake of housing refurbishment among homeowners and housing investors due to strategic ambiguity, cost overruns, and adverse refurbishment outcomes.

Improving new ways of predicting, managing and monitoring the impacts of the built environment, Building Information Modelling (BIM) has considerable potential for building refurbishment projects. One approach to energy-effcient retrofit is EnerPHit, which is the refurbishment version of the Passivhaus standard. This study aims to establish a new conceptual framework for applying BIM tools and the EnerPHit standards to the energy-efficient refurbishment process in the UK housing sector. Besides the benefits from 3D modelling (coordination), further dimensions of BIM implementation – 4D BIM (scheduling), 5D BIM (cost estimating) and its compatible tools for energy analysis – will be discussed for a virtual case study that represents a typical Victorian house in the UK. In this regard, EnerPHit standards will guide the housing refurbishment measures towards the energy efficiency targets considering Passivhaus criteria.

The key findings of the study contribute to the conceptual understanding of the implementation of BIM and EnerPHit assisted process for the energy-efficient housing refurbishment.

Keywords

Refurbishment, Energy Efficiency, BIM, Passivhaus, UK Housing Stock

1 Introduction

The UK government has formalised a target for net-zero greenhouse gas (GHG) emissions by 2050 [1].The existing building stock is the main contributor to the UK's energy consumption, and produces 22% of total GHG emissions. However, the annual building-related GHG emission rates are decreasing very gradually to meet the 2050 targets compared to other sectoral trends in the UK (Figure 1) [2]. Energy Performance Certificates (EPC) is a UK government energy efficiency rating system ranging from A (most efficient) to G (least efficient). Out of the 27 million homes in the UK, approximately 19 million have EPC ratings below C. Therefore, sustainable building refurbishment must play a crucial role in developing energy efficiency, reducing costs, and mitigating environmental impacts if the UK government is to meet its 2050 target [3]. Despite high energy consumption and GHG emissions in the UK housing stock, there has been, historically, a low demand for housing refurbishment amongst homeowners and housing investors.

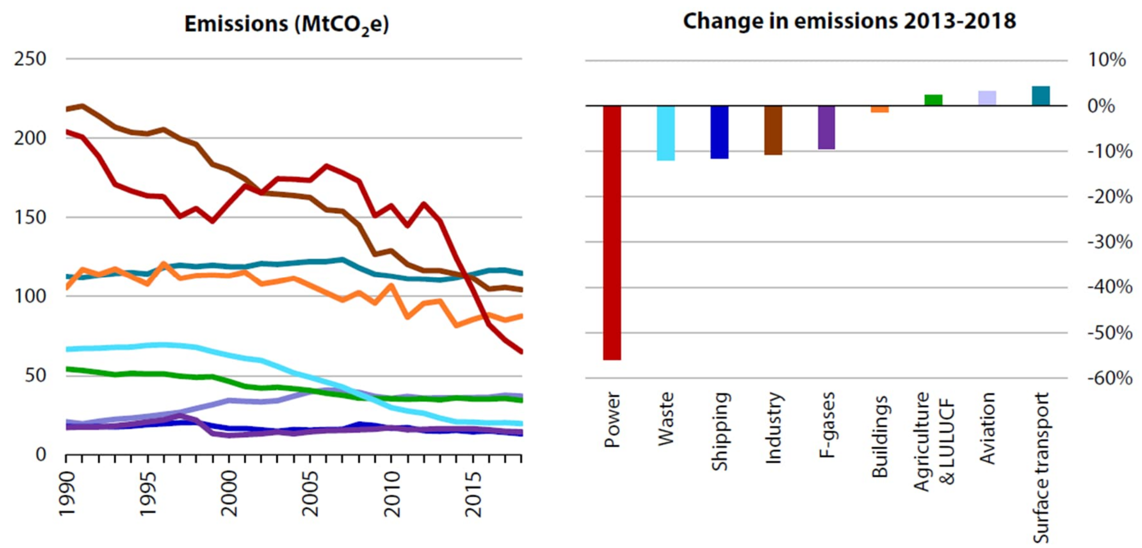

Figure 1. Trends in UK sectoral GHG emissions [2]

Recent literature on building refurbishment has concluded that the conventional retrofit processes lead to ambiguous refurbishment strategies, considerable project delays, cost overruns, extensive efforts, and unsatisfactory refurbishment outcomes to enhance thermal performance by making several alterations to the building envelope and the other components [4,5,6,7]. Some of the main reasons are the fragmented nature of the construction industry and complicated stakeholder requirements. These requirements should be agreed upon to enable the stakeholders to have effective collaboration by utilising new ways of running refurbishment projects [4,8,9,10]. With diverse backgrounds and interests, refurbishment project stakeholders face collaboration issues due to the lack of a common platform for effective teamwork. In addition, the conventional refurbishment process is not adequate for providing a collaborative platform as stakeholders from different disciplines tend to use different design and analysis tools individually [11]. For this reason, dissatisfaction with the refurbishment outcomes is likely for the homeowners due to the silo mentality of the project members to achieve accurate information sharing.

Various researchers have emphasised a holistic approach to sustainable building refurbishment as a new area of interest in the literature [3,12,13,14]. This can be categorised into three main stages:

- *Assessment Stage*: project setup and data collection
- *Method & Strategy Stage*: data analysis, strategy formulation, and implementation
- *Validation & Verification Stage*: post-measurement, post-occupancy survey

This paper focuses on the Method & Strategy stage of a sustainable building refurbishment model.

As a solution to the conventional building refurbishment challenges, several technological means of refurbishment processes – 3D building surveying, BIM, and building energy analysis – can be considered. With these means, it is possible to improve the aforementioned refurbishment stages in consideration of its environmental and economic aspects in the UK housing sector.

With its emerging technologies, innovative tools and collaborative platform, the use of BIM has growing potential for building refurbishment projects, and some considerable benefits of BIM include [15,16,17]:

- To avoid remedial works on refurbishment design
- To provide visual simulations for better coordination
- To optimise refurbishment time
- To reduce the required refurbishment materials

While BIM provides significant benefits in these areas, the German Passivhaus standards – named EnerPHit for building refurbishment – can be considered for energy efficiency in building refurbishment. The Passivhaus standards focus on a high level of occupant comfort while using very little energy for heating and cooling. Some fundamental building physics principles are applied: improved thermal comfort, thermal bridge free, improved airtightness, fresh air with heat recovery, and solar gain [18,19]. With approximately 60,000 Passivhaus-certified buildings, the Passivhaus standards have been rapidly growing low energy buildings not only in the UK but worldwide. Besides, these standards have been an increasing interest of sustainable building refurbishment in terms of energy efficiency [20]. While BIM supports the refurbishment projects with meeting the EnerPHit standards, there is limited research in implementing BIM tools and the EnerPHit standards for the energy-efficient refurbishment in the UK housing stock [9,10,12,14,21].

This paper investigates the semantically modelled refurbishment project of a hypothetical case study using BIM tools and the Passivhaus EnerPHit standards to achieve energy efficiency. In this regard, the proposed case-study methodology will describe how to use the selected BIM tools and EnerPHit standards. After the methodology, the research outcomes will be analysed and evaluated with their pros and cons and, finally, the last section will detail the conclusion of this paper.

2 Methodology

The main objective of this paper is to evaluate the selected BIM tools and the Passivhaus EnerPHit standards for the energy-efficient refurbishment of a typical UK 19th century Victorian house. To achieve this purpose, the proposed research approach to the methodology focuses on solution-oriented research to provide valid knowledge that helps practitioners solve problems [22]. In this regard, the proposed research design is developed to solve the aforementioned building refurbishment issues (Figure 2). A deep understanding of the reviewed literature plays a central role in defining the problem regarding the conventional refurbishment process. The proposed solution to the defined problems can be the development of the BIM framework. As a holistic approach to energy-efficient housing refurbishment, not only 3D BIM (coordination) but also further dimensions of BIM adoption – 4D BIM (scheduling), 5D BIM (cost estimating) and its compatible tools with the Passivhaus EnerPHit standards – has been considered as an aim of this study. This paper focuses on developing and implementing the solution for the energy-efficient refurbishment of housing stock in the UK.

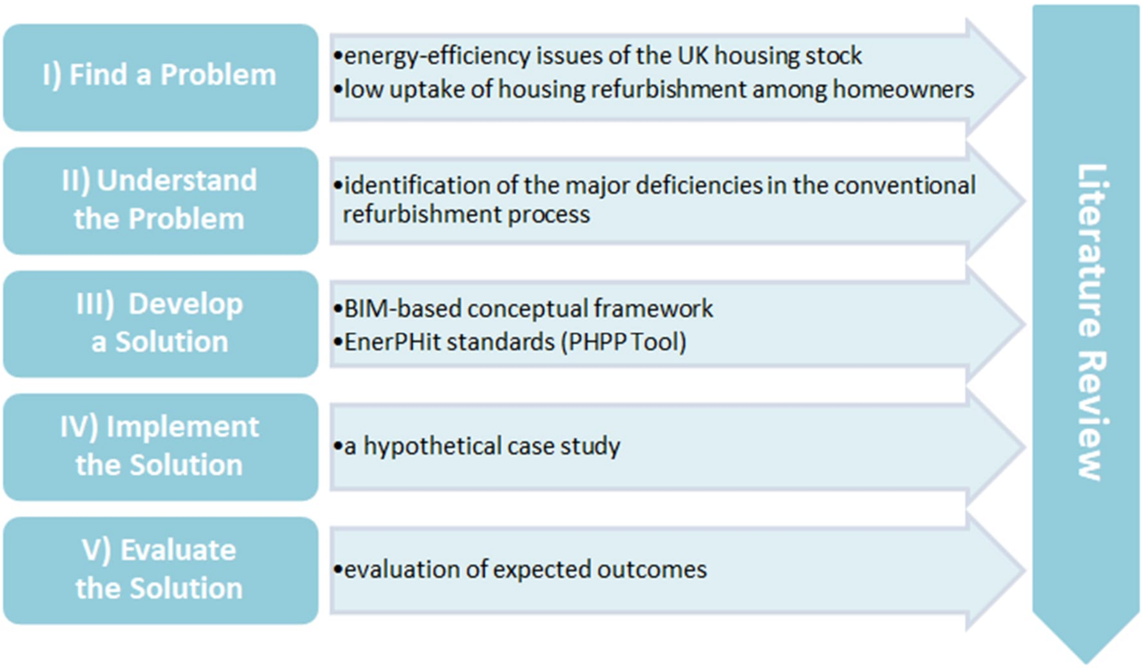

Figure 2. Research Design

The baseline scenario was modelled in ArchiCAD, one of the most convenient and versatile BIM tools used worldwide, with the features of a hypothetical case study representing an terraced 2-storey Victorian house located in Liverpool, UK, which has a temperate maritime climate of cool, wet winters and warm, wet summers The building has only residential use, and has 134m^2 total treated floor area, 3.2m floor to floor height, 19.7m^2 total glazing area, and 408m^3 net volume. The thermal information of the building envelope is shown in Table 1, and the whole-house refurbishment approach to this building is proposed.

Table 1: Construction details of the hypothetical case study

	Construction detail	U-value
External Wall	Gypsum board, concrete wall, membrane, cavity, brickwork	1.65 W/m²K
Ground Floor	Gravel fill, cast concrete, cavity, timber flooring, carpet	1.35 W/m²K
Window	Single glazed box-sash windows	4.53 W/m²K
Roof	Stone chipping, bitumen layers, slate tiles	4.50 W/m²K

Using its geometric and thermal details, the baseline model of the house was created in ArchiCAD - see Figure 3. The potential advantages of BIM in the proposed housing refurbishment model can be categorised as:

- 3D BIM model of the house can be used to better coordinate project stakeholders to avoid remedial works such as clash detection prior to implementing a refurbishment project.
- To simulate and visualise the whole-house refurbishment process in a virtual environment, 4D BIM can be proposed with the aim of developing construction site coordination and time management throughout the building refurbishment process (Annex A).
- With its semantically enriched model, 5D BIM can offer the cost estimation opportunity to the refurbishment project, performing the quantity take-off from the pre-refurbishment to the post-refurbishment processes regarding the chosen Passivhaus-certified building components.

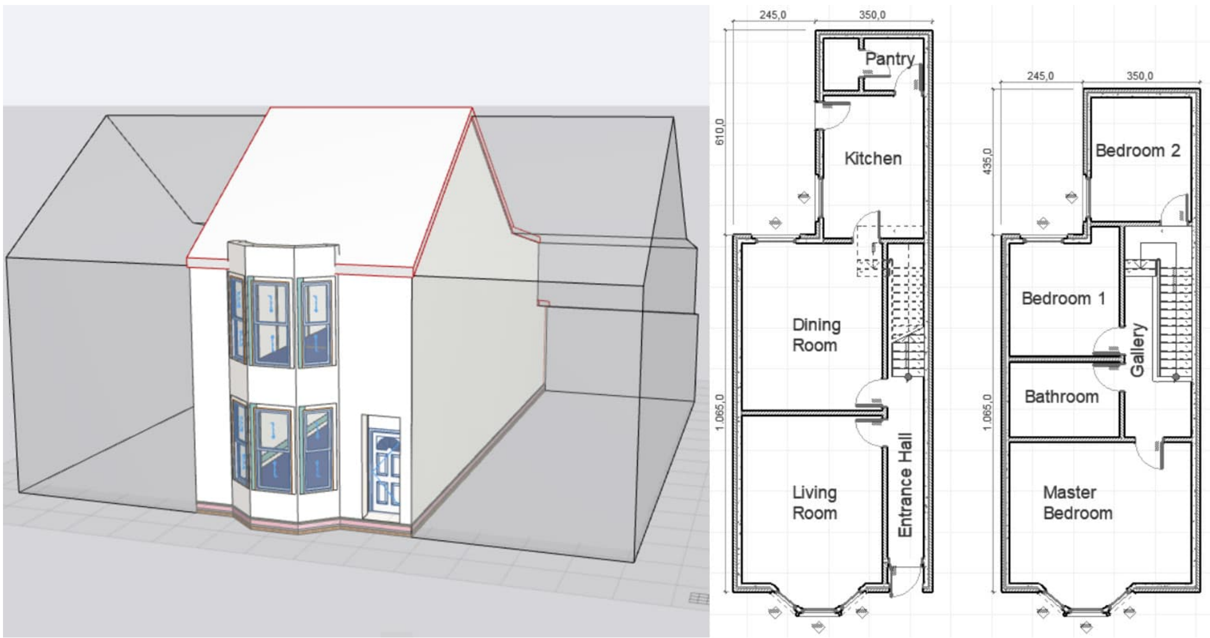

Figure 3. Baseline 3D model and plans

To achieve the Passivhaus EnerPHit standards in the proposed refurbishment model, it is essential to consider the concept of a 'fabric first' approach to introducing the refurbishment measures which focuses on heat retention and airtightness in terms of the material selection in the project. With regards to this, the proposed BIM framework is adapted for a phase-by-phase refurbishment to meet the EnerPHit standards.

3 Results and Discussion

To systematically evaluate sustainable building refurbishment issues related to the UK housing sector, a BIM-based refurbishment process model was proposed with its theoretical and methodological ideas. As an objective of this study, a semantically enriched BIM model of the chosen hypothetical case study (a typical Victorian house) was created in ArchiCAD. Prior to assembling the whole-house refurbishment framework, a number of essential criteria were considered: 3D coordination, time scheduling, cost estimation, and the building component selection.

The presented baseline BIM model was generated with consideration of the current building envelope characteristics of the house. All appropriate components of the building were defined as different categories and layers in the BIM model: external walls, internal walls, floors, roof, windows, and doors. In this way, the geometric and non-geometric data could be obtained from the model to analyse the current condition of the building and develop highly convenient refurbishment strategies. Furthermore, the generated baseline BIM model can enable the project stakeholders to use a collaborative platform for new material selection among all building components and composite building materials in detail (Figure 4).

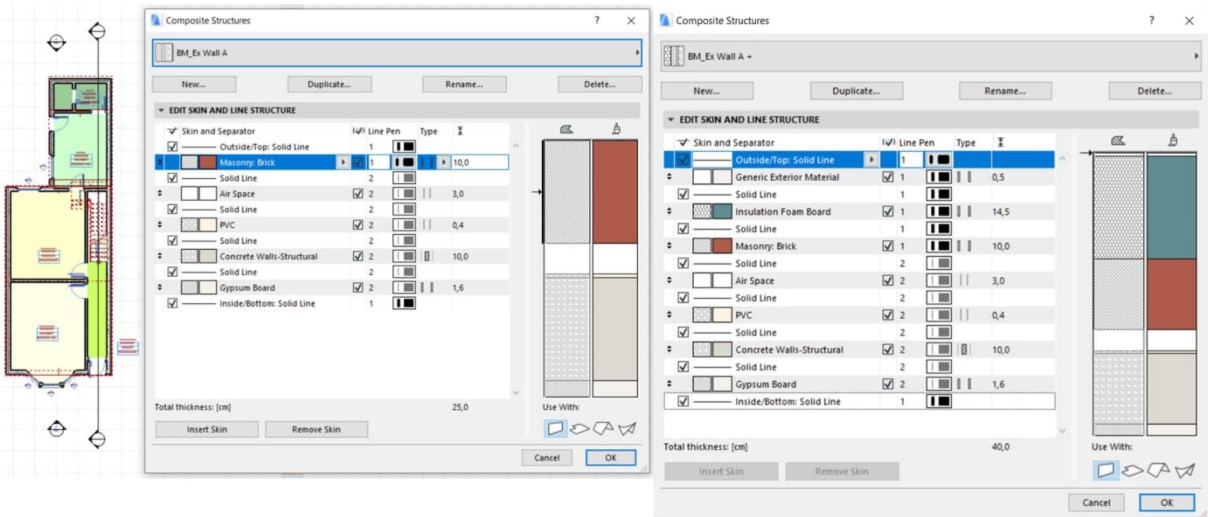

Figure 4. The external wall components before and after the refurbishment project

To organise the implementation process of the Passivhaus EnerPHit standards, the 4D BIM simulation of the refurbishment project was provided, including the definition of the sequences of refurbishment activities. The simulation shows 21-day refurbishment project activities, describing the sequences of external wall, ground floor and roof insulation, windows, doors and ventilation upgrades (Annex A). The external side walls were considered as a different category due to the adjacent buildings providing internal wall insulation. As one of the benefits of the 4D simulation, different construction areas were defined with specific time periods in order to improve time management and avoid overlapping areas throughout the refurbishment project.

To develop the house's base model using BIM tools and the Passivhaus EnerPHit standards, the following building components and insulation materials were implemented phase-by-phase as the main purpose of the proposed refurbishment model - see Table 2.

Table 2: Refurbishment phases, including a summary of U-values (W/m^{2}K) used for each element of the building fabric

Upgrade	**Insulation**	**External Wall** U-value (W/m^{2}K)	**Ground Floor** U-value (W/m^{2}K)	**Window** U-value (W/m^{2}K)	**Roof** U-value (W/m^{2}K)
Base Case	House as-built	1.65	1.35	4.53	4.50
PH-Phase 1	EnerPHit wall insulation	**0.23**	1.35	4.53	4.50
PH-Phase 2	EnerPHit floor insulation	**0.23**	**0.24**	4.53	4.50
PH-Phase 3	Argon-filled double-glazing timber window	**0.23**	**0.24**	**1.23**	4.50
PH-Phase 4	EnerPHit roof insulation: Solid (TICS)	**0.23**	**0.24**	**1.23**	**0.14**

The generated BIM model offered an opportunity to assess the house for the each of the existing and proposed building components to meet the Passivhaus EnerPHit standards (Annex B). Using these obtained data, the alternative refurbishment scenarios can be measured to achieve the cost estimation stage of the housing refurbishment project.

Overall results of the Passivhaus EnerPHit criteria, which were based on the PHPP calculation, where PHPP is the building energy modelling software for Passivhaus building design, verified the impact on projected energy savings of various insulation (walls, floor, windows, and roof) improvements. Figure 5 shows specific losses and gains heating balance [kWh/(m^{2}month] of the baseline model and proposed refurbishment model calculated with PHPP.

Figure 5 illustrate how refurbishment improvements from the inadequately insulated base case model to the systematically refurbished model achieved the Passivhaus EnerPHit heating demand criteria of less than 25 kWh/m^2 during the entire year. Based on these results, the Passivhaus-certified building components have a significant role to play in achieving an energy-efficient housing refurbishment project.

The proposed energy-efficient refurbishment model of a typical Victorian house meets the real needs of the UK housing stock as solution-oriented research to provide valid knowledge that helps practitioners and homeowners solve problems. Implementing the BIM-based refurbishment model offered an opportunity for better coordination in building material selection, organisational hierarchy of the refurbishment phases, and collective decision making for the project stakeholders with consideration of the Passivhaus EnerPHit standards. With the use of the Passivhaus-certified building components, this BIM-based approach to housing refurbishment can propose alternative scenarios for homeowners to achieve the EnerPHit criteria in terms of energy efficiency. Although the presented hypothetical case study achieved the heating demand level based on the EnerPHit standards, the thermal performance could be affected by thermal bridging and airtightness issues. In this regard, further research is required to focus on these issues to achieve the Passivhaus EnerPHit criteria ultimately. Experimental research can also be considered to measure the economic feasibility of the proposed model in terms of return on investment in the UK housing stock as a prospective study in the future.

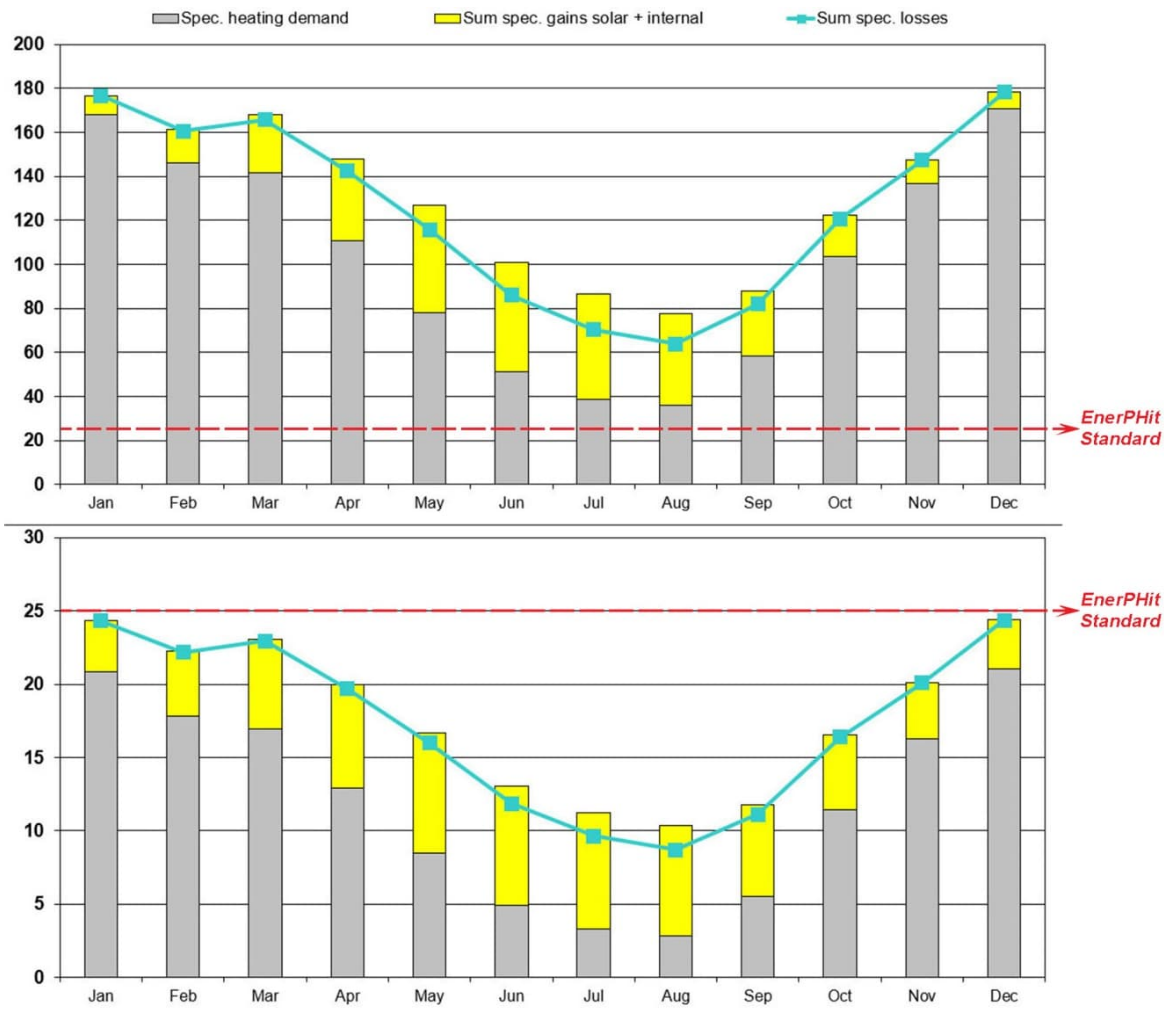

Figure 5. Comparison of specific losses and gains heating balance [kWh/(m^{2}month] of the base case (above) and proposed refurbishment model (below)

4 Conclusion

This paper has outlined the evaluation of BIM tools and the Passivhaus EnerPHit standards for the energy-efficient refurbishment of the chosen hypothetical case study, which represents a typical Victorian house in the UK. This study considered some of the main reasons for the low uptake for housing refurbishment in the UK and proposed some realistic and effective solutions to the problems of the conventional refurbishment process. The development of the BIM-based model played an integral role to support comprehensive strategies in sustainable housing refurbishment for energy-efficient thermal improvements. The complexity of the conventional building refurbishment process has been addressed through a holistic approach to the solution-oriented research methodology and the correlations between the selected BIM tools and the EnerPHit standards throughout the refurbishment process, which have been established as the purpose of this study. The main finding of this study was that the Passivhaus EnerPHit criteria for energy efficiency could be achieved by implementing the proposed BIM-based housing refurbishment model. The assessment of the presented refurbishment phases shows that the BIM-assisted step-by-step housing refurbishment has considerable potential as an innovative solution to the conventional refurbishment model with utilising its multidimensional benefits for the energy-efficient housing refurbishment in the UK. This paper only focused on the Method & Strategy stage of the sustainable building refurbishment model. Further research, such as the validation & verification stage, will be required to thoroughly investigate and understand the potential outcomes of implementing the BIM and EnerPHit assisted process model for the energy-efficient housing refurbishment.

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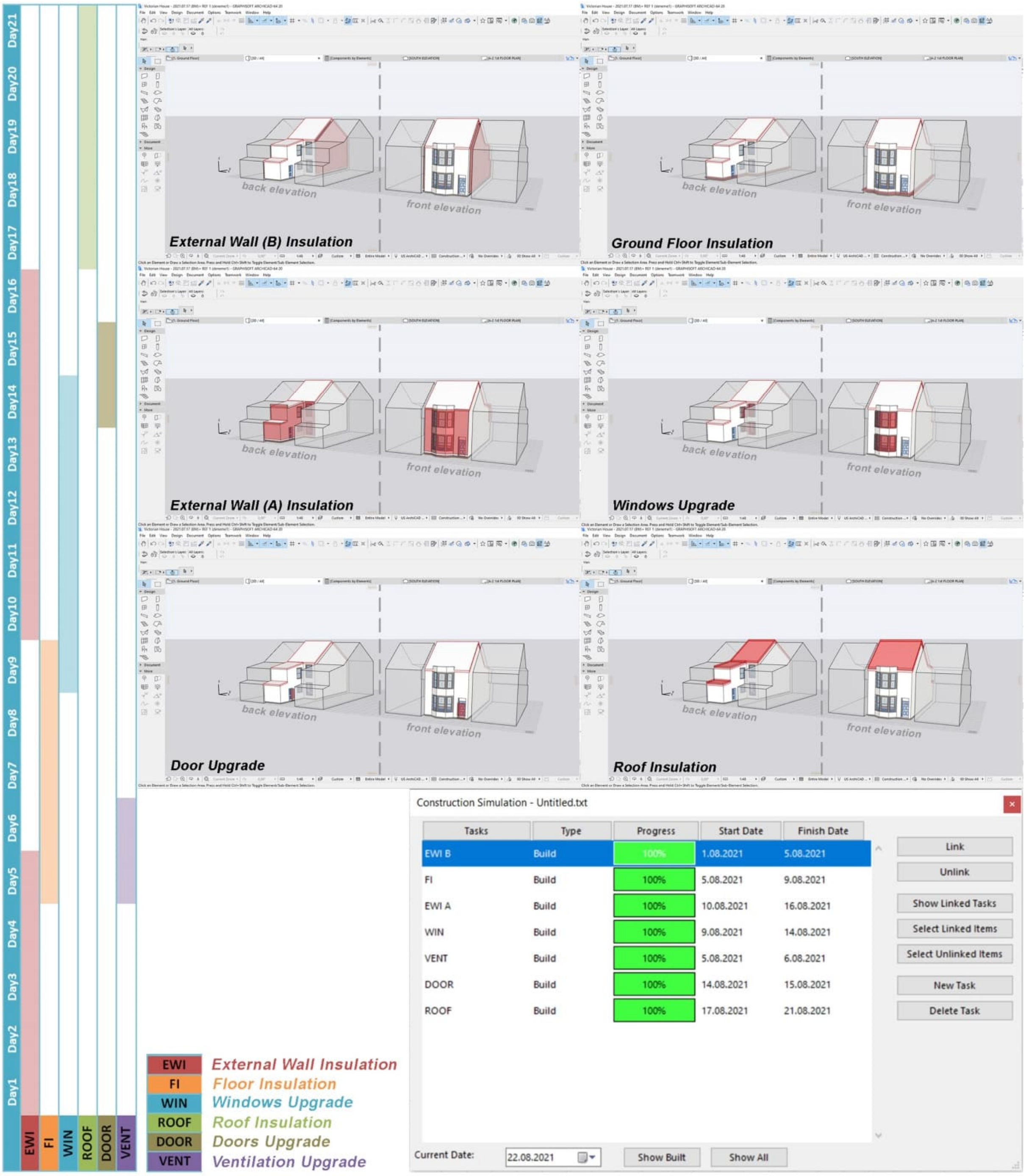
ANNEX A – 4D BIM simulation of the project



ANNEX B – BIM Model Component Lists (Pre-refurbishment)

Components by Layers			
	Component		
Layer Name	**Name**	**Volume (m^3)**	**Area (m^2)**
Floor - Ground			
	Airspace	2.94	87.07
	Carpet	0.86	86.27
	Cast Concrete	4.31	86.27
	Gravel Fill	7.76	86.27
	Plywood	1.37	86.27
Roofs			
	Air Space	0.29	102.34
	Bitumen Layers	5.06	101.34
	Slate Tiles	2.02	101.65
	Stone Chipping	13.14	102.47
Walls Ex A			
	Air Space	2.45	83.60
	Brickwork	7.84	81.02
	Concrete Block	8.13	84.28
	Gypsum Board	1.20	74.81
	Membrane	0.33	82.26
Walls Ex B			
	Air Space	6.03	200.70
	Brickwork	20.20	202.02
	Concrete Block	19.88	198.77
	Gypsum Board	3.00	189.50
	Membrane	0.80	200.38
Walls Int			
	Brickwork	12.70	111.55
	Gypsum Board	3.76	210.18

ANNEX B – BIM Model Component Lists (Post-refurbishment)

Components by Layers			
	Component		
Layer Name	**Name**	**Volume (m^3)**	**Area (m^2)**
Floor - Ground			
	Air Space	10.78	86.27
	Carpet	0.86	86.27
	Cast Concrete	4.31	86.27
	Cavity	2.93	86.27
	Insulation (wood fibre)	10.76	86.27
	Plywood	1.37	86.27
Roofs			
	Air Space	0.29	102.34
	Bitumen Layers	5.06	101.34
	Insulation (m. wool)	75.16	102.64
	Slate Tiles	2.02	101.65
	Stone Chipping	13.14	102.47
Walls Ex A			
	Air Space	2.48	83.75
	Background Fill	0.41	79.25
	Brickwork	8.43	87.05
	Concrete Block	8.20	84.24
	Gypsum Board	1.07	68.21
	Insulation (m. wool)	12.25	88.71
	Membrane	0.33	82.47
Walls Ex B			
	Air Space	5.91	197.04
	Background Fill	0.92	182.78
	Brickwork	19.84	198.38
	Concrete Block	19.51	195.11
	Gypsum Board	3.02	190.32
	Insulation (m. wool)	27.62	190.45
	Membrane	0.79	196.72
Walls Int			
	Brickwork	12.50	109.70
	Gypsum Board	3.60	200.33

COMPARATIVE REVIEW OF INTERNATIONAL APPROACHES TO NET-ZERO BUILDINGS. A KNOWLEDGE-SHARING INITIATIVE TO DEVELOP CLIMATE-RESILIENT DESIGN STRATEGIES FOR GREENHOUSE GASES EMISSIONS REDUCTION

Daniel Satola[1*], Aoife Houlihan Wiberg[2], Manan Singh[3], Sushanth Babu[5], Ben James[2], Manish Dixit[4], Ryan Sharston[3], Yann Grynberg[5], Arild Gustavsen[1]

[a] The Research Centre for Zero Emission Neighbourhoods in Smart Cities (ZEN), Norwegian University of Science and Technology (NTNU), Trondheim, Norway

[b] The Belfast School of Architecture and the Built Environment, Faculty of Computing, Engineering and the Built Environment, Ulster University, Belfast BT15 1AS, United Kingdom.

[c] The Florida Institute for Built Environment Resilience (FIBER) The College of Design, Construction and Planning, University of Florida, P.O. Box 115701 Gainesville, FL 32611-5701, USA

[d] Department of Construction Science, Texas A&M University, USA

[e] Energy Research Institute @ NTU (ERI@N), Nanyang Technological University (NTU), Singapore

*daniel.satola@ntnu.no

Abstract

Achieving carbon neutrality by the year 2050 is considered the world's most urgent mission, already being committed by more than 110 countries worldwide. Moreover, with the construction sector being responsible for almost 40% of global greenhouse gases (GHG) emissions, the concept of net-zero GHG emission or energy buildings is gaining wide international attention and starting to be a leading ambition of the future national building stocks. This article aims to present the current progress of net-zero building legislation, policy and voluntary frameworks in Norway, the United Kingdom, United States and Singapore, which are leading regional actors concerning the climate-neutral construction sector. Firstly, the study provides an overview of each country-specific context and motivation related to climate change adaptation and mitigation in the construction sector. Secondly, the summary of the essential features from market-leading methodologies, definitions, schemes, and tools describing specific building approaches in each investigated country is presented. Finally, based on the selected case studies, the article presents the most promising design strategies for GHG emission reductions, considering each specific climatic and country context.

Keywords:

net-zero, zero-emission, zero-energy, buildings, climate neutrality

1. Introduction

1.1 Net-zero GHG emission and resilient buildings: a key solution for achieving climate neutrality and change adaptation in the construction sector and real estate industry

Achieving carbon neutrality by 2050 is widely recognised as the world's most urgent and challenging mission, being at the same time a key opportunity to build a better future for the next generations [1]. The climate neutrality target has been officially implemented to biding European Union(EU) law by introducing Climate Law Regulation [2] in April 2021. Consequently, each EU member is obligated to develop and further enforce national law, which will enable achieving carbon neutrality by 2050. The ambition of achieving carbon neutrality by the EU is supported and claimed by the other largest world's economies: United States, China or Japan; however, to this day, not being implemented as national law but only as a statement of intent.

The transformation of the construction sector, currently responsible for almost 40% of total GHG emissions [3], is a key for achieving carbon neutrality in the whole economy. Consequently, the global development of transparent carbon-neutral building definition, which addresses the GHG emissions from the entire building's life cycle, is crucial for achieving carbon neutrality targets.. Unfortunately, based on a recent review [4], such regulations are often lacking. However, recently, the promising first steps towards net-zero requirements in the building policy were taken by France [5], Finland [6], and Denmark, which introduced mandatory limit values of life cycle GHG emissions related to the new buildings.

1.2 Towards climate-neutral construction sector: specific national motivation and background

1.2.1 Norway

In February 2020, Norway submitted its enhanced Paris Agreement target (NDC), which targets reducing GHG emissions by at least 50% below 1990 levels by 2030. The long-term national goal is becoming a "low carbon society", with an emission reduction target of 90%-95% from the level in the reference year 1990. The Norwegian government has introduced this goal as legally binding in the Climate Change Act [7].

Climate change effects will have significant impacts in Norway. Based on future projections for the climate in Norway up to 2100 [8], the annual temperature and precipitation can increase by an average of 4.5°C and 18%, respectively. The expected increase in mean sea level is estimated between 15-55cm, depending on location along the coast. This hazard can significantly damage more than 110 000 existing buildings along the Norwegian coastline situated less than 1m above normal sea level [9].

The construction and real estate sector in Norway is responsible for 18% of national GHG emissions and 40% of final energy use, with the largest share attributed to space heating needs [10]. Nowadays, electricity is the most commonly used energy source in the building sector, getting nearly 85% share in 2017 [11]. The environmental impact of electricity consumption in Norway is one of the lowest globally due to the dominant share of renewable hydropower sources (95%) in domestic power generation [12].

In the last years, the main focus on governmental incentives was to reduce operational GHG emissions of the buildings, mainly by progressive improvement of energy efficiency requirements in the biding building regulations. However, the rising awareness of the need to address GHG emissions during the whole building lifecycle led to the development and further market implementation of zero-emission buildings (ZEB) [13]. In 2018, the focus was shifted from single buildings to neighbourhoods with the main vision to develop sustainable neighbourhoods with zero greenhouse gas emissions (ZEN) [14].

1.2.2 United Kingdom

On 27 June 2019, the United Kingdom (UK) became the first major economy to pass a net-zero emissions target into law [15]. This target will require the UK to bring all greenhouse gas emissions to be net-zero by 2050, compared with the previous target of at least 80% reduction from 1990 levels.

According to the Committee on Climate Change (CCC) [16], both direct and indirect emissions from buildings contributed approximately 23% of the UK's total GHG emissions in 2019. The significance of embodied GHG emissions in the new buildings is rising and can account for up to half of the building's lifecycle emissions [17]. In 2019, for the first time in history, the UK's energy supply from renewable sources overtook fossil fuels. This high share of renewable energy sources in the electricity mix leads to the electricity emission factor of 0.25 kgCO2eq/kWh [18]. Despite this shift towards renewable energy production, around 90% of homes in the UK still rely on fossil fuels for heating, which is the dominant contributor to energy consumption.

The impacts of climate change on the built environment in the UK range from more widespread flooding to more frequent extreme weather events. As seen in recent years, flooding has become a significant challenge in parts of the UK, with the CCC states that 1.8million people are currently at significant risk, which is projected to rise to 3.8million by 2080.Beyond current government legislation and policy within the UK, emerging voluntary frameworks aim to support progress towards Net Zero Emission Buildings, such as the UKGBC's 'Net Zero Carbon Buildings [19] and LETI's 'Climate Emergency Design Guide' [20].

1.2.3 United States

With less than 5% of the world's population, the USA consumes about 17% of the world's energy [21,22]. About 40% of this energy can be directly attributed to usage in commercial and residential buildings [23]. According to the United States Environment Protection Agency (US EPA), in 2020, only 12.5% of primary energy consumption is provided from renewable sources, while a staggering 78% from fossil fuels, resulting in an average national grid emission factor of 0.4 $kgCO_{2eq}$/kWh [24].

So far, in terms of national-level efforts towards decarbonising the construction sector, the definitions and initiatives within the US have solely been focused on the operational impacts, essentially ignoring the embodied GHG emissions. This has resulted in significantly more importance given to the 'net-zero energy buildings' concept, with the most recognised framework developed by the US Department of Energy [25]. Furthermore, considering the relevance of local standards and codes within the US, multiple cities and states have come forward in recent years, showing their commitment towards minimising the carbon emissions from the building sector. The net-zero carbon buildings commitment by WGBC is one such initiative, joined by the state of California along with seven other major cities within the US [26]. Similarly, 8 US cities have signed the net-zero carbon buildings declaration by C40 cities [27].

1.2.4 Singapore

Singapore is a highly urbanised megacity that has a broad coverage of the built-up area. This contributes to more than 20% of the island state's carbon emissions [28]. The growth rate of Singapore's construction in 2019 was 2.8% and accounted for 4% of the total GDP. Based on data from 2019 [29], natural gas accounts for 95.6% of the fuel mix for electricity generation in Singapore, followed by other energy sources. The average operating margin grid emission factor was 0.41 $kgCO_{2eq}$/kWh.

In order to tackle and reduce the GHG emissions from the built environment sector, governmental Singapore's Building Construction Authority (BCA) launched Green Mark: A green building rating scheme based on a point score system to assess a building's overall environmental impact and performance in 2005 [30]. By employing this scheme, BCA targeted "greening" 80% of all buildings, by Gross Floor Area (GFA), by 2030 and already achieved 40% of this target as of the current date. The Green plan aims to position Singapore to achieve the long-term net-zero emission aspiration as soon as viable.

2. Comparative overview of leading sustainable building approaches in Norway, United Kingdom, United States and Singapore

2.1. Overview of the key features from market leading net-zero building approaches

The overview of the key features extracted from the leading sustainable building approaches in Norway, the United Kingdom, the United States and Singapore are presented in Table 1. The following sections provide a more detailed description of the building approach features in each considered country.

Table 1 Comparative overview of the key features occurring in the respective country of the building assessment approach

Country	Building approach, standard, scheme	Status, launching year	Founder	Scale of application	Key performance indicator/s	System boundaries
Norway	Zero Emission Building [31]	Voluntary, 2015	Research organisation	All types of new and existing buildings	Greenhouse gas emissions (GHG)	Whole life cycle (operational and embodied)
United Kingdom	Net-Zero Carbon Building [19]	Voluntary, 2019	UK Green Building Council	All types of new and existing buildings	Greenhouse gas emissions (GHG)	Whole life cycle (operational and embodied)
United States	Zero-energy building [25]	Voluntary, 2015	Government, Department of Energy	All types of new and existing buildings	Energy consumption (delivered energy)	Operational
Singapore	Green Mark Scheme [32]	Voluntary. 2005	Government, Building Construction Authority,	All types of new and existing buildings	i) Sustainability indicators (including embodied carbon) ii) Energy efficiency iii) IAQ iv) Greenery provision v) materials and waste	Whole life cycle (operational and embodied)

2.1.1 Norway: Zero emission buildings (ZEB)

In contrast to the current energy performance requirements present in the mandatory building standards or widely used distinct methodologies like Passivhaus or zero/nearly zero energy buildings, the Norwegian zero-emission building (ZEB) framework has moved the focus from operational energy use to the life cycle GHG emissions as a key performance indicator. The central vision of the zero-emission building is to achieve the net-zero GHG emission balance, taking into consideration the complete lifecycle of the buildings. However, to provide more flexibility and increase feasibility for market implementation, the framework proposes different progressive ambition levels, based on life cycle stages defined in EN15978 [33] and described as follow:

• The lowest ambition level – ZEB-O-EQ describes the building where on-site renewable energy production compensates GHG emissions related only to the operation of the building - O (ventilation, heating, hot water, lighting), excluding energy required for the user equipment and plug loads (EQ);

• The next ambition level - ZEB-O - describes a building where on-site renewable energy production compensates greenhouse gas emission related to the operation of the building – O - including energy for the user equipment and plug loads;

• The ambition level – ZEB-OM - describes the building where on-site renewable energy production compensates greenhouse gas emission related to the operation of the building, as well as emission from production (A1-A3) and replacement (B4) of building materials;

• The ambition level – ZEB-COM - describes the building where on-site renewable energy production compensates greenhouse gas emission related to the operation of the building, emission from production (A1-A3) and replacement (B4) of building materials; and emissions from construction of the building (A4-A5).

• The highest ambition level – ZEB-COME describes a building where on-site renewable energy production compensates greenhouse gas emissions related to the building's entire lifespan (product stage, construction process, use stage and end of life).

2.1.2 United Kingdom: net zero carbon buildings

The Net Zero Carbon Framework, developed by UK Green Building Council (UKGBC), is a voluntary scheme outlining definitions for net zero carbon buildings in the United Kingdom. The framework emerges from a task group comprising various businesses, trade bodies and professional associations within the construction and property industries. It seeks to build consensus within the industry as to net-zero carbon building definition in the UK. The framework sets out three different ambition levels of net-zero carbon building construction, operational energy, and whole lifecycle, described as follow:

- Net Zero Carbon – Construction (1.1): "When the amount of carbon emissions associated with a buildings product and construction stages up to practical completion is zero or negative, through the use of offsets or the net export of on-site renewable energy."
- Net Zero Carbon – Operational Energy (1.2): "When the amount of carbon emissions associated with the building's operational energy on an annual basis is zero or negative. A net-zero carbon building is highly energy-efficient and powered from on-site and/or off-site renewable energy sources, with any remaining carbon balance offset."
- Net Zero Carbon – Whole Life (1.3): "When the amount of carbon emissions associated with a building's embodied and operational impacts over the life of the building, including its disposal, are zero or negative."

Whilst the framework applies to most buildings scales and typologies; its primary focus is the commercial sector; this is due to a focus on transparency and disclosure of energy use, which is harder to control and manage in domestic scenarios with privacy concerns and measurement potentially harder.

2.1.3 United States – zero energy buildings (ZEB)

In 2014, the US Department of Energy (DOE) contracted with the National Institute of Building Sciences to develop the common national definitions, associated nomenclature and measurement guidelines for zero energy buildings. The developed frameworks set out two separate terms of ZEB buildings, which distinguish the use of renewable energy certificates for balancing the delivered energy, described as follow:

- Zero Energy Building (ZEB) - An energy-efficient building where, on source energy basics, the annual delivered energy is less than or equal to the on-site renewable exported energy.
- Renewable Energy Certificate: Zero Energy Building (REC-ZEB) – building, where on source energy basics, the annual delivered energy is less than equal to the on-site exported energy plus acquired Renewable Energy Certificates (RECs).

The zero-energy framework is mainly focused on single buildings scope, with no limitations regarding type. Additionally, the definitions describing campus, building portfolio and communities coverage are provided.

2.1.4: Singapore – Green Mark 2021 for buildings

The Green Mark certification scheme was launched in 2005 by Governmental Building and Construction Authority (BCA). The certification scheme proposes different mark scheme criteria, based on building function (residential, non-residential, infrastructure, district, retail) and type (new or existing), with the most ambitious one named as" Super Low Energy Buildings (SLE)". Until 2021, the SLE certification focused only on operational lifecycle impacts (energy and water) and indoor environment quality. However, in 2021 the new pilot version of the Green Mark and SLE certification framework introduces additional levels (Ecosystem), which consider also embodied lifecycle impacts. Consequently, the most up to date certification version cover seven main areas: sustainability indicators, energy efficiency, indoor air quality, greenery provision, active mobility, materials and waste, and water efficiency.

The Green Mark SLE provides three ambitions/performance categories of buildings, described in rising ambition level as follows:

- Super Low Energy Building (SLE) – the building which achieves at least 60% energy savings through adopting energy efficiency measures and on-site renewable energy, compared to building codes.
- Zero Energy Building (ZE) – defined as the super low energy building (SLE) with all (100%) energy consumption supplied from renewable energy sources.
- Positive Energy Building (PE) – defined as the super low energy building (SLE) with at least 115% of all energy consumption, supplied from renewable energy sources.

Based on building categories (SLE, ZE and PE) as well as maximum scoring of 75 points from tentative sustainability sections (15 points for each section: intelligence, health&well-being, whole-life carbon, maintainability, resilience), the final certification rate is divided into three primary levels:

- SLE (incl. ZE, PE) – the rate excludes assessment of sustainability indicators and only considers the energy performance of the building (SLE, ZE, PE).
- Gold Plus SLE (incl. ZE, PE) – The score related to sustainability indicators is more than 30.
- Platinium SLE (incl. ZE, PE) - The score related to sustainability indicators is more than 40 points

It is worth noticing that, in comparison to previously introduced net-zero approaches, the Singapore framework put a strong focus not only on climate change mitigation but also on adaptation (resilience) measures.

2.2 System boundaries and minimum requirements related to operational life cycle stages: an overview of leading building approaches in Norway, United Kingdom, United States and Singapore.

The overview of information regarding the scope of the operational life cycle modules in considered building approaches in Norway, the United Kingdom, Singapore and the United States is presented in Table 2. The description of system boundaries is based on the modular framework adopted from EN 15978 [47], shown in the Appendix section (Fig A1).
Additionaly, the detailed description of the each country approach is in presented in Appendix section.

Table 2 System boundaries and minimum requirements related to operational life cycle stages-overview

			System boundaries - operational life cycle modules						Energy efficiency and IEQ requirements		
Country	Approach, Standard or scheme name	Ambition/ performance level	B6.1	B6.2	B6.3	B7	B8	TP[1]	EUI $[kWh/m^2a]$	IEQ	Electricity GHG emissions factor $[gCO_2eq/kWh]$
Norway	Zero emission buildings	ZEB:O-EQ	X					X	Detached house - 100+1600/ GFA Multifamily building – 95 Office – 115	X	132 (Dynamic factor)
		ZEB:O	X		X			X			
		ZEB: OM, COM, COME	X	X	X			X			
United Kingdom	Net-zero carbon buildings	Net-zero carbon – construction	Outside the scope of the assessment						From: 2025 - 2030: Offices 90, Residential 70 From 2030: Offices: 70, Residential: 35	X	Local or market based. Country average – **210** (Static factor)
		Net-zero carbon – operational energy	X		X						
		Net-zero carbon – whole life cycle	X		X	X					
United States	Zero energy buildings		X	X	X				n/d	X	Country average - 400 (Static factor)

Singapore	Green Mark 2021	SLE, Gold Plus SLE, Platinium SLE	X	X	X	X		X	Office: 100(small), 115(large), Retail:160 Educational: 90	X	Country average - 410 (static factor)

X – included, [1]TP- Thermal performance of building elements, EUI – Energy use intensity of building, IEQ – Indoor environmental quality, GFA – Gross floor area [m^2]

2.3 System boundaries and minimum requirements related to embodied life cycle stages: overview of approaches in Norway, United Kingdom, United States and Singapore.

The overview of information regarding the scope of the embodied life cycle modules and recommended LCA databases and calculation methods in presented building approaches in Norway, the United Kingdom, United States and Singapore are shown in Table 3. The following sections provide a detailed description of the analysed embodied features in each presented country. Additionaly, the detailed description of the each country approach is in presented in Appendix section.

Table 3 System boundaries and minimum requirements related to embodied life cycle stages

			System boundaries Life cycle stages/modules						
Country	Standard/Scheme name	Ambition level	A1-A3 Product stage	A4-A5 Construction stage	B1-B5 use stage	C1-C4 End of life stage	D Benefits and loads outside the system boundaries	LCA databases and methods	Minimum verification requirements
Norway	Zero-emission buildings	ZEB: O-EQ, O	Outside the scope of assessment						
		ZEB:OM	X		X (B4)			Specific (EPD) data from EPD-Norge or generic data from the Ecoinvent database	As-build assessment of embodied emissions Independent verification of LCA calculations.
		ZEB:COM	X	X	X (B4)				
		ZEB:COME	X	X	X (B4)	X	X[1]		
United Kingdom	Net-zero carbon buildings	Net-zero carbon – construction	X	X				Method: RICS guidance on whole-life carbon assessment. LCA databases: Inventory of Carbon and Energy or RICS building carbon	Independent verification of LCA calculations.
		Net-zero carbon – whole life	X	X	X	X	X		
United States	Zero energy buildings		Outside the scope of assessment						

Singapore	Green Mark 2021	SLE	Outside the scope of assessment			
		Gold Plus SLE, Platinium SLE	X	X (A4)	Adopted from UKGBC framework	n/c

[1]Reported only as additional information, not included in GHG emission balance

2.4 Options of energy or GHG emissions compensation: overview of approaches in Norway, United Kindom, United States and Singapore

Implementing different compensation measures are essential for achieving the net-zero energy or GHG emissions balance during the building operation. The overview of allowed options in assessed building approaches in Norway, the UK, the USA and Singapore are presented in Table 4. A detailed description of each of the considered compensation options can be found in the Satola et al. study [4]. Additionaly, the detailed description of the each country approach is in presented in Appendix section.

Table 4 Options for compensation allowed in the analysed building approaches

Country	Standard/Ambition level	On-site generation(PV/solar)	On-site generation from off-site renewables (biomass/biofuels)	Off-site generation/supply	Implementation of negative carbon technologies	Renewable energy certificates/off-set credits
Norway	Zero-emission buildings	X	X			
United Kingdom	Net-zero carbon	X	X	X	X	X
United States	Zero energy building	X				
	Renewable Certificate Zero Energy Building (REC-ZEB)	X				X
Singapore	Green Mark 2021	X	X	X		X

3. Case buildings and design strategies for GHG emission reduction

The summary of key data regarding selected case study buildings, which represent a specific country net-zero approach, is presented in Table 5. A detailed description of each case building with higlgiting the most promising GHG emission/energy reduction strategies is shown in the following sections.

Table 5 Key performance data from the selected case building, representative for country net-zero approach

Country	Standard /scheme name	Ambition level	Building name/ reference	Type	Location, climate zone	Heated(H)/ Gross(G) Floor Area (FA) (m^2)	Reference period (years)	Embodied emissions/ energy ($kgCO_{2eq}$/ m^2/a)	Operational emissions ($kgCO_{2eq}$/ m^2a)	EUI (kWh/ m^2a)	Energy or GHG emission compensation
Norway	Zero Emission Building	ZEB-COM-EQ	Powerhouse Kjorbo [34]	Renovation of Office Building	Sandvika Cold Dry	5180 (HFA)	60	6.58 (A1-C4)	5.94	45.0	-5.7 ($kgCO_{2eq}$/m^2a)
United Kingdom	Zero Carbon Building	Net-zero – operational energy	Max Fordham Office – Rotunda [35]	New office building	London, Marine Coast	1317 (HFA)	60	n/a	38	154	-38.0 ($kgCO_{2eq}$/m^2a)
United States	Zero Energy Building		NREL Research Support Facility [36]	New office building	Golden, Colorado, Cold Semi-arid	33 445 (GFA)	n/a	n/a	n/a	112	-112 (kWh/m^2a)
Singapore	Green Mark 2021	Zero Energy Building (ZE)	NUS SDE4 [37]	New educational building	Singapore, Tropical rainforest	8588 (GFA) 3280 (HFA)	n/a	n/a	n/a	65.4	-65.8 (kWh/m^2a)

3.1 Norway: zero emission building

3.1.1 Powerhouse Kjorbo – office building renovation

Powerhouse Kjorbo, located in Sandvika near Oslo, consists of two renovated office buildings initially constructed in 1979 (Fig.1). The total heated floor area is 5180 m^2. The design ambition was to transform the highly energy-intensive building into the "energy positive building", which at least generates the same amount of on-site renewable energy as the energy used to produce building materials, construction process, maintenance, and replacement, and building operation. This ambition can be translated into ZEB: COM-EQ level. The building design integrates several passive and active strategies for both embodied and operational GHG emission reduction to achieve such high ambition. Firstly, the indoor spaces were located by taking into consideration the outdoor environmental conditions. Large open offices were allocated along the southern facade. In contrast, small office box areas were placed along the north and western parts to make the indoor climate more robust against overheating. In addition, the building envelope was well insulated, taking into consideration the minimum requirements of Passive-house standard NS3701. Special attention was taken to improve the airtightness of the building envelope, from 2 air changes per hour to a measured value of 0.24 [1/h] (at 50Pa difference). The external shading devices were integrated into the facade to reduce the solar heat gains in summer periods.

The heating and cooling system is based on two brine-to-water heat pumps connected to the boreholes system. District heating network is used as peak load and backup source. The cooling system is mainly based on the free-cooling cooming from the boreholes water flow, with the possibility of transforming one of the heat pumps into the chiller. The energy demand related to the ventilation system was identified as one of the leading GHG emissions drivers. Consequently, the set of measures, including heat recovery, demand control of airflows and personal air distribution, was implemented to reduce energy consumption. The staircases are used as a ventilation exhaust duct, reducing the fans' pressure drops and consequential energy consumption (Fig.2). Most (80%) of interior concrete-based structures are exposed, increasing the thermal mass and reducing indoor temperature fluctuations.

All steel and concrete structures from the existing building were maintained and reused in refurbished buildings to reduce embodied GHG emissions. Additionally, the existing glass facade panels were reused as interior office fronts. The low emissions charred wood was chosen as the cladding material. The roof-integrated PV panels (1556m^2) with the peak power of 312 kW are used to compensate lifecycle GHG emissions from operational energy use (without equipment -EQ) and embodied GHG emissions (A1-A3 and B4).

The total investment cost was estimated as 30% higher than the alternative design scenario, in line with Norwegian building regulations (TEK10).

Fig. 1 Powerhouse Kjorbo – visualisation

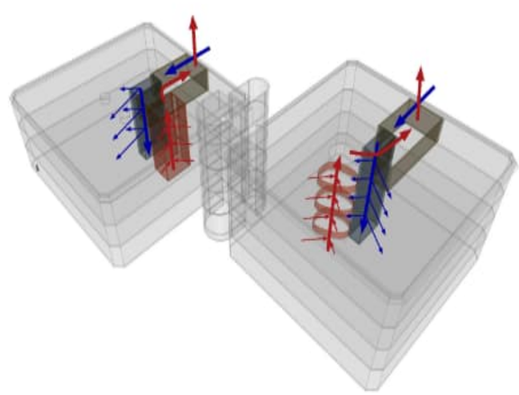


Fig. 2 Powerhouse Kjorbo – ventilation system

3.2 United Kingdom: net-zero carbon buildings

3.2.1 Max Fordham office – office building renovation, net-zero carbon: operational energy

Initially constructed in 1850 and serving as a former piano factory, the five-storey building has been remodelled and refurbished many times since then; however, most original architectural features remained (Fig.3). The last retrofit of the building was performed in 2019, with the main design goal to significantly increase energy efficiency and achieve net-zero carbon: operational energy ambition. Nowadays, the office building serves as the new head office of the World Wide Fund for Nature (WWF) organisation and acts as a sustainable example and education centre for the public and industry.

The key implemented design strategies for operational GHG emissions included:

- Additional design of roof vents to enhance the natural ventilation airflow and ensuring no need for cooling energy in the summer,
- Added a drought lobby to the main entrance to reduce infiltration heat loss,
- Thermal insulation added to the existing roof and secondary glazing to existing windows to reduce heat loss,
- Upgrade of the internal windows blinds to enhance passive cooling,
- Installation of new heating system based on efficient gas boilers and energy management system,
- Implementation of an on-site PV system – 3kW.

The retrofitted building has achieved BREEAM outstanding score, and operational GHG emissions were reduced by 42%. After renovation, energy consumption and operational GHG emissions in the Rotunda office are nearly 20-30% lower than market-based benchmarks.

The total amount of consumed electricity (95 kWh/m2a) is purchased from Green Energy, claiming that 100% of the electricity supply comes from renewable energy sources. However, due to unclear UKGBC's requirements related to demonstrating the additionality feature of the off-site renewable energy at the certification (2019) time, the purchased electricity was not accounted as offset carbon. Consequently, the whole amount of annual operational GHG emissions was balanced by purchasing the "UK Woodland Creation for Carbon Capture by Forest Carbon". The main rationality of selecting this particular offsetting scheme lies in the reliability and localisation of the project inside the UK.

Fig. 3 Max Fordham' Rotunda office building'

3.3 Unites States: Zero energy buildings

3.3.1. NREL Research Support Facility – new office building, zero energy building

The Research Support Facility (RSF), located on the main campus of the National Renewable Energy Laboratory, was constructed in 2010 (Fig.4) . It was designed to showcase highly sustainable, highly energy effective, and zero energy building that incorporates a multidisciplinary approach to a "whole building" integrated design process. The primary building design strategy was firstly to focus on the energy efficiency of the building. Later, after achieving efficiency goals, on-site renewable energy sources were designed to achieve a net-zero energy balance.

The implemented energy efficiency strategies for operational energy reduction incorporates both: passive architectural and active strategies and include:

- Building form and massing drove by energy and the environment.
  The building is organised in long, 18m wide office wings for optimal solar orientation, and natural ventilation (Fig.5, point 1)
- Maximise natural ventilation flow from operable and automatic windows controls.
  On both the south and north elevation of the building, the lower part of the window can be opened manually and automatically. The occupants are informed by the central energy management system when conditions are optimal for natural ventilation (Fig.5, point 6)
- Triple-glazed windows with individual overhangs.
  The windows size and glass combination were designed, maximising the daylighting, minimising glare and exceeding the heat loss and gain at the same time. The east and west elevations feature thermochromic and electrochromic glazing, respectively, to reduce heat loss and gains (Fig.5, point 4)
- Heating and cooling system based on radiant slabs.
  Both office wings are heated and cooled by a radiant ceiling slab, using the heat/cold energy from the campus plant. The building's heating and cooling system features 42 miles of radiant heating/cooling tubes that run through the ceilings on each level (Fig.5, point 5)

The whole building energy consumption (112 kWh/m^{2}a) is balanced by an on-site renewable system, which is based on rooftop PV panels (Fig.5, point 2) (450kW) and additional 1150kW PV modules located in the adjacent parking structures.

Fig. 4 NREL Research Support Facility, zero energy building

Fig. 5 NREL Research Support Facility – overview of operational energy use reduction strategies

3.4. Singapore: Zero and energy positive energy buildings

3.4.1 School of Design and Environment of the National University of Singapore. Zero-energy educational building

Located within the National University of Singapore, the new six-storey building (Fig.6) serves as an educational living laboratory to demonstrate and explore human-centric approaches for integrated sustainable development. The most important strategies deployed to reduce the building's energy demand include:

- Optimal facade construction for tropical conditions.
  The design of the external facade was based on the series of" floating boxes", which creates the porous space enabling natural cross ventilation, natural lighting and view to outdoors. The facades are partly shaded and provide extensive access to daylight.
- Overhang shading.
  The large overhanging roof on the south, together with east and west facades, shade the building from the sun's heat, as well as located the rooftop PV panels (south side)
- Thermal zoning of the building.
  The building is divided into three types of spaces: naturally ventilated zones(communication spaces), limited air-conditioned zones (laboratories) and the most common hybrid zones (classrooms, gathering zones).
- The innovative hybrid cooling system supplies fresh air at higher speed, temperatures, and humidity levels than in a conventional system, ensuring that rooms are not overly cooled (Fig.7)

The consumed energy of the building (497 MWh/a) is fully balanced by generation from on-site solar energy (500MWh/a) based on 1225 roof solar photovoltaic panels (Fig.6)

Fig. 6 NUS SDE4 building

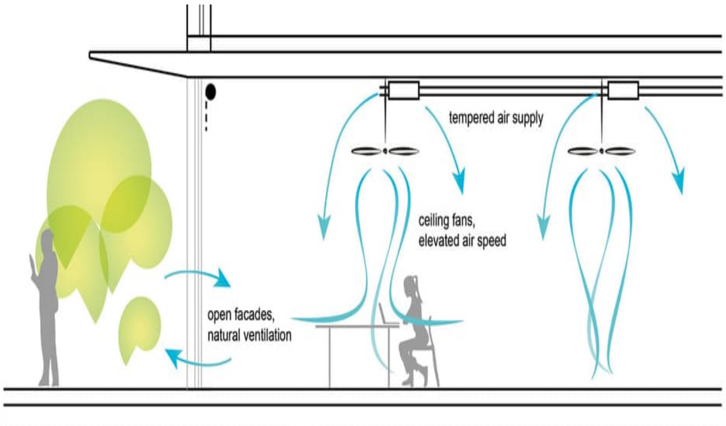


Fig. 7 Hybrid cooling system in NUS SDE4 building

4. Conclusions

To be written in the final version of the article

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TIMBER-CONCRETE COMPOSITE – A CONTRIBUTION TO SUSTAINABILTY IN ARCHITECTURE AND CIVIL ENGINEERING

Klaus HOLSCHEAMCHER*, Ulrike QUAPP

HTWK Leipzig, University of Applied Sciences, Faulty of Civil Engineering
Karl-Liebknecht-Str. 132, 04277 Leipzig, Germany; klaus.holschemacher@htwk-leipzig.de

Abstract

Timber-concrete composite (TCC) has been a familiar construction method for more than 100 years. Especially for the construction of floors it is a well-approved technology. A typical TCC slab consists of timber beams, plain or reinforced concrete slab, and shear connectors.

In past, TCC slabs have been primarily applied for strengthening of existing timber beam ceilings. Timber beam ceilings in older buildings often must be revaluated or strengthened due to their relative low bending stiffness which causes high deflections or by fire safety reasons. When utilizing the TCC technique, existing timber beams and boarding on timber beams must not be removed, leading to economic advantages in comparison to other strengthening methods. There are only shear connectors assembled at the top of the timber beams, followed by casting the concrete slab. The result is in an essentially increased load-bearing capacity, lower deflections and higher fire safety.

Additionally, TCC is an ambitious construction method for design of new buildings in presence. TCC is the compromise between pure timber beam ceilings and reinforced concrete slabs regarding their load-bearing behaviour and ecological issues. The paper reports the state-of-the-art in TCC, compares the different floor constructions in this context and reports the building law requirements when applying TCC in Germany, Austria and Switzerland.

Keywords

Timber-concrete composite, strengthening, sustainability, building law requirements.

1 Introduction

1.1 Historical development

TCC has been a well-known construction technology for more than 100 years. Main motivation for its application in the early 20th century was the lack of building materials. By combination of timber and concrete in a composite member, it was possible to take the advantageous properties of both materials resulting in efficient and resource saving structures [1]. The patents by Müller in the year 1922 and Schaub in the year 1939 demonstrate very impressive the state-of-the-art in TCC at this time, see Fig. 1.

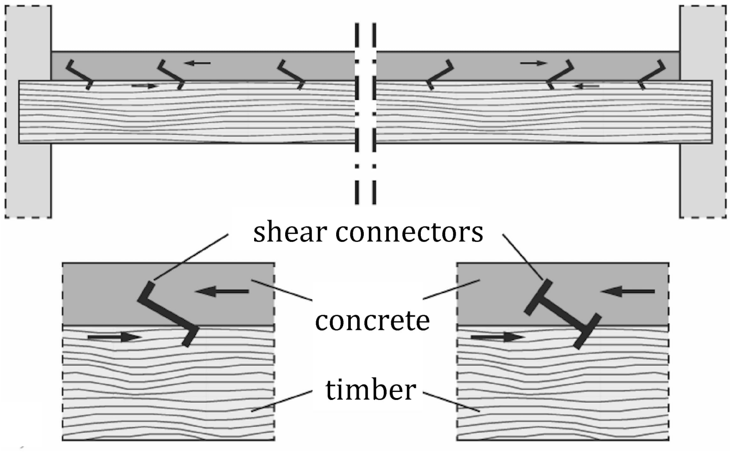

Figure 1. TCC patent by Schaub [2]

In the 1930s and 1940s, a remarkable number TCC bridges was constructed in the USA. Some of them are still under traffic [3]. Later, especially in the 1950s to 1980s, TCC application was mainly focused on strengthening and revaluation of existing timber beam ceilings. Nowadays, application of TCC for new buildings and even wide-span bridges is strongly increasing. The main reason for recent upturn of TCC is probably its contribution to better sustainability and lower ecological footprint in architecture and civil engineering [4].

1.2 General structure of TCC

Basically, TCC members consist of timber beams, concrete slab, and shear connectors [1], [5]. Additionally, there may be exist or arranged a not load-bearing boarding between the top of the timber beams and the bottom of the concrete slab. Such boarding can be present in case of strengthening of existing timber beam ceilings or act as formwork for casting the fresh concrete when building new TCC constructions. Expediently, the concrete slab is arranged at the compression side of the TCC section, whereas the timber beams are at the sections' tensile side. This is useful, because concrete is a material that is well bearing compression stresses. For bearing tensile stresses, concrete must be reinforced. A typical TCC section is shown in Fig. 2.

The timber beams are mostly arranged with spacing between it. Another possible solution is their arrangement without any gap between it (Fig. 3) [6].

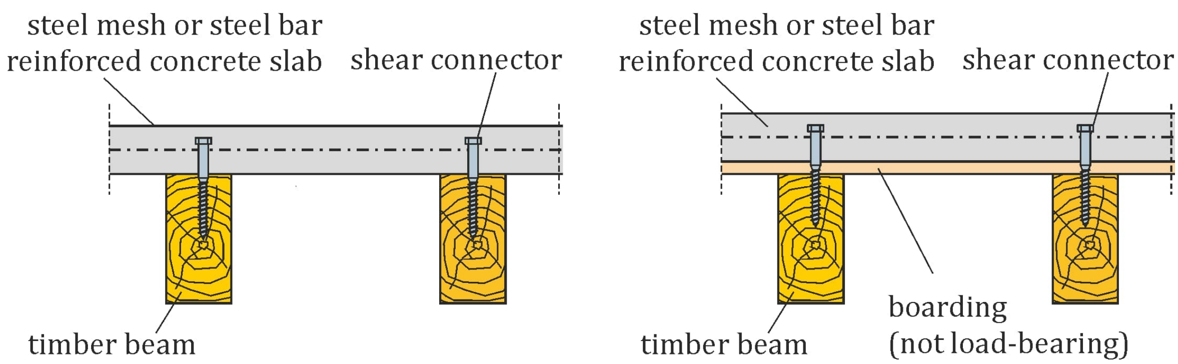

Figure 2. Typical TCC section

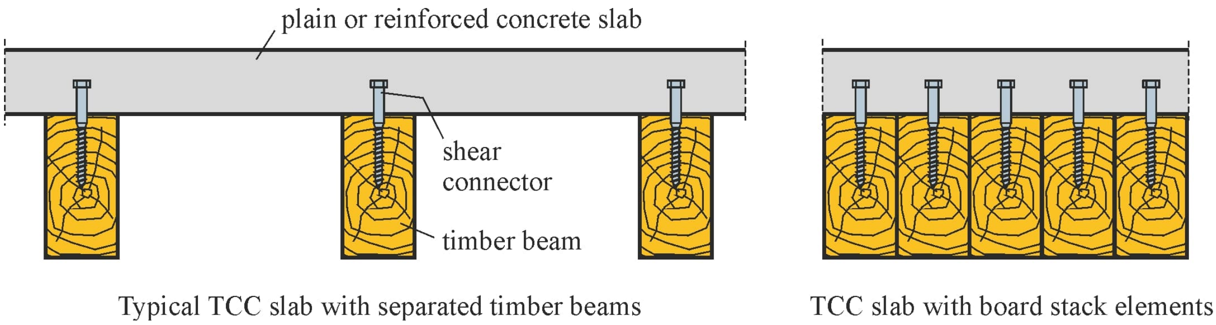

Figure 3. Arrangement of timber beams in TCC

The shear connectors ensure that the timber beams and the concrete slab interact in the composite section in a sufficient matter. Usual shear connectors are dowel-type steel fasteners (e.g. bolts, screws, nails), notches and combination of notches with dowels, see Fig. 4. In some cases, special shear connectors like steel wire meshes are glued in a prepared slit at the top of the timber beams. A directly glued connection between timber and concrete is rarely used in construction practice. The load-bearing behaviour of dowel-type steel fasteners may be improved if they are assembled in parallel to the timber beam axis with an angel of more than 45° to the interface [5].

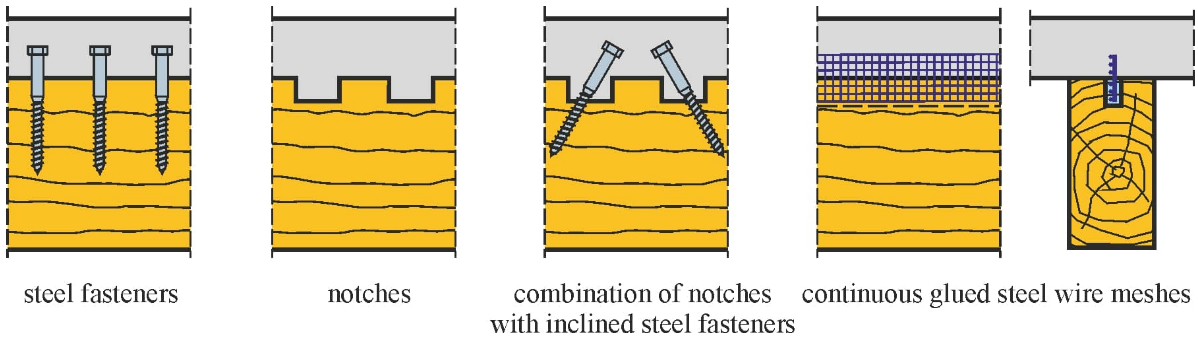

Figure 4. Arrangement of timber beams in TCC

2 Structural Behaviour and Design of TCC

2.1 Flexible bond and bending stiffness

Usual shear connectors provide only flexible bond between the timber part and the concrete part of the TCC section. It means that a slip in the interface between timber and concrete is unavoidable. Another result of flexible bond is the jump in the strain distribution (Fig. 5). Nevertheless, it is visible that in case of positive bending moments (typical for single span members) concrete is predominant under compression and timber under tension.

Caused by the flexible bond, the bending stiffness of TCC members is between those of comparable members without any bond and with rigid bond. The bending stiffness of TCC members may be influenced through various parameters. Main influence parameter is the height of the concrete slab (Fig. 6). However, for moderate spans up to 6,00 m, a concrete slab height of few centimetres is sufficient from the point of load-bearing behaviour.

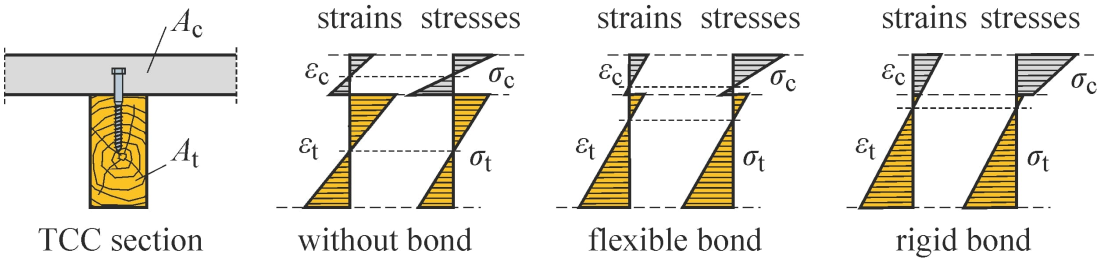

Figure 5. Stress and strain distribution for design situations without bond, flexible bond, and rigid bond (positive bending moment presupposed)

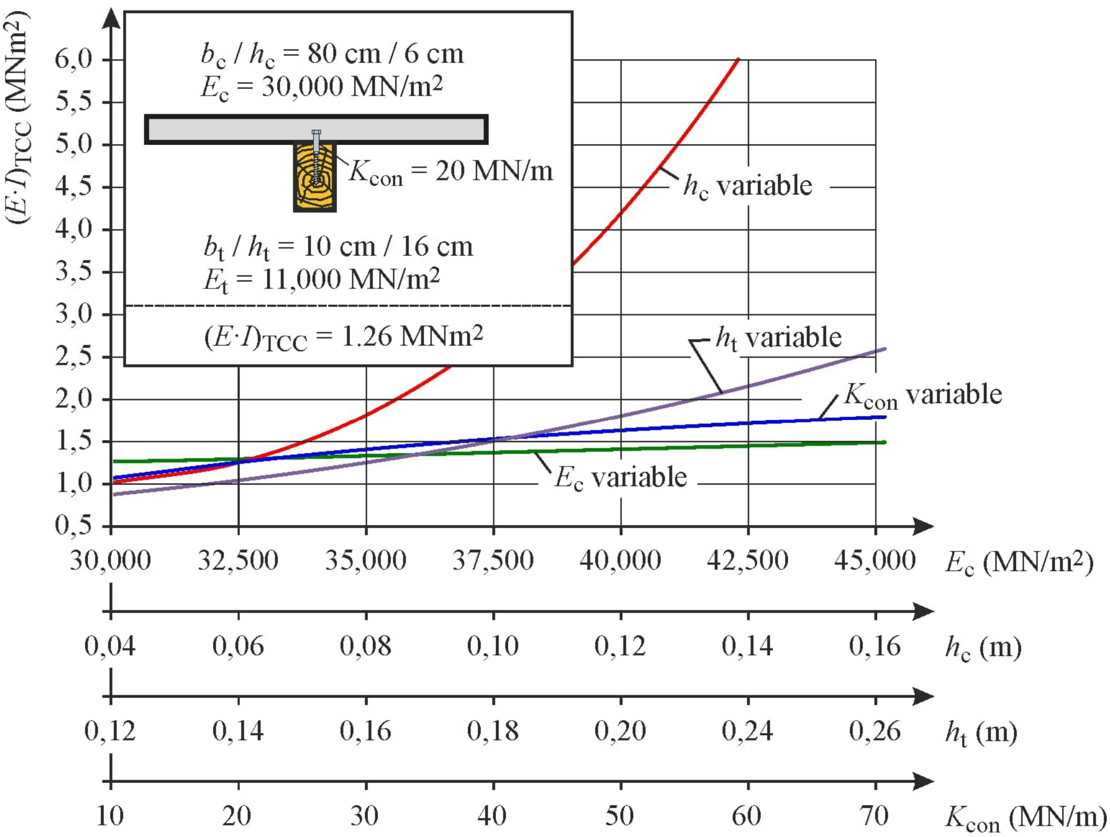

Figure 6. Influence of various mechanical parameters on bending stiffness [6]

2.2 Required concrete properties

Sometimes it is discussed if plain concrete may be used for the construction of the slab in TCC systems. In this context it is to investigate if there are acting considerable tensile stresses in the concrete. According to Fig. 5 there are almost no tensile stresses in the concrete in parallel to the timber beams. However, there is a positive bending moment presupposed in Fig. 5. For continuous systems there is a positive bending moment only in the span, but negative bending moment at the interior supports. In this case, at interior supports the sign of stresses is inversed and there are major tensile stresses in the concrete requiring reinforcement.

There are more reasons for tensile stresses in concrete, especially in lateral direction to the timber beams. Such situations are heavy loads acting on only one beam or between the beams or varying spans of adjacent beams (Fig. 7). Furthermore, TCC slabs are part of the bracing system. Therefore, it is to note that application of plain concrete is an exceptional case in TCC [7].

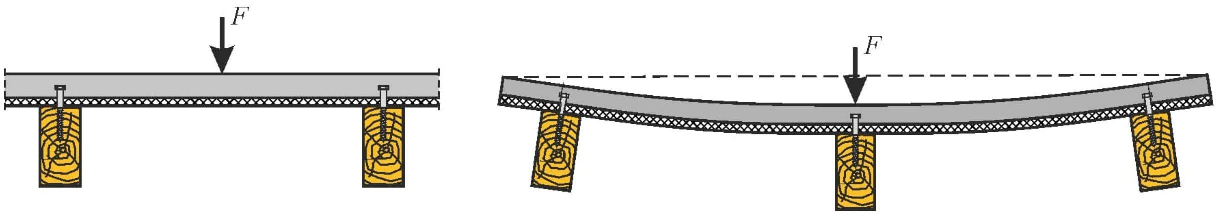

Figure 7. Lateral load sharing in TCC structure

Usually, steel bar or steel mesh reinforcement is applied in reinforced concrete members. For this reinforcement a concrete cover of at least 2 cm is required. Considering that mesh reinforcement needs lap splices in longitudinal as well as in lateral direction, the minimum height of the concrete slab results in 7 cm or more. In many cases this depth is clearly more than necessary for bearing the load.

Therefore, application of fibre reinforced concrete may be advantageous because there is no need for concrete cover [5]. By usage of fibre reinforced concrete, the height of the concrete slab may be reduced to values determined by building physical and load-bearing requests. In the result, dead load of the construction and consumption of building materials can be lowered. This is also achievable when textile reinforced concrete is applied instead of steel bar or steel mesh reinforced concrete.

2.3 Normative regulations

Mechanical properties of timber are provided in Eurocode 5 [8] and for concrete in Eurocode 2 [9]. The verifications in Eurocode 5, Annex B may be used for the design of TCC members. However, there are no normative regulations for the mechanical properties of shear connectors available at time [10]. This issue is a clear disadvantage for application of TCC in construction practice. How to deal with this situation is discussed in Chapter 3.

3 Legal Requirements for Application of TCC

3.1 Germany

In Germany, building materials and construction methods normally have to prove compliance with national technical regulations. If building materials and construction methods are not regulated in one of the acknowledged technical regulations or do not comply with them, usability must be proofed by an official certificate of usability. That can be a general German Technical Approval or European Technical Assessment, a General Construction Supervision

Test Report or an Approval in the Individual Case by the highest building authority. This shall ensure that from using the construction method no danger arises to public safety and order.

TCC is a not regulated construction method because there are no normative rules for the design of TCC. Even if TCC members can be designed according to codes for timber structures, e.g. Eurocode 5 [8], there is no information about characteristic or design values of stiffness and ultimate load of shear connectors available in the codes. These parameters need to be defined in the Technical Approvals of the shear connectors. This circumstance is the main obstacle for application of TCC in practice. To solve these normative problems, the upcoming version of EN 1995 shall additionally regulate the TCC construction method [11].

3.2 Austria

The legal situation in Austria is similar to the German. Structures and all of its parts must be designed and built in a way that they, in accordance with the State-of-the-art, comply with the regulations of the construction law.

In the year 2019, the Austrian Construction Technology Association published the directive "Timber Concrete Composite Slab". Apart from that, concrete and timber are regulated in national codes [12], [13] but the shear connectors are not. That is why the applicant for a building permit has to proof the usability of the shear connectors by submitting a report of an officially acknowledged construction expert [14].

3.3 Switzerland

In Switzerland, a globally unique variety of construction law regulations exist. Due to 26 regional planning and building codes along with executive regulations and numerous local building regulations, the legal situation of using TCC is quite complex.

Nevertheless, all Swiss construction regulations require a compliance of the structure and its parts with generally accepted engineering standards and State-of-the-art. That shall avoid any danger for personnel and property [15].

TCC is a not regulated construction method in Swiss construction law, although design codes for timer and concrete exist [16], [17]. Therefore, it is the same situation as in Germany and Austria. Because of missing normative regulations for TCC structures, a proof the safety for the construction is necessary. For the review, the building authority may require a proof of the structural strength, for example based on experimental examinations.

4 Application of TCC in Construction Practice

4.1 Strengthening of existing timber beam ceilings

Timber beam ceilings are the typical floor construction in older buildings. Caused by insufficient bending stiffness they often suffer non-tolerable deflections followed by the need for strengthening. Other reasons for strengthening of existing timber beam ceilings are their vibration sensitivity, inadequate fire resistance, deterioration of material properties and higher imposed floor loads.

There are many strengthening techniques available in this context. A very easy and time as well as material saving method is the application of TCC. For this purpose, shear connectors are installed at the top of the timber beams and subsequently the concrete slab is cast (Fig. 8). In many cases there is no need to remove the boarding and the fill of the timber beam ceilings. Therefore, TCC is a very economic strengthening method in comparison with other possible strengthening techniques [18].

Another substantial advantage of strengthening with TCC is the fact that the bottom side of timber beam ceilings may be unchanged. Beside the economical benefit, this circumstance may be decisive for application of TCC in the context of heritage protection.

Within the last decades, many timber beam ceilings have been successfully strengthened with TCC. Some impressions are shown in Fig. 9.

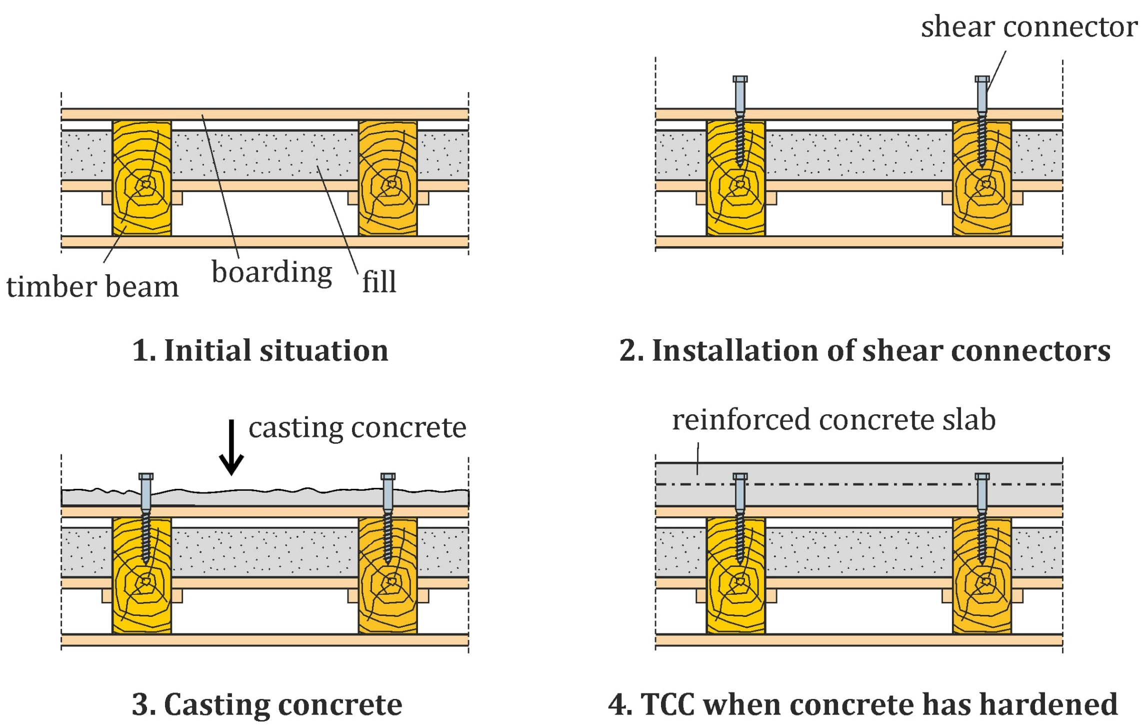

Figure 8. Strengthening of timber beam ceilings with TCC

installed shear connectors and
timber beam ceiling covered with PE-foil

concrete casting

Figure 9. Strengthening of timber beam ceilings with TCC

4.2 New TCC constructions

For some years there may be noticed a strong increase of TCC applications for construction of new buildings and even bridges. Main motivation may be the challenge to make architecture and civil engineering more sustainable. In this context it is to consider that the production of Portland cement is responsible for estimated 8% of total greenhouse emissions. Thus, there are many efforts to replace Portland cement in concrete production by other cementitious materials or to avoid concrete application in general. Because of its favourable properties, the authors believe that concrete will remain an important construction material in future. However, it seems to be useful to combine concrete with other renewable materials in composite members, as realized in TCC.

Regarding the structural behaviour, fire resistance, and sustainability, TCC slabs are to classify between pure timber beam ceilings and ordinary reinforced concrete slabs. In a recent study it was demonstrated that under comparable conditions (imposed load q_k = 3 kN/m^2, effective span l = 4,50 m, 50 years service life etc.) the global warming potential of TCC slab is around 30% lower than those of a reinforced concrete slab [4], [19].

For the production of slabs in new buildings, the application of prefabricated TCC elements has been proved successfully. This means that a timber beam with pre-installed shear connectors is inserted in fresh concrete. After hardening of concrete, the TCC element is transported to the site and assembled there (Fig. 10).

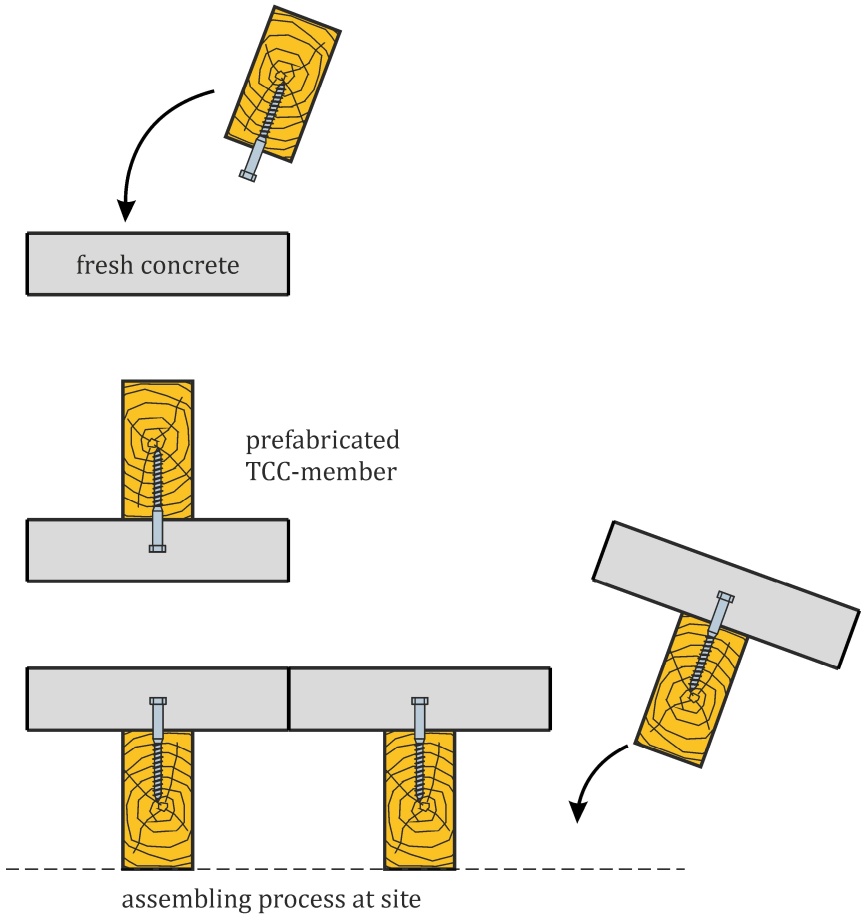

Figure 10. Construction with prefabricated TCC elements

5 Summary

Though TCC is an old construction method, its importance is rapidly increasing nowadays. TCC slabs are a useful solution for strengthening of existing timber beam ceilings. Because bottom side of timber beam ceilings may be unchanged in the result of strengthening procedure, it is the preferred technique in the context of heritage protection. In this way, strengthened floors convince with their improved load-bearing behaviour, much better fire resistance, and advantageous building-physical properties.

One of the main reasons for the current significant success of TCC in construction of new buildings is its better sustainability in comparison to ordinary reinforced concrete slabs without substantial loss of fire resistance or other important mechanical properties.

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THE POLITICS OF POROSITY: FROM MATERIALITY TO SOCIALITY

Diandra Pandu SAGINATARI*[1], Jonathan HALE[1], Tim COLLETT[1]

[1]University of Nottingham
University Park Campus, NG7 2RD Nottingham, UK; diandra.saginatari@nottingham.ac.uk

Abstract

This paper is drawn from a larger PhD project that proposes a new definition of porosity as an architectural condition - one that promotes interdependence between a building and its surrounding context, at a range of scales from micro to macro.

Porosity is a relatively familiar term in architectural discourse, at least since Walter Benjamin and Asja Lacis's essay *Naples,* originally written in 1925. Within this essay, the idea of porosity was used metaphorically, linking the quality of the stone buildings to the quality and the livelihood of the city as a whole. This showed how porosity as a concept could be seen at both micro and macros scales: viewed as both a quality of the masonry surface and as an urban spatial characteristic, with a range of possible applications between these two scales.

The present paper begins by exploring porosity both on and around an architectural surface through the specific case of a neglected wall in the neighbourhood of Majalengka, Indonesia and Nottingham, UK. The investigation starts with visual observation of surface conditions and various phenomena on and around the wall surface, capturing porosity based on the traces of inhabitation. From this preliminary investigation, the paper develops a discussion of porosity as a tool for dialogue between previously demarcated contexts, for example, inside-outside, public-private, culture-nature, and intention-contingency.

Rather than thinking of porosity as simply an ability to *transmit* (for example, to allow moisture to pass through), this study instead explores porosity as an ability to *absorb* – to expand from a two-dimensional membrane into a three-dimensional volume, accommodating various phenomena – both material and spatial – within its own thickness. It, therefore, views porosity as a constructed active political condition that generates relations between the surface and its contexts, both environmental and social, as a form of spatial production.

Keywords

Porosity, materiality, wall, inhabitation, spatial production

1 Introduction

Porosity is a relatively familiar term within architectural discourse, and the reference mostly goes to Walter Benjamin and Asja Laci's essay *Naples*, originally written in 1925. Within the essay, the term porosity is used metaphorically, "As porous as this stone is the architecture.

Building and action interpenetrate in the courtyards, arcades and stairways"[1]. It suggests that porosity as a concept could be perceived both within micro and macro scales: viewed as the quality of the masonry surface and as an urban spatial characteristic, as material and spatial conditions.

In microscale, porosity emerges within the discussion of building material as a material property and becomes one of the many properties that define the material's performance. This is usually related to the material's ability to transfer and retain elements such as heat and moisture. Furthermore, porosity is also considered a material property that alters material durability. Vitruvius did suggest this in his book *The Ten Book on Architecture*. He mentioned porosity and porous quality of fir and rubble is rather unpreferable as it will suck the moisture in and influence the strength of the material [2]. Besides, porosity allows decay and the bio-colonisation of the material, which leads to deterioration.

On a macro scale, porosity is perceived as an urban socio-spatial condition. For example, in the essay *Naples*, porosity is considered "the inexhaustible law" [1], which creates the livelihood of the city. Porosity provides and allows events to interpenetrate through the architecture; it blurs the boundary of the built environment, between public and private, day and night, and holidays and weekdays [3]. Furthermore, "porosity is the space of opportunities and improvisation" [4]; it "provides a way of making space and time to work together" [5] which allows spatial production through appropriation and re-appropriation that occurs continually in time [6]. Porosity also "forms the antithesis of the permanent and final" [3]. Thus, porosity seems to suggest spatiotemporal phenomena of which involves time within the spatial dimension.

The discussion of porosity in architecture is arguably situated within the two domains, the material and the socio-spatial domain, implying the two scales of micro and macro. The material domain refers to the physical existence of architectural elements and their materiality, while the socio-spatial domain refers to the relationship between social conditions and the spatial structure. This paper then aims to inquire about the politics of porosity. Politics of porosity here is viewed as an attempt to see how porosity allows the production of space through the dialogue between the material and the socio-spatial domain.

To begin the inquiry, this paper investigates architectural surfaces, in particular the neglected walls in the neighbourhood of Majalengka, Indonesia and Nottingham, UK. Neglected wall in this study refers to a sidewall of a house that usually exists next to the street, pedestrian way, or another leftover space in the neighbourhood. The investigation starts with visual observation of surface conditions and various phenomena on and around the wall surface, capturing porosity based on the traces of inhabitation. This investigation leads to the discussion of porosity as an ability to *absorb*, which creates a three-dimensional volume that can accommodate various phenomena – both material and spatial – within its own thickness. It, therefore, views porosity as a constructed active political condition that generates a dialogue between the surface and its contexts, both environmental and social, as a form of spatial production.

2 Porosity, Wall, and the Porosity of Wall

The etymological root of porosity is the Greek word of *porós*, which refers to the river's shallow part where one can cross [7]; it also refers to a passage or openings [3]. Porosity relates with the existence of pore, an interstice, minute of openings, void among solid. A pore is not just a given lacuna, but it has a relational function to the environment that connect two contexts [3]. An example is the pore of our skin which functioned as the interface between the body and the environment [8] that protects and regulates our body. The skin pore is a space where heat and moisture transfer and pathogen and dirt filtration occur. The other example is the pore of soil which gives the capacity for the soil to transfer and contain water and become the living space for the other organisms [9].

Looking at the example of skin and soil, porosity arguably rests on the pore geometry (i.e., the material, shape, size, distribution, the configuration of solid and void) and the context where it exists. The contexts here include the environmental context, which refers to the weather, the micro and macro climate, and the social context, which refers to the social law that exists within the society that would impact how the society inhabit the space. For example, when porosity is discussed within the micro-scale of the material, the size, shape, and distribution of the pore, and also the environmental condition such as humidity, will be investigated to see how the material porosity performs in transferring and retaining moisture. Another example, in the case of Naples, mentioned that the porosity relates to how action occurs in the balcony, courtyards, arcades, and staircases [10], suggesting some spatial, physical configurations on which porosity performs together with the "indolence of the Southern artisan" [10]. To see porosity as a performance of both solid and void within a context, both environmental and social contexts, could potentially unravel how porosity works as a political condition that allows the production of space.

Based on the discussion above this paper will begin the inquiry on porosity by investigating neglected architectural wall that arguably has both material and socio-spatial presence. In architecture, a wall is considered an envelope, one of the basic elements of architecture that creates a materialised boundary of enclosed space [11,12]. Wall separates and demarcates inside/outside, public/private [12]; it excludes and includes at the same time [11]. Wall is a material artefact that has a direct impact on the body as, first of all, it constrains circulation [13,14]. Second of all, a wall is experienced through bodily engagement. For example, walking through a gate on the wall, walking alongside a wall, leaning to the wall, and climbing the wall [11]. Wall, through its surface and materiality, gives effect to the space around it as the material of the wall "interrelates with the life they accommodate, which takes place in space and time" [11].

Some walls act as façade of a building, the main face of a building designated as a surface of representation that sometimes is political as it expresses identity or power [12]. However, this paper will not be looking at such a wall. This paper will look at the neglected architectural wall, which refers to a sidewall of a house that usually exists next to the street, pedestrian way, or other leftover space in the neighbourhood. It is worth acknowledging that any architectural wall needs to be understood as one that has two surfaces, one is facing the inside, and the other is facing the outside [15]. Its surfaces will be treated differently depending on the space they are facing. Surfaces facing the inside will be treated to suit the needs of the interior, while surfaces facing the outside will be treated depending on the role they play. The sidewall of a house might be neglected, while the façade will be carefully treated.

When a wall surface is facing a public realm and everyday context, it could be considered part of urban walls, and its ownership might be challenged. As a material object, it belongs to the building. However, as a surface, it contributes to shaping the face of the neighbourhood. And if it is neglected, the space in front of it could be perceived as leftover and ambiguous space, possible to be occupied. Therefore 'informal' spatial practice might occur as "everyday context is always 'working' in some way" [16] through what Lefebvre indicated as the act of continual appropriation and re-appropriation [6] and “production of regimes of habitudes” as means of inhabiting the space [17].

Furthermore, the surface of such a wall is a space for tactical urban intervention [14,18]. An example is an urban graffiti that sees a wall as a visible surface for inscriptions [14]. However, in the case of urban graffiti, it is not just about the visibility and availability of the surface. Instead, graffiti is a "materially consequential act", making it topo-sensitive [19], highlighting the importance of the material and the location of the wall.

This neglected condition of the wall also implies the lack of maintenance towards the wall, making it exposed to not only social conditions, as mentioned previously, but also environmental conditions, which usually lead to decay and deterioration. Such a wall experiences the subtraction of the weather [20], the possible leaks or cracks from any utility pipes coming through, and the possibility of bio-colonisation, which relates to how the material could have the potential to give a living space for living organisms [21]. Wall, even though it is considered an extreme habitat [22], can act as an urban ecosystem and habitat for various organisms [23,24] once it is bio-colonised, especially neglected wall as without maintenance, the bio-colonisation will occur without any delay [25].

The discussion above attempts to view the neglected architectural wall as both a porous object and a porous space. A porous object relates to how a neglected wall is viewed as a porous material with a surface condition where material treatment (i.e. exposed bricks) constantly interacts with the environmental condition and the act of maintenance. It also relates to the existence of pores on the wall, including, for example, the pore of the bricks and also any openings such as windows. Porous space relates to how the neglected wall is viewed as part of the surface that shapes the urban everyday space, as a 'pore' of the neighbourhood, as an ambiguous space of inhabitation and improvisation. By viewing neglected walls as both porous objects and porous space, this paper will investigate how the politics of porosity contributes to spatial production through the trace of inhabitation that existed on and around the wall.

3 Porosity through Captured Traces of Inhabitation

Porosity could be measured and observed in different ways depending on the context and scale. For example, in microscale of material, the pore dimension and morphology of porous silicon can be investigated by electron microscopy, while pore distribution can be investigated by porosimetry which injecting substances such as mercury to see the capacity of the pore [26]. Another example is within the macroscale of urban space where porosity is observed through the interpenetration of actions and the built environment and of public and private, as explained in the case of Naples where action interpenetrate within staircases, arcades, and courtyards and how home extends to the street and the street to the home [10]. Furthermore, it is observed through accessibility, the flow of people, occurrence of events, and through time such as through how long a private space could be accessible to the public [27]. Both measurement and observation indicate the importance of the physical aspect, such as the dimension and morphology and how they relate to porosity's performance, which usually involves flows of matter and events within the period of time.

This paper will particularly observe, not necessarily measure, the porosity of the neglected wall by looking at traces of inhabitation as events on and around the wall. Traces of inhabitation observed here are not just human's but also other organisms'. Observing physical traces could offer an imageable, unobtrusive method that usually deals with long-lasting phenomena [28]. By looking at traces, which may have been consciously or unconsciously left behind, we could infer how an environment got the way it is and how people use it [28]. Therefore by observing traces of inhabitation on and around a neglected architectural wall, it is possible to infer how the politics of porosity performs.

The investigation starts with visual observation of traces captured by photographs of walls, making the photographs of walls the basis for the investigation. Then, the investigation continues through tracing drawings. "Tracing constitutes a form of knowledge production within architecture… Tracing offers opportunities for both copying and novelty through selection and omission of lines, introduction of variation and intervention" [29]. The idea of tracing is fundamentally lying in working with layers, both analogue and digital mode. Within each layer, there are freedoms in selecting what to 'copy'. In addition, the layers themselves could be reconfigured, creating different readings upon the materials. This is the power of tracing. It allows us to highlight some aspects from the original visual material and utilise that to unfold unforeseen phenomena.

This paper traces the traces of inhabitation from wall photographs captured in the neighbourhood of Majalengka, Indonesia and Nottingham, UK, not to compare but to seek for variety. The walls selected (Figure 1) are the sidewalls of a house that is directly facing a street, alley, pedestrian, or leftover spaces in the neighbourhood. Through the tracing drawings, the investigation attempts to see the wall as a porous object and space by highlighting the surface condition, objects attached to the wall and objects that exist in front of the wall. The surface conditions include any marks caused by humans and the environment, and the objects include both living and non-living objects that signify the trace of inhabitation. Then, the surface conditions and the objects are categorised and speculated regarding how they end up in such phenomena. Later, this investigation will attempt to infer how the politics of porosity perform on such a wall.

Figure 1. Photographs of wall samples in Majalengka and Nottingham

4 Porosity of Wall and Traces of Inhabitation

This paper investigates six examples of walls from the neighbourhood of Majalengka, Indonesia and Nottingham, UK (Figure 2). The three walls in Majalengka are situated within different settings with different surface conditions. Wall 1 is a side wall facing a courtyard and façade of another house. It is a plastered and painted brick wall with a small opening, presumably for ventilation. Some of the paint and plaster are peeled, creating cracks of which some plants are growing. In front of the wall, there is an electrical water pump in front of the wall, a potted plant and laundry lines attached to this wall and the wall next to it. Wall 2 is a side wall facing a leftover space. It is an exposed brick wall with a window plastered only around the window. The exposed brick is covered with moss, and some plants are growing from the surface. In front of the wall, there are many neglected potted plants and electrical poles. Wall 3 is a side wall facing an alley. It is a brick wall with a plastered and painted surface in the human reached area of which some graffiti is inscribed. The lower part of the wall is not plastered and facing a shallow gutter. Therefore many plants are growing on the surface, and some potted plants are also located in front of it.

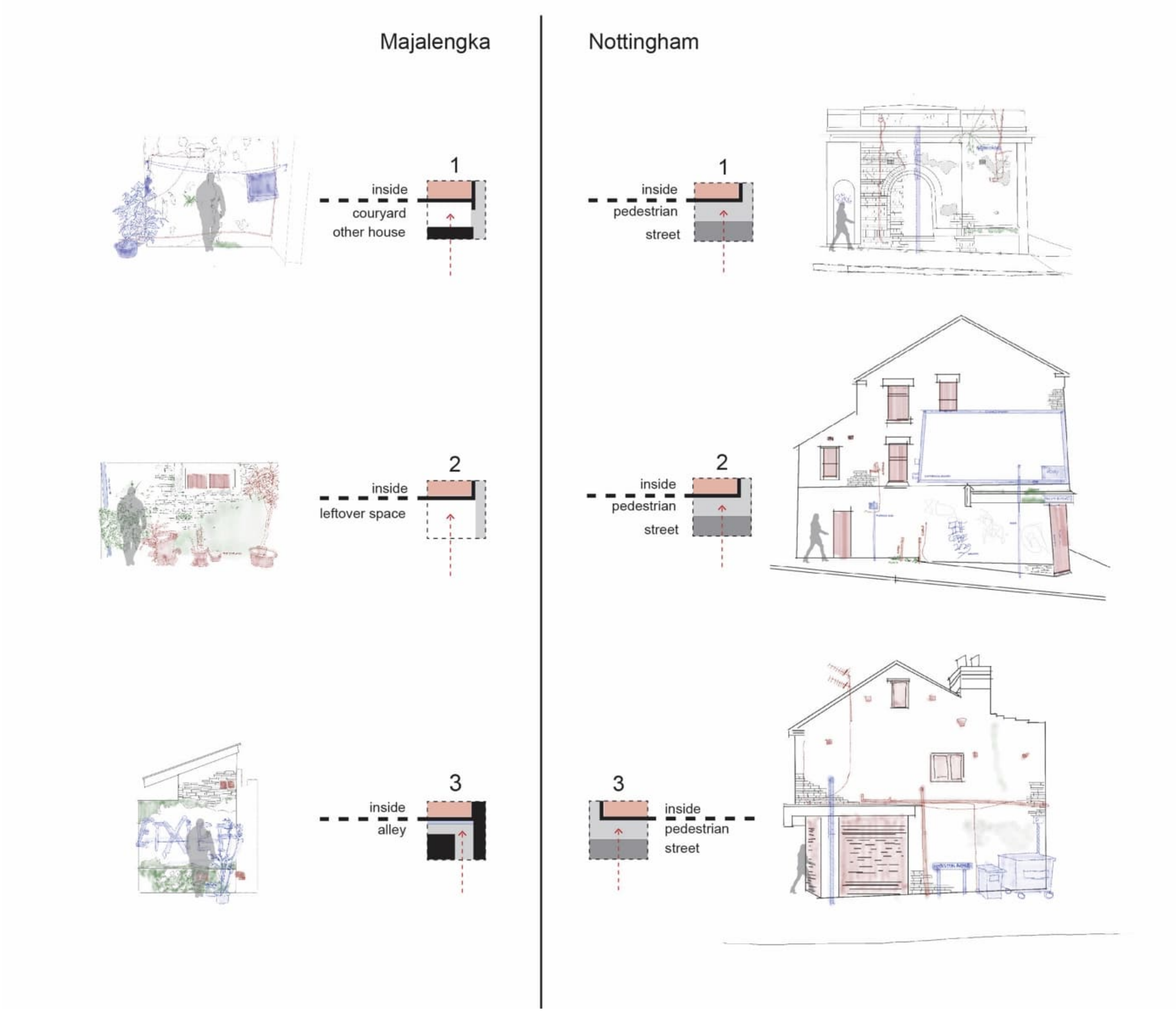

Figure 2. Wall situation and traces of inhabitation

The three walls in Nottingham are situated in a somewhat similar setting where all three are side walls facing a pedestrian way. Wall 1 is an exposed brick wall with some parts is plastered and painted. Some water stains appear on the bricks, and graffiti appears on the plastered surface. A plant is also growing near the top part of the wall. Wall 2 is a multi-storey side wall exposed bricks with doors and windows. However, the ground floor part of the wall is plastered, and some graffiti is inscribed there. On the higher part of the wall, there is a commercial board attached to it. Wall 3 is also a multi-storey side wall with exposed bricks with a rolling door. There are some trash bins in front of the walls. On the surface of the three walls, a street name is attached. Moreover, in front of the three walls, there is a traffic and parking sign.

Figure 2 and the discussion above briefly capture the traces of inhabitation that exist on and around the walls. Some of the traces are made by a human, such as the existence of laundry lines, potted plants, commercial boards, and graffiti; some are created by the environment and other organisms such as plants and weathered stains on the surface. However, these traces of inhabitation could be inferred and categorised further based on the speculated possibility of ownership of the objects.

Figure 3 attempts to further categorise the objects by looking at Wall 1 Majalengka and Nottingham closer. It is observed in Wall 1 Majalengka some objects that seem to belong to the inside (highlighted with red in Figure 3). For example, is the electric water pump. Even though it is located in front of the wall, on the outside, it seems to be powered from the socket inside as there is a cable coming in/out through the ventilation. There are also water pipes coming out of the pump and go inside through the wall for the water to flow in. There are some plants growing on the surface where the paint and plaster are peeled (highlighted with green in Figure 3). In front of the wall, there are objects that seem to belong to the house in front of the wall, such as the laundry lines and hooks attached to the wall, potted plants, and a bucket (highlighted with blue in Figure 3). The other house seems to perceive the wall as a vacant space to extend their domestic space.

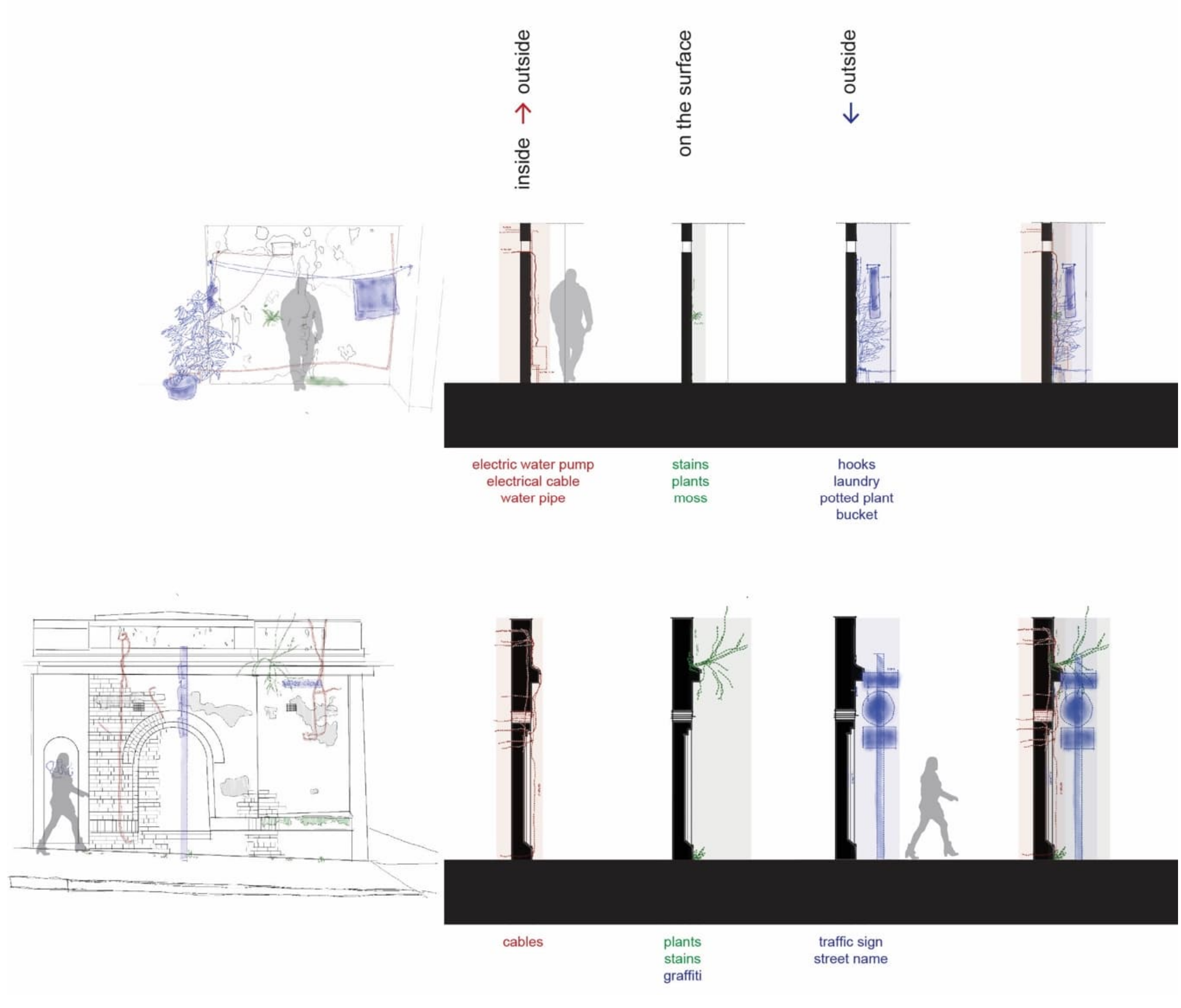

Figure 3. Layers of traces of inhabitation

On Wall 1 Nottingham, the objects that seem to relate with the inside are cables, presumably electrical, internet, or antenna cables, that go in/out through the bulk of the wall (highlighted with red in Figure 3). On the surface, there is a plant growing in the higher part of the wall; its roots penetrate the bulk of the wall (highlighted with green in Figure 3). Furthermore, on and in front of the wall, there are objects and traces made by others (highlighted with blue in Figure 3). Since this wall is facing a pedestrian, the public can 'access' the wall directly. There is graffiti on the painted part of the wall. There is also a street name attached to the wall and a traffic sign right in front of the wall. The street name and traffic sign must belong to the municipality who sees this wall as a vacant space that can be utilised as a background where information can be placed.

The investigation above attempts to illustrate the walls as porous objects and porous space. The walls are porous objects as some literal pores, such as ventilation and windows, are observed. Besides, the walls are porous objects as some parts of them are pierced with pipes, cables, hooks, nails and penetrated by the roots of the plants that are growing on the surface. The existence of objects on and through the wall suggests that the porosity of the wall creates a relationship between inside and outside other than the inside and outside created by the literal pores such as windows. The fact that most of the relationship are related with utility, it shows that relationship between inside and outside it's not just limited to visual connection or air circulation, but also other flow of matter, such as water, wastewater, electricity, and even Wi-Fi and television signal. This draws a further relationship between the house and the context, such as the sewer and the electrical grid, highlighting the fact that the house requires such a relationship to work.

In addition to that, the existence of plants that are growing from the wall shows how the porosity of the wall interacts with the environment. In this case, porosity also interacts with the presence or absence of human acts of maintenance or of coating the materials. It implies the dialogue between culture and nature, which occurs right on the bulk of the material up to the surface. How humans create and treat the object, such as the choice of material and the wall finish, will generate different interactions with the environment. As if the material is relatively porous, because it is not coated or becomes porous over time due to weathering, other organisms will be able to occupy the bulk and the surface, making the wall a habitat for the plants and other organisms.

The existence of objects on and in front of the walls that do not belong or relate to the inside makes the walls a porous space. This relates to how public and private interpenetrate. Due to its situation, as sidewalls facing a public realm, these walls are sometimes perceived as vacant space or background that can be 'inhabited'. The inhabitation arguably depends on both the material of the wall and the social 'law' applied to the neighbourhood. For example, in the case of Wall 1 Majalengka, where the neighbourhood flourished through informal practice, the existence of laundry lines on that wall as an extension of the neighbour’s domestic space is a possible and common practice. Another example is the inscribed graffiti which usually exists on smoother surfaces, and obviously, the graffiti bombers did the graffiti while there was no authority around. Furthermore, another example of how the municipality uses side walls in Nottingham to put street names, placed traffic signs against the wall, and also permit the commercial board to be attached to the wall raise a question on to whom the surface of the wall belong, does it belong to the house or the city?

5 Towards The Politics of Porosity

Walter Benjamin and Asja Laci's essay *Naples* introduces the term porosity as a 'law' that creates the livelihood of the city [10]. The idea of porosity is narrated through series of interpenetrations between sets of two demarcated ideas, such as public/private, day/night, and dirty/pure. However, it is not through refusing the distinction but through defining relations [5]. The relations between the two ideas are created through the interaction between the 'porous' built environment and the social 'law' and everyday practice of the people. The essay mentioned various types of space such as a church, living room, café, arcades, stairways, and balcony and how the activities occur and what could be experienced bodily. And porosity is the working together of the materialised space, the spatial practice and behaviour in time and context and how porosity allows or generates the working together of these unfolds the politics of porosity.

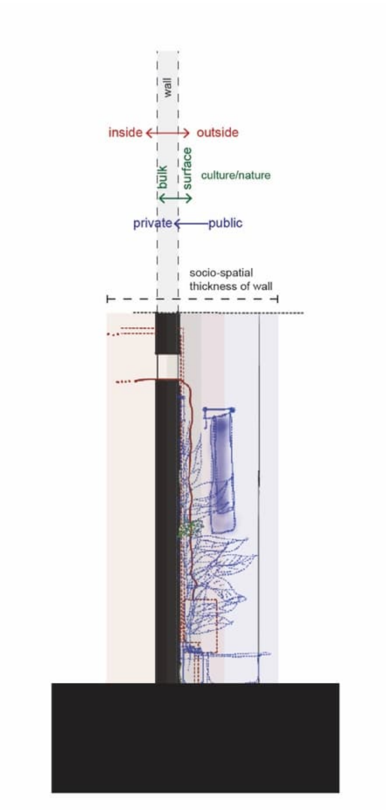

Figure 4. Socio-spatial thickness of wall

This paper investigated how the politics of porosity perform around neglected walls which are architectural elements facing the urban realm. Even though it did not narrate porosity on the literal urban or city scale, like *Naples,* this paper managed to initially draw the relationship between the microscale of the material and the macroscale of urban space. The neglected walls are viewed as both porous objects and porous spaces. The politics of porosity begins with the existence of walls in a context. Then the walls, as porous objects, interact with the environmental and social context, leaving traces of inhabitation on and around it, making the walls porous space. Objects and organisms on and around the walls exist in time and build up the thickness of the wall beyond its material thickness. In this way, the politics of porosity contributes to the spatial production, from the material to the socio-spatial domain. The politics of porosity produces socio-spatial thickness of the wall, which contain inhabitation, suggesting the idea of *absorb* as the performance of porosity (Figure 4).

The politics of porosity investigated within this paper also contributes to the extension of dialogue between inside/outside, culture/nature and public/private around the wall. It makes the wall an assemblage of all three sets, and the dialogue is constantly producing and reproducing situations on and around the wall. Furthermore, the politics of porosity could trigger the discussion and dialogue between design intension and contingency. Porosity gives a space for improvisation, which suggest contingency. However, it might be worth looking at if porosity could be part of the design intention. By looking at porosity as design intension and contingency in architecture, it will potentially open the discussion of porosity within the middle scale, between the micro and macro scale that would probably draw further relationships among scales.

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COCOON BIOFLOSS – FABRICATION & SUSTAINABLE MATERIALS

Maria VERGOPOULOU-EFSTATHIOU*, Anna EFSTATHIOU

University of Westminster
69 Abbey Road, NW8 0AE, London, UK; maria.vergop@gmail.com &
maria.vergopoulou-efstathiou@zaha-hadid.com
University of Nicosia
31 Michael Giorgalla srt., CY-2409, Engomi, Nicosia, Cyprus; efstathiou.a@unic.ac.cy

Abstract

The Cocoon BioFloss project is the outcome of rigorous physical and computational experimentation, focused in the combination of bioplastic and its different application methods, with digital design and fabrication. The ambition is to create a resistant and environmentally friendly building method, available for everyone to reproduce. The project is focused on the process of making, creating a manual for the construction of a prototype house, using materials and construction techniques that are accessible and affordable by the majority of the public, and that can be adjusted to adapt in many locations and climate conditions. The Cocoon BioFloss is creating a cocoon-like house that will follow a DIY construction and a maintenance scheme when necessary, by using natural materials that are harvested within the housing complex. The main material used is bioplastic, a type of plastic that derives from renewable biomass sources that can be produced locally by the occupants of the building. The physical properties of bioplastic vary depending on the fabrication and application process. Two main application methods of bioplastic are used in this project which have been explored through physical testing and digital simulation.

Keywords

bioplastic, sustainability, fabrication, self-built

1 Digital design & fabrication and biomaterials – shaping the future of cities

Materiality and design are continually in close association and designers have always been interested in the value of materiality, not only because of the certain physical properties and finishes that building materials provide, but also on their importance to achieve efficiency, their life-cycle and their availability and source origins from where they are obtained. Climate challenge is no longer a future imminent threat, but a reality that we are inevitably facing and most industries are re-thinking their models of consumption, including the materials and fabrication methods that they use. Human activity has led to the overuse of finite resources and we are now obliged to rethink our actions, in order to adapt and co-exist with nature, instead of exploiting it. The need for designers to continue adapting and responding to this transition to a more sustainable era is urgent.

One of the great accomplishments of the technological advancements of recent years is the re-connection of the fabrication process to the user or the creator, eliminating or reducing the third parties involved in the procedure. Digital design is allowing us to create and experiment in a virtual world with great accuracy, ultimately minimising waste or the volume of waste and predicting the behaviour of materials and their efficiency. In combination with digital fabrication tools, that are accessible now to most creators, the final product is becoming once again closely connected to the user's needs. Creators or users are becoming more aware of the amount of resources that they use or waste and they are now becoming again more capable of creating on site, with materials available on location, therefore reducing transit and achieving a close connection between need, resources and materiality.

The Cocoon BioFloss is an experimentation project, that aims to investigate the combination of digital design and digital fabrication with biomaterials, produced by renewable resources. It is exploring a present or near future of scarce resources and uncertainty, where citizens will use their skills and technological capabilities to address their emerging needs. It is aiming to investigate the use of sustainable and recyclable materials in construction, and ultimately challenge the relationship between time and shelter.

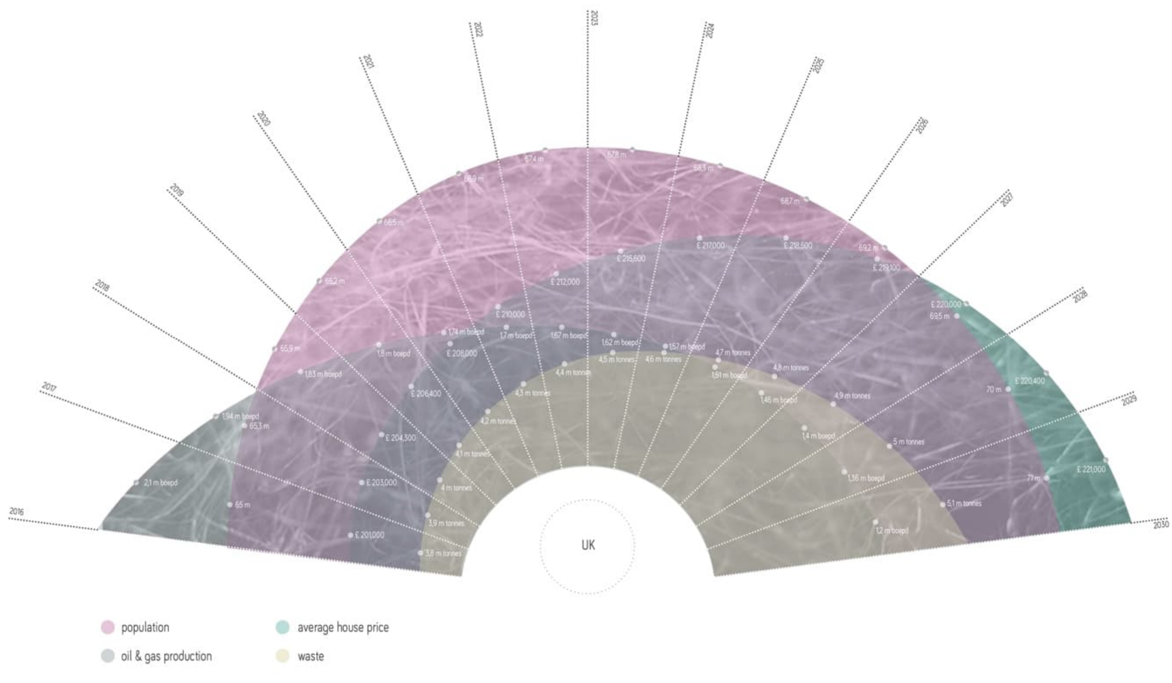

Figure 1. Progressive estimates of waste, average house prices, oil & gas production compared to population growth - progressive estimates according to existing data

2 Coccon BioFloss – a self-made future living

The Cocoon BioFloss is a project focused mainly on the process of making and the use of alternative, innovative, sustainable and environmentally friendly building materials. It aims to create a prototype short-term residence, studio and laboratory, using materials and construction techniques that are accessible and affordable by the majority of the public, and that can be adjusted to adapt in many locations and climate conditions.

Partly following the communication techniques of the Victory Gardens propaganda – a UK and US governments initiative to encourage people to plant their own vegetable, fruit and herb gardens in public or private spaces during World War I and World War II, in order to reduce pressure on the public food supply, while boosting civil morale - this project produces a manual for the creation of the proposed prototype Cocoon BioFloss, addressing a future community in times of scarcity. It aims to create an alternative way of shelter, by using materials at hand, that are sustainable, recyclable and reusable. The Cocoon BioFloss is creating a cocoon-like house that will follow a DIY construction and maintenance scheme when necessary, by using natural materials that are harvested within the housing complex.

Figure 2. Grow your own home – the manual for the Cocoon BioFloss house

2.1 Material experimentation

This prototype design is the outcome of rigorous physical and computational experimentation, focused in the study of bioplastic and its various application methods. The ambition is to create a resistant and environmentally friendly building technique and construction methodology, available for everyone to reproduce.

Initial material experiments, which led to the following study, were made with a household candy floss machine and granulated sugar. Common candy floss machines have a heated perforated drum in which sugar granules are poured. When spun, the melted sugar fibres escape the drum and create loops of sugar, that are attached to each other, forming an orbital cloud. The melted sugar fibres create a cloud of candy floss that floats above the candy floss machine, when not obstructed by other elements. When there is an object in close distance, the sugar fibres get attached to it. The next layer of fibres gets attached to the previous, creating loops of accumulating matter, like a web of sugar threads. By investigating the creation of candy floss, there was a realisation that 3D printing fabrication is following a similar technique. Most 3D printers create three-dimensional objects by setting a succession of layers of matter, in a repeating manner. Therefore, by replacing sugar with a resistant filament, the candy floss machine becomes a 3D printer, creating loops of fibres, accumulating on top of each layer. The next step of this experimentation was to use a sustainable plastic filament as the building material.

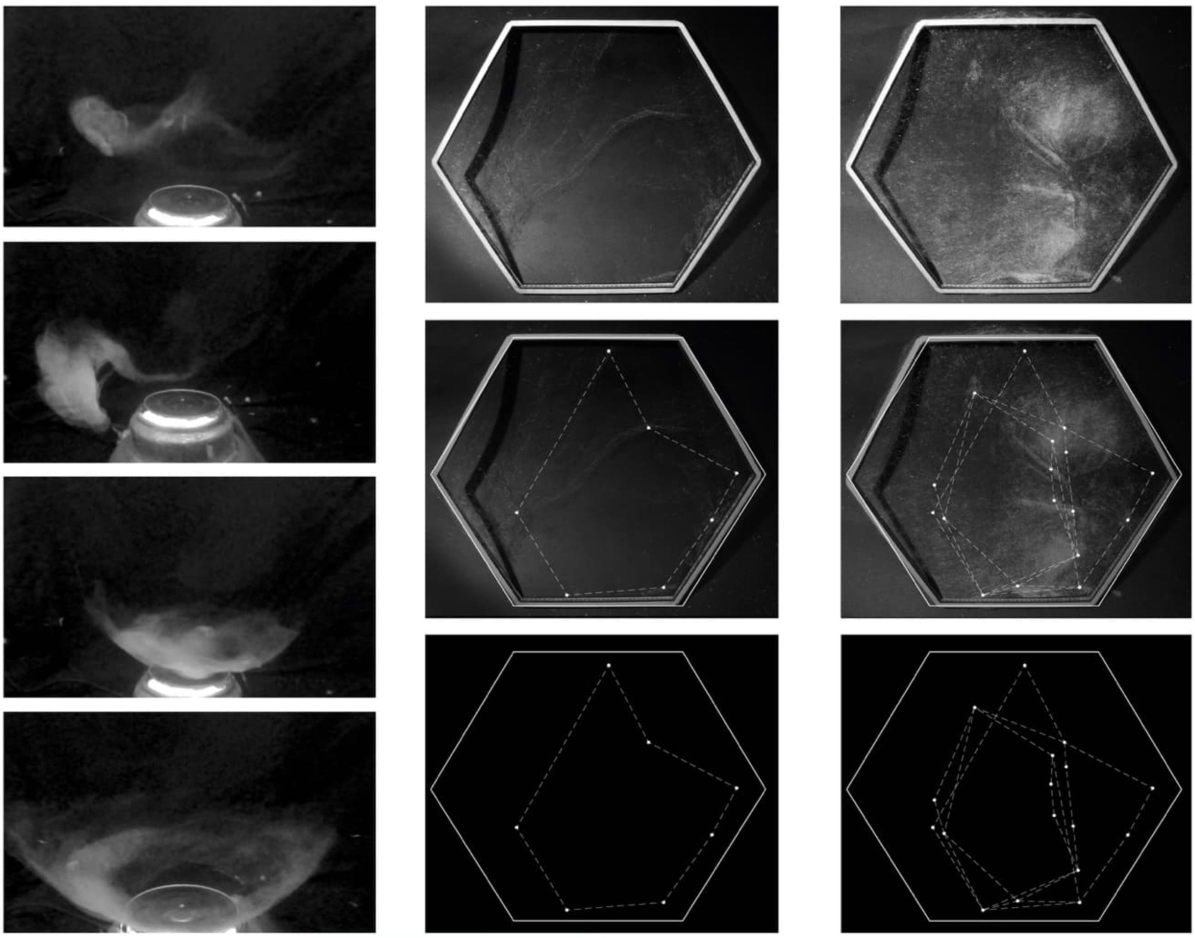

Figure 3. Initial material experimentations of spun mater

Bioplastic is a type of plastic that derives from completely renewable biomass sources and can be made with household materials. Starch-based bioplastic requires four main ingredients in order to be made; one part starch (potato starch, corn starch, tapioca starch etc.), four parts water, half part glycerine and half part vinegar. When stirred all together over heat, these naturally sourced materials create a biodegradable, compostable pasty mixture that can be spread, moulded or sprayable dispersed. When cooled, the mixture becomes stiff and durable. Bioplastics can be fully decomposed in 7 years, whereas common plastics take more than 100 years to be dissolved. The physical properties of bioplastic vary depending on the fabrication and application process.

One important characteristic of bioplastic is its melting point, which stands at around 130° Celsius. The melting point of sugar is 160° C, which means that the heat in the spinning drum of regular candy floss machines reaches up to 175° C. This similarity of melting points between sugar and bioplastics enabled the experimentation using a household candy floss machine as a 3D printer, by replacing sugar with a homemade starch-based bioplastic filament. When heated and spun, the plastic escaped the machine in thin fibres, creating a floss-like 3D printed plastic, thus forming the first application method of bioplastic as a construction material. The accumulation of matter was then explored digitally, using particle simulation software, in order to test possible variations of flossed bioplastic structures.

Figure 4. Application Method One - 3D printing bioplastic using a candy floss machine

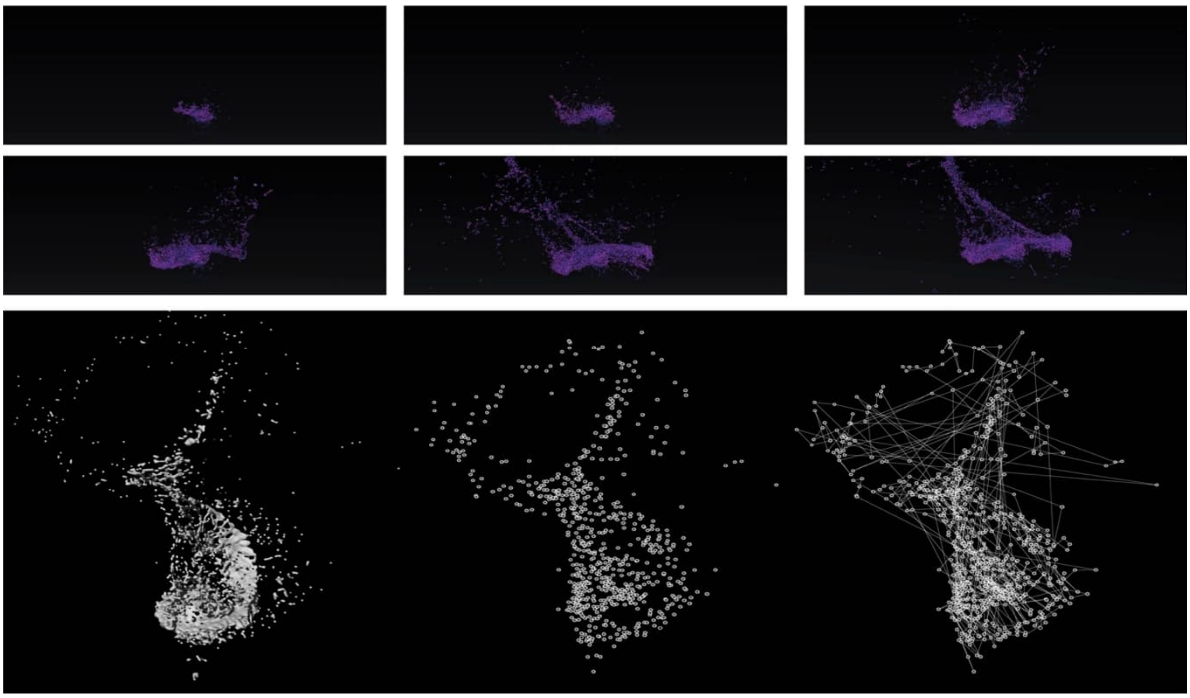

Figure 5. Spun particles digital simulation

While flossed bioplastic as a first application method was an interesting experimentation, the results remained quite arbitrary. There was a requirement for a second application method that would create a more durable and buildable construction material. In further experimentation, bioplastic was spread on a variation of tense thread guidelines, in order to explore its potential durability when combined with a base skeleton structure. When spreading the warm bioplastic, it is mouldable and easily attached to the thread substructure. The set product of threads and the cooled bioplastic is bonded the two elements together, making a strong, durable material, forming the second application method explored for the creation of this prototype housing unit. Different weaving patterns were explored by using parametric software, testing variations and form-finding optimisation and their structural abilities, by simulating their physical attributes. Later, those patterns were examined through physical experimentation, in order to achieve maximum durability.

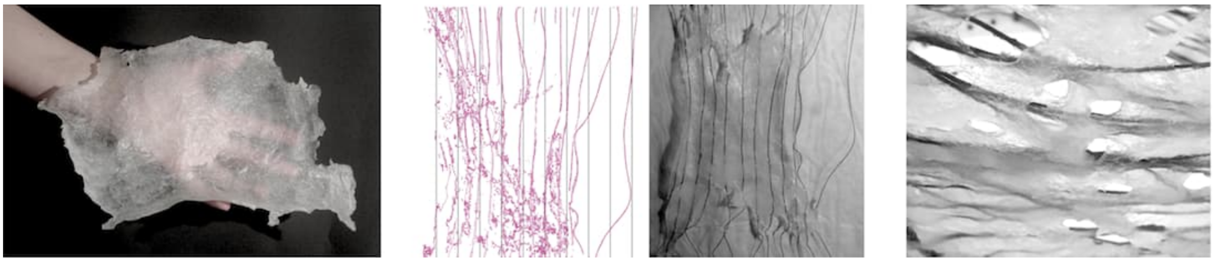

Figure 6. Application Method Two – Spread bioplastic on tense weaved guidelines

These two application methods of bioplastic are used to create the Cocoon BioFloss. The spreading of the material on a tense wire thread substructure creates a thick semi-transparent weather resistant skin and the main construction material of the prototype. The second application method uses a modified candy floss machine that produces a web of thin fibres that are attached on a secondary thread guideline and the exterior skin, creating interior separations and furniture artifacts.

2.2 The prototype – construction methodology

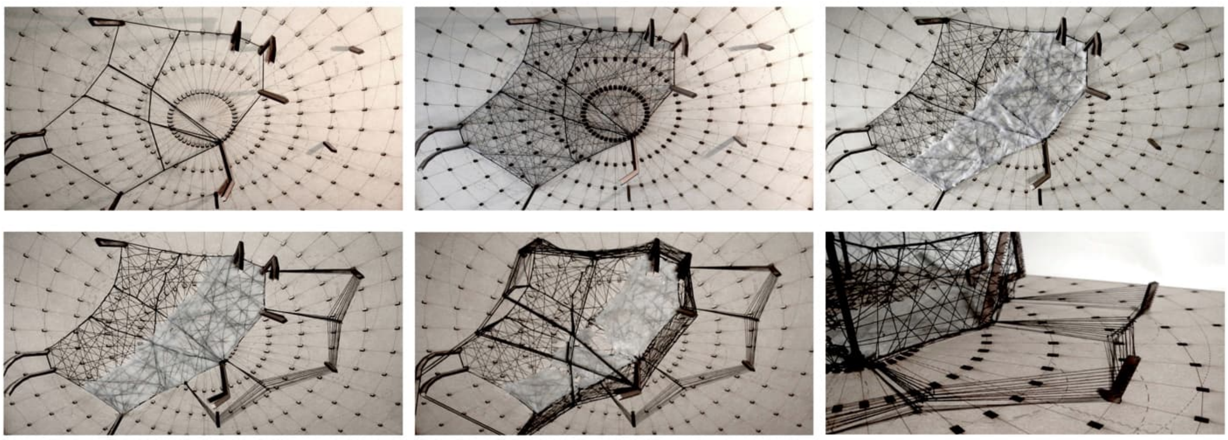

Figure 7. Prototype model

2.3 After the exploration of materiality and application methods of bioplastic, a construction methodology was established, that would allow for each user/inhabitant of the proposed community, to create their own Cocoon BioFloss home. While the manual suggests a methodology and a set of tools and guidelines, the exact orientation, placement and size of spaces is entirely based on the needs of the occupant. Therefore, the housing unit can be adjusted according to the specific needs of the inhabitant and to the requirements of the site location.

The main ingredients for the creation of the building material, the bioplastic, are harvested within the housing unit, from the cultivation of potatoes, sunflowers and apples that are grown in the location of the house. The three ingredients of bioplastic, starch coming from potatoes, glycerine, produced by sunflower seed oil and vinegar, made from apple cider, are produced on site and the fabrication of bioplastic is taking place in the central space of the housing unit. The rest of the spaces are located around the working area, according to the sun path and water location of the proposed site. The formation of the prototype is made by adjusting the web formation of the housing unit within the minimum and maximum space requirements for each area. The main focus of the space arrangement strategy is the location of the agriculture fields, from which the ingredients of the bioplastic are harvested.

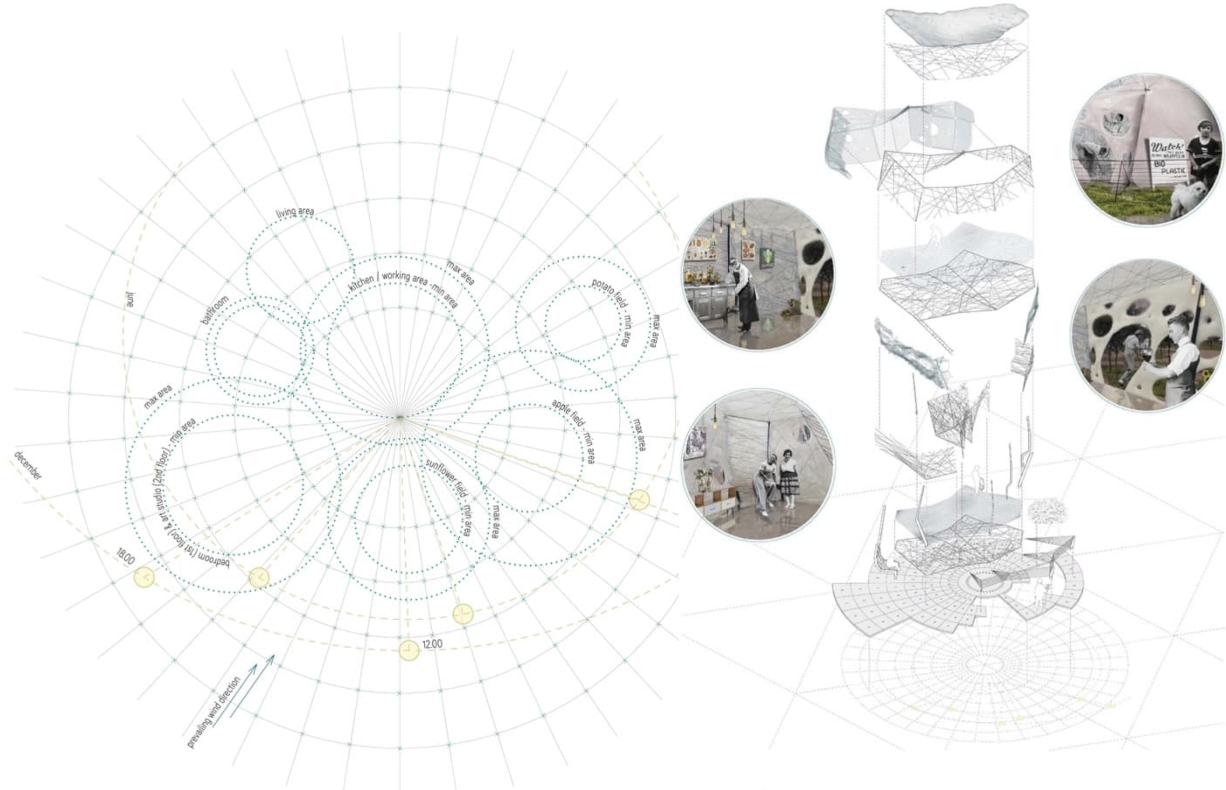

Figure 8. Prototype spatial arrangement & construction layers

The base of the housing unit is a foundation deck formed on a circular grid, which complies with the general layout of each housing unit. The deck is constructed by a wooden frame and laminated wood panels and it is able to support the main construction pillars. The raised floor deck enables cables and utility pipes to pass through, under the ground level of the unit. Prefabricated wood pillars are then slotted in in the deck foundation, according to the tenant's preference. The pillars come in a variation of typologies that can be used for different layouts and purposes. Their perforation on both sides is used for the weaving of the wire thread substructure, upon which the bioplastic is spread, on the outer side of the shell. The pillars are wrapped with wire thread, creating the base of the tense construction and additional wire thread weaving is creating the arrangement of interior spaces.

The different fields for the cultivation of the source materials for the creation of the house, are separated with tense wire thread, supported by additional pillars. The floor plates are weaved and wood fibre reinforced bioplastic is spread on them. Similarly, the exterior substructure of weaved threads is set with spread bioplastic, creating the main geometry form and ultimately the exterior weather resistant, breathable skin of the housing unit. Following this step, the interior spaces that have been defined by the weaving patterns, are covered with flossed bioplastic. A modified candy floss machine placed in the interior of each unit creates a wool web of bioplastic, which gets attached on the interior weaving, and in some parts to the existing bioplastic exterior skin, adding the second layer of skin.

Figure 9. Construction Methodology

3 Conclusions

The Cocoon BioFloss remains an experimental project, within the academia field; nevertheless, its purpose is to explore and test alternative construction materials and methodologies that could have the potential of being implemented and explored further by architects and designers, in an attempt to address climate change and the emerging needs of near future. While the exploration and use of sustainable and recyclable materials deriving from natural resources is increasing in product design, fashion and small-scale design items, the construction industry is still using, with small adjustments, the same construction methods and materials that have been used for the last half of the century. The emergency of climate crisis is leading us to reconsider the concept of durability and the lifespan of the artifacts we create. The notion of time should be closely related with materiality. Our industry has a big impact on the shaping of the future, and while it is already taking advantage of the digital fabrication methods and their efficiency, the implementation of materials that meet sustainability criteria would benefit immensely the transition to a sustainable era, in co-existence with nature.

Figure 10. Cocoon BioFloss

Acknowledgements

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OUR PLASTIC FUTURE: PLASTICS AS PRIMARY BUILDING MATERIAL

David Costanza
Cornell University College of Architecture, Art, and Planning
129 Sibley Dome, Ithaca, NY 14853

Abstract

Our Plastic Futures seeks to unpack, document, and project the world of plastics as they relate to the discipline of Architecture. The shift from single-use use to recyclable plastics, and from synthetic—nonrenewable—to bio-plastics—renewable—position plastics as not only impervious, durable, and affordable, but now also sustainable.

This paper describes the introduction and development of plastic materials more broadly and finally their adaptation into the discipline of architecture. The historical context outlined in part 1—OUR PLASTIC PAST—positions the conversations around plastics as an aesthetic, cultural, and technological invention. As well as the early attempts at translating plastic into an architectural context through the 'All Plastic Homes' which are catalogued and contextualized.

This framework sets the ground for part 2—OUR PLASTIC PRESENT—which documents and describes the current use and ubiquity of plastics in building construction. In particular the shift from plastics as a primary building material to plastics as a secondary or tertiary material.

Finally, part 3—OUR PLASTIC FUTURE—imagines and projects how plastic materials can and will operate moving forward. The focus will be placed on the capacity for recycled plastics and renewable bioplastics to perform structurally in architecture.

The limiting factor when working with liquid materials like plastics is the fabrication process which necessitates the construction of a mold. The introduction of 3D printing and Robotics offers an alternative fabrication method that reduces the labor and the additional materials required in the production of a mold. In addition, using digital fabrication processes allows for mass customization, rather than the economies of scales typically associated with plastic manufacturing.

Keywords

Material Research, Plastics, Sustainability, Academia, Pedagogy

1 Our Plastic Past

First developed in the late nineteenth century, plastics remained largely invisible until the second world war. Material shortages and the desire for higher performance—durability, lightness, strength, etc.— pushed plastics into the mainstream. Adhesives for airplane assemblies, nylon for parachutes, phenolic resins for handles and electrical insulation, polymer sealants, and coatings for waterproofing all emerged during wartime efforts and would later infiltrate architecture and building construction [1].

Post 1944 the plastic market and culture rapidly expanded becoming one of the largest material industries, leading many architects to consider the possibilities of plastic both as a structural material as well as a representational one. The aesthetics of this new material were new, futuristic, and seemingly infinite. Optimism around plastic in the early ’50s produced a culture in which plastic was considered a material that could replace all others while increasing performance and reducing cost. During this period, several so-called ‘All Plastic Homes’ were developed and put forward by architects. Often these homes were part of exhibitions or world fairs, and largely they were sponsored by the plastic industry.

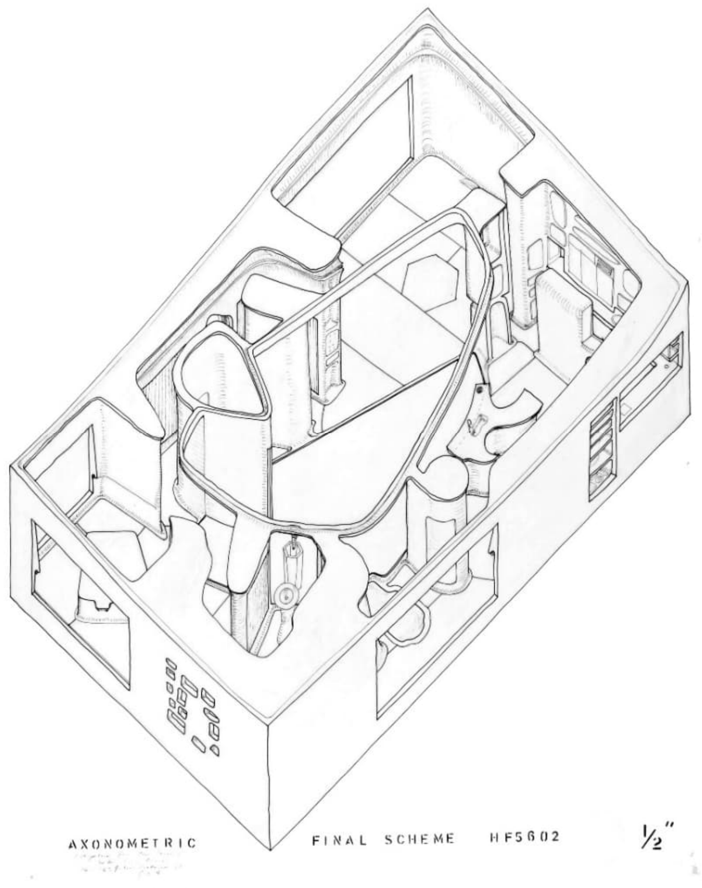

Figure 1. “Architectural Drawing for ‘House of the Future’: Smithson, Alison.” V&A Search the Collections. Accessed November 15, 2020. http://collections.vam.ac.uk/item/O155879/architectural-drawing-for-house-of-architectural-drawing-smithson-alison/.

The earliest example is the Vinylite House at the 1933 Chicago World's Fair. Following the Vinylite House, ten high-profile homes were put forward between 1956 and 1972 which suggested a range of approaches to the plastic paradigm in architecture. In 1956, Alison and Peter Smithson designed the House of the Future which projected the futuristic aesthetics of plastic as white, smooth, continuous, and malleable. Though not built from plastic, due to manufacturing limitations at the time, the house put forward an aesthetic ideology toward plastics that remains prevalent today [2]. In the same year, Lonel Schein & Yves Magnant designed the Plastic Motel Cabin and Lonel Schein also put forward an All plastic house. In 1957, Marvin Goody and Richard Hamilton, two MIT Architecture faculty designed and built the Monsanto House Of The Future. The Monsanto House of the Future was sponsored by the Monsanto chemical company and sited at Disneyland as a proto-dwelling [3]. In the following year's Dieter Schmidt designed the Kunststoffhaus in 1963, Jean Maneval designed the Bubble House in 1966, Wolfgang Feierbach designed the FG 2000 prototype in 1968, Matti Suuronen designed the Futuro House in 1968 and the Venturo House in 1971, and finally, Georges Candilis and Anja Blomstedt designed the modular Hexacube in 1972. The projects listed here represent the initial attempt to use plastics as a structural material in architecture, in these 'All Plastic Homes' architects were eager to explore the possibilities of plastics and define the expression and aesthetics of plasticity.

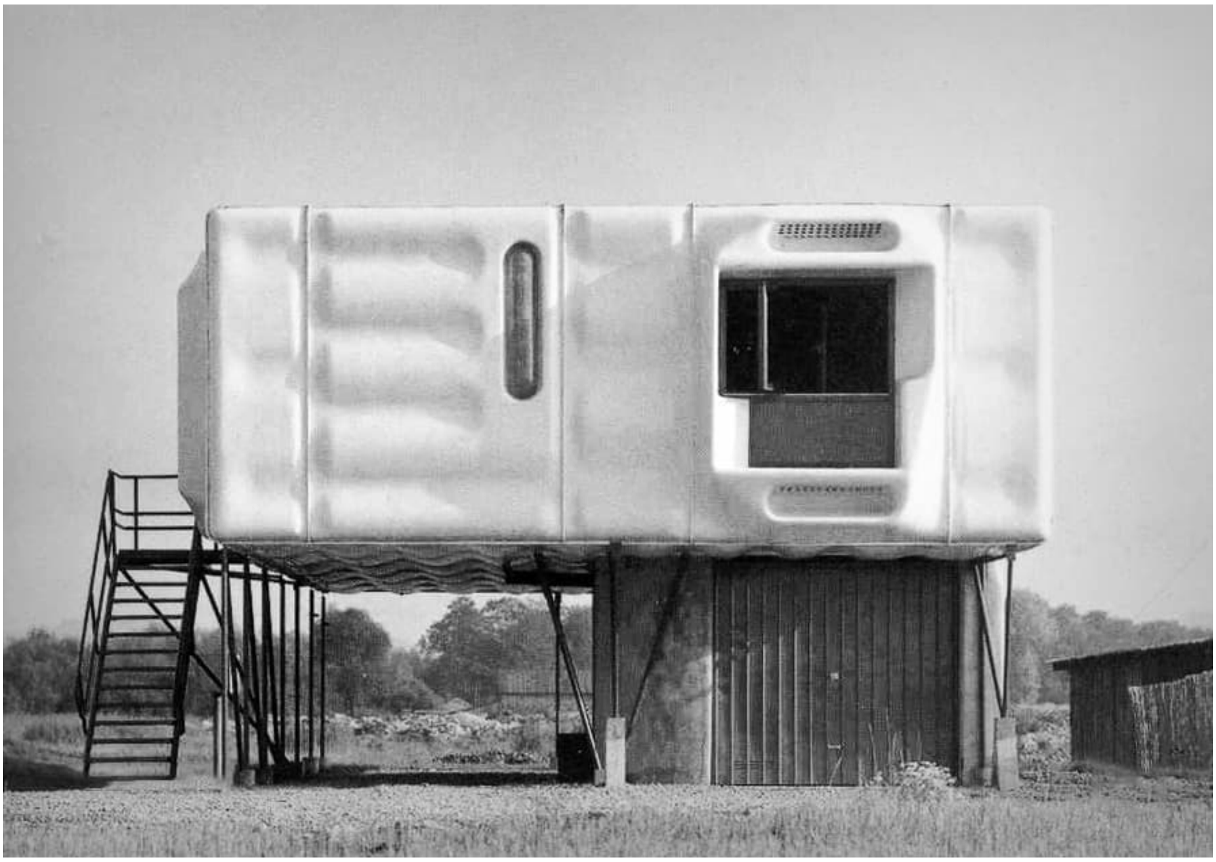

Figure 2. "House of the Day: Plastic House by Dieter Schmid: Journal." The Modern House, August 21, 2014. https://www.themodernhouse.com/journal/house-of-the-day-plastic-house-by-dieter-schmid/.

With the sudden expansion of plastics into the discipline of architecture, the adolescence of the industry was quickly felt. What initially was conceptualized as a limitless, formless, adaptable, super material, was found to have many new limitations of its own. Plastic expanded and contracted at a different rate to most building materials, requiring new detailing and connection types. They initially lacked UV stabilizers and would yellow and become brittle over time when exposed to solar radiation. Plastics also required specialized manufacturing, often relegated to factory settings, which began to standardize this once moldable, formable, super material, into a more regulated set of products.

As with any new material and industries, the continued implementation of the material in the discipline of architecture—as well as others, such aerospace, automobile, etc.—discovered new problems and limitations that required solving. As has been argued by Anthony Walker in Plastics: The Building Block of the Twentieth Century, this shifted the popular narrative around plastics:

> "Do new materials inspire dreams or do dreams latch on to new materials for their realization? It is clear that plastics inspired many designers but that, lacking the major component runs of the car and boat industries, the producers were more interested in the ordinary component, such as the translucent sheet or the dampproof membrane. If the plastic age has arrived in building it is not in the expression of plasticity but in the ubiquitous ordinariness of the products and their chameleon-like ability to assume the appearance of the surroundings. In that quality lies their true nature which can now be recognized and will provide the freedom for design, unhampered by the preconceptions of the expression of the material."

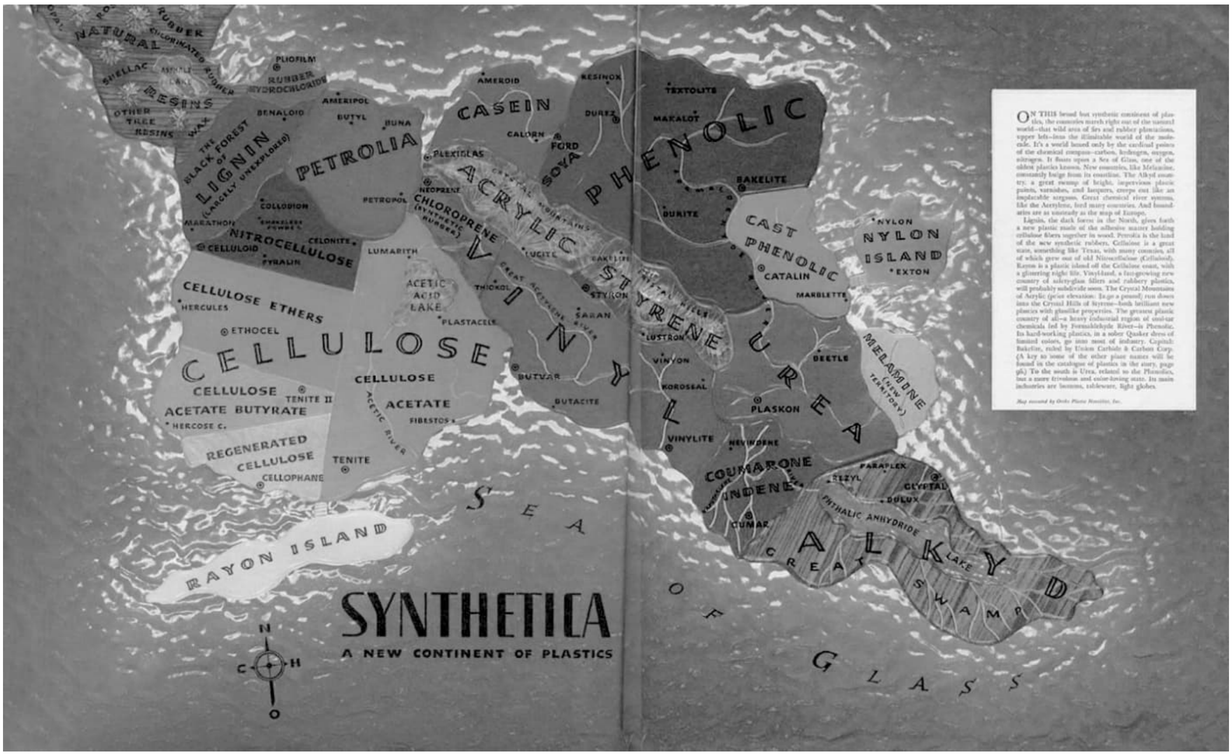

Figure 3. 'Synthetica: A New Continent of Plastics'. Fortune, 1940

Lacking the economies of scale of other industries, plastics in architecture became regulated to objects of standardization that could conform to the limits of the existing manufacturing techniques. Molding entire buildings or structures, proved costly, requiring customizable formwork to produce one-off structures, as was put forward in the 'All Plastic Homes' of the '50s and '60s. Instead, the idea of plastics as a primary and expressive material was replaced with the idea of plastics as secondary and ordinary. This can be most clearly seen in the ICI House of 1963 [4] The difficultly around the production of a one-off all plastic home, fundamentally shifted the conversation around plastics, from the infinite material, capable of replacing all others, to that of simply a more durable or cheaper version of some standardizable components of a dwelling. These standardized components had the economies of scale that existed in other industries and with which plastic manufacturing was most conducive. PVC fascia board, Vinyl siding, Formica countertops, polystyrene insulation, polymer building wrap, adhesives, sealants, coatings, etc. all became ubiquitous in the light frame timber constructed dwelling.

2 Our Plastic Present

Plastic materials, manufacturing processes, and overall pervasiveness have shifted drastically from the initial all-plastic homes. The combination of the environmental movement of the late '60s, the oil embargo of the early '70s, and the oil crisis of the late '70s, changed the widespread acceptance and attitude towards plastics. As the cost of oil decreased and plastics began to resituate themselves in the building industry, they manifest themselves largely as secondary or tertiary materials in support of other building systems. Plastic building wraps, waterproofing, coatings, sealants, insulation, etc. subsidized the widespread production of light-frame timber dwellings. In addition, engineered wood products emerged, which were made possible through plastic binders and glues. These products aesthetically read as 'wood'—presenting themselves as 'natural'— further distancing plastics from their synthetic aesthetics.

In this shift, the ambition for and production of the 'All Plastic Home' was replaced with plastic camouflage. It is impossible to imagine any building system without plastics, yet rarely are buildings discussed in terms of their plastic dependency. Plastics are prevalent and ubiquitous in contemporary architecture and building construction, but due to past limitations encountered in its manufacturing, the culture around plastics is largely one of the 'ordinary' assuming the role of other materials, either by reduced cost or extended durability. It is this shift from a primary building system to a secondary supportive role that defines our present position and attitude towards plastics in architecture and building construction. However, the promising allure of plastics continues to present an exciting frontier in architecture. Why do we all not live in a version of the Monsanto House of the Future

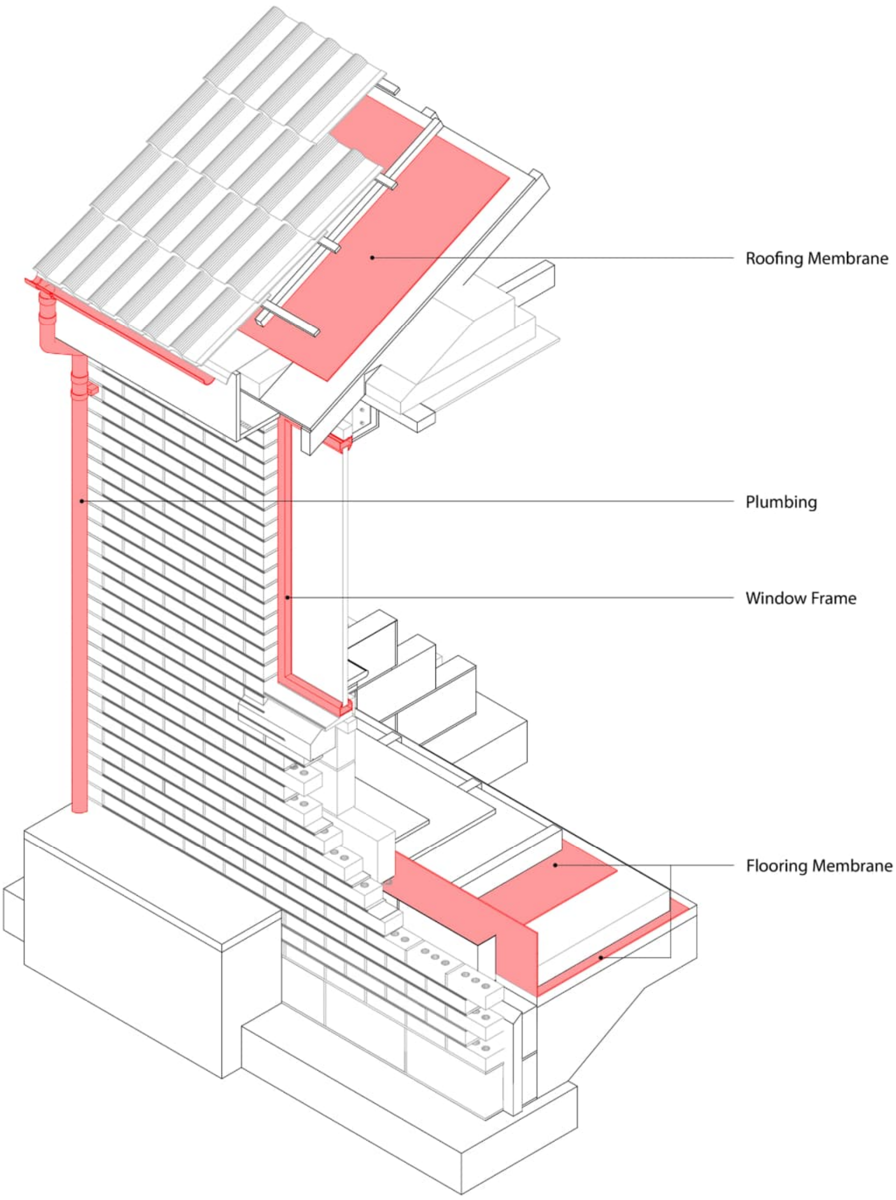

Figure 4. Jiayi and Ducharme, Olivier; Plastic in Masonry Wood Construction. Student Drawing, 2019.

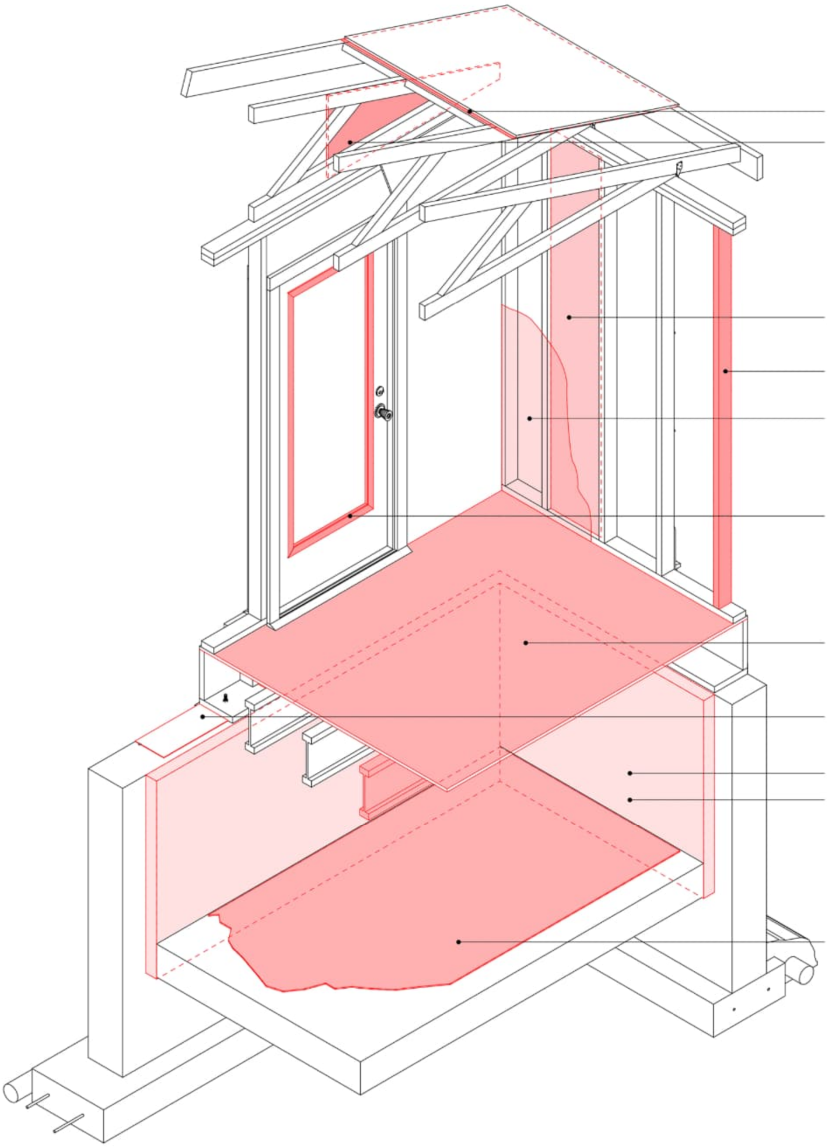

Figure 5. Xing, Jiayi and Ducharme, Olivier; Plastic in Light Frame Wood Construction. Student Drawing, 2019.

3 Our Plastic Future

Considering the current computational capacities and new digital tools in manufacturing, plastics are just beginning to re-situate themselves in the field of architecture. Digital manufacturing introduced the possibility to manufacture plastics in a non-standard way. Also, with the development of bioplastics and new recycling and repurposing techniques for old plastics, a contemporary 'All Plastic Home' has the potential to address the ecological impact of the material, in addition to its technical and aesthetic possibilities.

Efficiency and durability coupled with a load-bearing capacity make a strong case for the use of plastics as a primary building material [5]. In particular, the longevity of plastics is well suited to the building construction industry in which structures typically have a 30-50-year minimum lifespan. Recent advancements in both the material production and manufacturing of plastics, allow for plastic materials to operate outside of simple plastic form, as was largely the case with the 'All Plastic Homes' of the mid-twentieth century. The workflow from digital conception to digital production allows for a variety of plastic structures to be produced at no greater expense. In this context, the potential for an efficient "one-off" plastic architecture empowered by digital manufacturing and computation can be reconsidered.

Figure 6. Costanza, David; Fibrous Tectonics Material Research, Inflatable Mold with Bio-Resin Infused Burlap, 2015.

For the role of plastics to evolve in the discipline, I posit that this will require a three-part approach. Firstly, a shift in the physical materials used—where they are sourced, what they are made from, and how they can be reused. Secondly, an expansion of manufacturing processes, in particular digital and automated workflows that would facilitate a non-standard form of production suited to the one-off discipline of architecture. Finally, a perceptual change in how we discuss, describe and think about plastics, no longer as cheap and disposable, but rather durable, impervious, and essential to building construction.

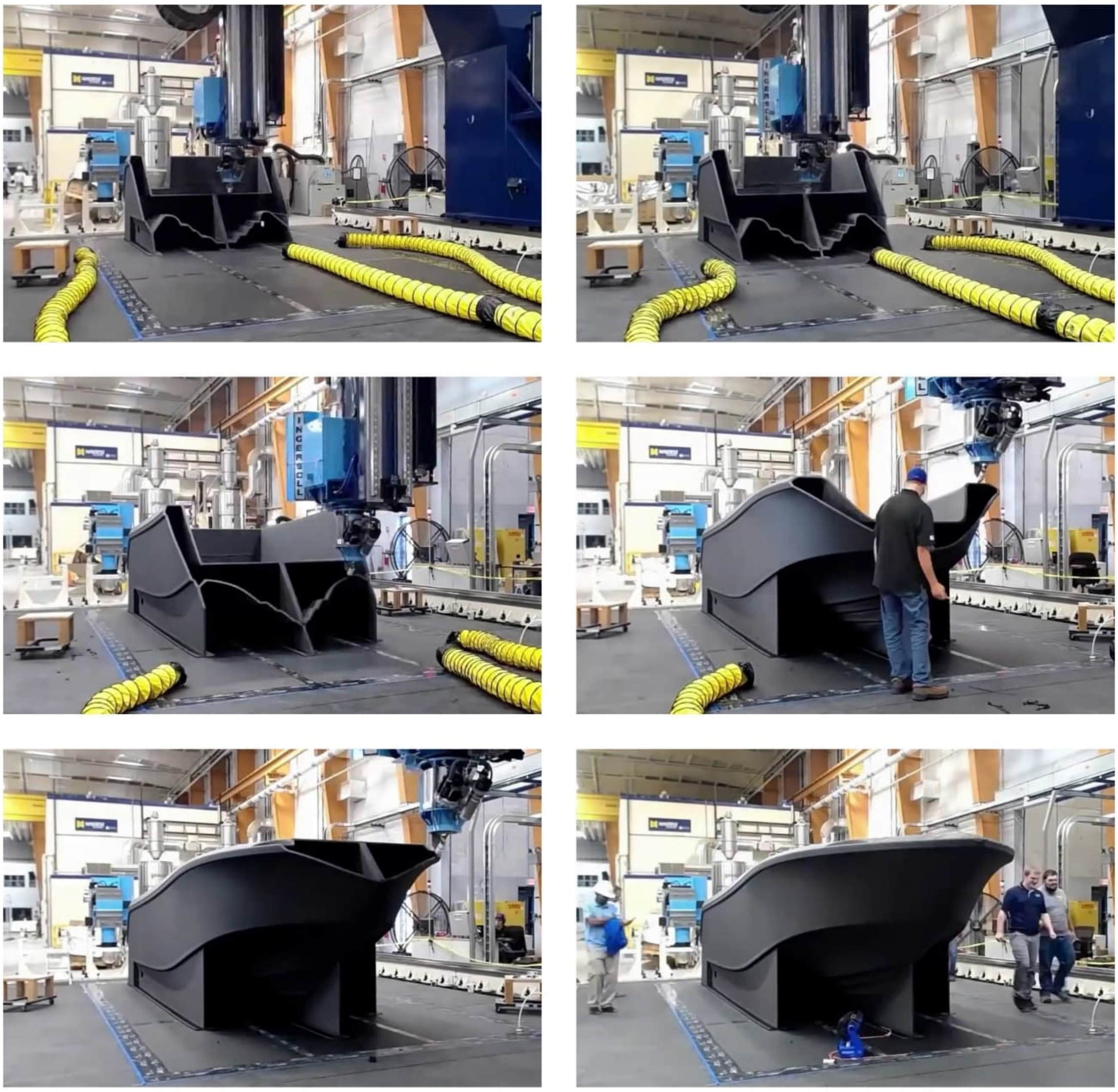

Figure 7. UMaine Composites Center, "Time-lapse of the World's Largest 3D Printed Boat," YouTube video, 0:36, October 10, 2019, https://www.youtube.com/watch?v=34F71XqvOjg

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