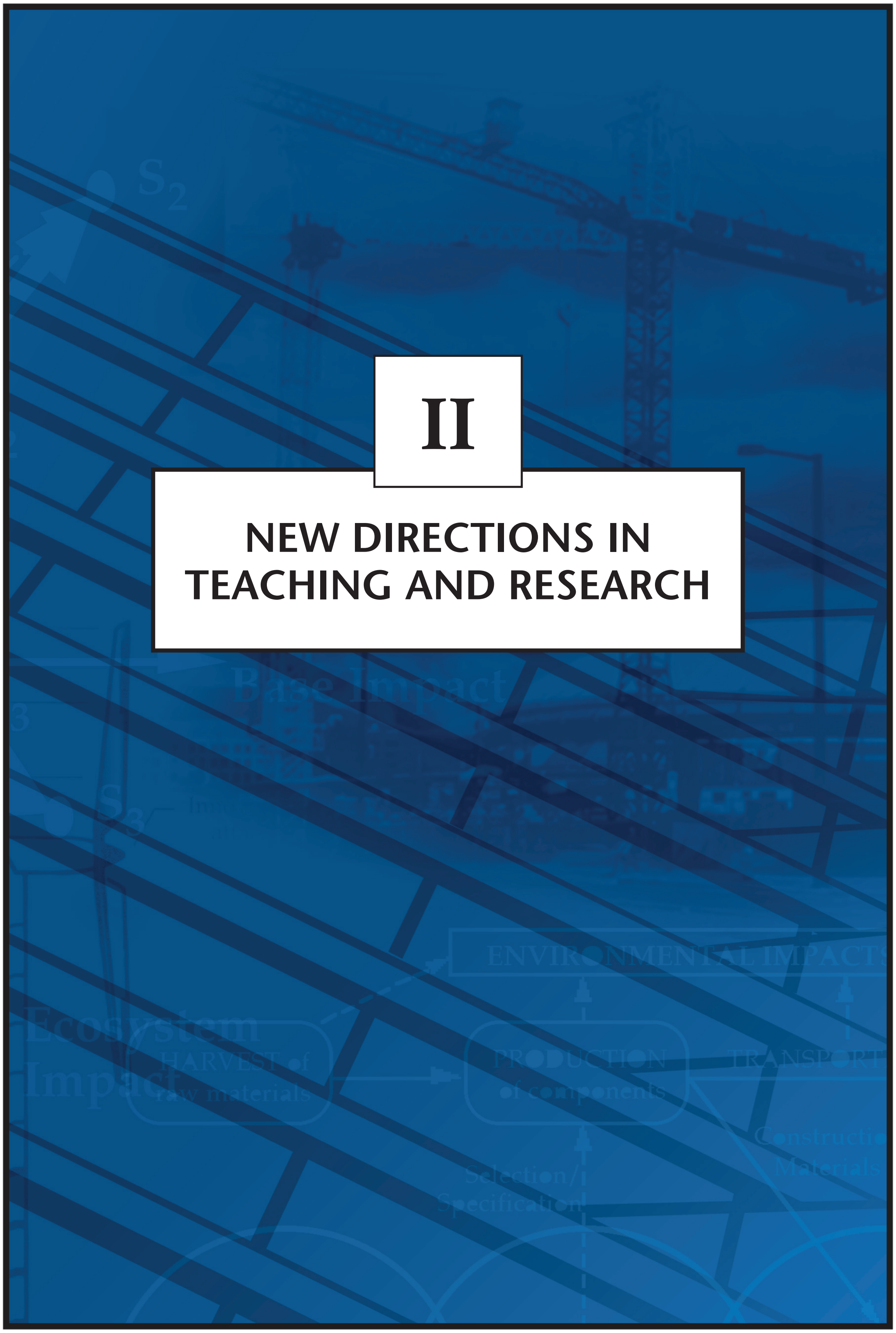

II

NEW DIRECTIONS IN TEACHING AND RESEARCH

ENVIRONMENTAL TENDENCIES IN MODULAR GREEN INSTALLATIONS

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ABSTRACT

There are two main approaches when discussing living green walls: an ecological one and an artistic one. Ecological thinking mainly considers environmental aspects, comfort enhancement and energy consumption and oversees human interaction and actual proximity to plants. In opposition, art or architecture installations that involve vegetation, lack technical and ecological aspects, aiming to raise awareness on environmental issues using human interaction either physically (direct) or emotionally (indirect). The present paper aims to analyze methods of combining the two directions, in a functional, ecological, yet aesthetically pleasing composition. In order to further develop previous experiences gathered by the team members, authors of this article, a green installation concept made out of interactive modular systems unites all the knowledge into a new, living, moving, dynamic, interactive structure whose inspiration is taken from nature while using biomimicry as main principle for its development. This new concept responds and is influenced by both external, natural stimuli and by the human factor. Multidisciplinarity is a key element in developing this project, involving architecture, art, interior and landscape design, botany, geometry, mechanical and electrical engineering, leading towards new research directions and innovative approaches in greenery—interior environment connections.

KEYWORDS

living green walls, ecological, vegetation, architecture installation, interactive modular systems

1. INTRODUCTION

Regardless of the growing tendency of introducing vegetation indoors, living green walls are the least used of all green systems. Various typologies and studies have emerged in recent years that propose vertical greening with complex requirements, to counteract the shortages of human-made environments: professional installation, irrigation systems, supporting structure, illumination, and costly maintenance.

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Since vegetation consists of living elements that are characterized by resilience, flexibility and constant growth, these aspects should be considered when designing systems related to nature. Current products overlook the "living" character of vegetation, creating rigid, inadaptable systems that transform "living walls" into simple aesthetical elements, independent of their organic nature.

First and foremost, a classification and comparison of existing systems was mandatory to determine some of the causes that restrain usage of green walls on a wider scale. Searching for solutions of at least one of the identified issues, there is a higher chance of optimizing the functionality of vertical greenery.

Thus, the estimated impact of the proposal, firstly on a scientific level, can be of great significance in transforming green walls into attractive, interactive mechanisms that take into account the dynamic necessities of the living plants hosted within. The new concept will take inspiration from nature, making use of biomimicry as a principle for its development, also experimenting with sensorial kinetic-based design to establish better connections with the surroundings.

Natural inspiration is a recurrent theme found in multiple creative and technical areas, offering versatile solutions through step-by-step processes (Mehaffy 2015) and adaptable to solving complex problems of humanity. The continuous transformation of lifestyle has led to the removal of architecture and man from the natural environment, with globally visible effects on climate change and the rise in stress as the main cause of health degradation in modern society. Introducing vegetation into the interior environment becomes a contemporary environmental requirement, as the time spent indoors is steadily rising. The challenges of intent refer to decisions (Bartczak and Dunbar 20183) of structural, architectural, human and social nature, simultaneously taking into account the physical, functional and psychological environment of the interior (Cooper 2016).

Vertical green structures had experienced a technologically and aesthetically diversified evolution, experimenting with implementation procedures, of which modular systems have proven to be the most versatile (Manso and Castro-Gomes 2015). However, the static character of the elements contradicts the normal evolutionary nature of the vegetation, the rigid support being conceived independently of the expansion needs of the natural material.

The support-material cooperation can solve the problem of maintenance, an obstacle that is often required from the economic feasibility stage of the implementation of the green wall systems. Models with potential in experimenting with the proposed versatile system (Schumacher 2011) will be taken from the natural growth patterns whose coherence is sustained by the field of Biomimetics (Benyus 1997).

Natural inspiration is reflected in the technical and digital domain by the style called parametricism, which allows the creation of algorithms that determine metamorphosis due to external influences; this being the main subject of the proposed interactive modular green wall (Schumacher 2012).

2. CLASSIFICATION OF VERTICAL GREEN SYSTEMS, THEORETICAL SUPPORT

Vertical vegetation is a recurring approach in architecture and landscape design. Although there is no novelty in the procedure, the system has been constantly developed and adapted to lifestyles and occupations of any period throughout history. The first presumed intentions of anthropic vertical organization of plants appears in Ancient times in graphical representations of the Suspended Gardens of Babylon. Ancient Romans embellish the "villa Romana," temples and palaces with lush gardens and punctual interventions of vegetation on vertical supports, as first attested practices. The use of vertical planting techniques changes with the passage of time, always aiming towards fulfilling both aesthetic and functional utilities. From directing vineyard growth and other climbing edible plants on wood or natural structures, to the symbol of wealth in Roman gardens and dwellings, to pergolas and complex plant sculptures and parks during the Baroque period.

Contemporary approaches on vertical greenery are based on consistent research regarding auxiliary supporting structure, plant species juxtaposition, irrigation and light demands. While experiments of the 20th century explored the aesthetical and botanical aspects of vertical gardens, now visual stimulus is insufficient for such an investment to become feasible. Hence, health, productivity and spatial improvement are targeted, leading to a better and wider use of architectural greenery. The practice is supported by global and local certificates and standards such as LEEDS, BREEAM, WELL, SITES or HQE, that not only evaluate the ecological footprint and energy consumption of a building, but also indoor quality expressed through air, use of high-quality natural materials with low Volatile Organic Compounds, access to natural lightning, complemented by visually and physically accessible greenery. Taking into consideration recent innovation such as "Active living walls" (Pérez-Urrestarazu, Fernández-Cañero and Franco 2016) or "Biowalls" (Furbish 2018), (Gunawardena and Steemers 2019) that participate significantly in enhancing indoor air filtration and removal of particulate matter, green walls will determine a clear reduction of the "Sick building Syndrome" (Dovjak and Kukec 2014), a frequent phenomenon of contemporary buildings that leads to illnesses, high stress levels, absenteeism and low productivity. From an economic point of view, indoor greenery investments, are partly absorbed when considering the positive physical and psychological effects on employees, that aid in reducing significant costs for medical leave and absenteeism.

Climate change is a recently defined global issue that involves rising temperatures due to various factors like excessive land, air and water pollution, gas emissions, scattered urban developments, natural landscape fragmentation, that all lead to nature's resilient capacity. To fight the effects of global warming it is strongly argued that green infrastructure (Benedict and McMahon 2014) recovery, conservation and development is among the feasible solutions. An actual example of the many positive implications when using vegetation in the built environment is the reduction of the "heat island effect" in densely built environments, by locally decreasing temperature in "green island" areas (Connolly and Connolly 2014).

Although other planting systems are used on a larger scale than the vertical ones (green terraces, interior courtyards, squares, parks), a series of arguments justify the in-depth study and the constant research involved in their optimization to encourage deployment on a wider scale:

- Vertical gardens oftentimes represent the unique solution for densely built urban areas greenery (Anghel, Nicolau and Bica 2016).
- It is stated among the very few planted systems with applications both indoors and outdoors, vertical vegetated systems are highly adaptable due to various typologies, dimensional possibilities and techniques. Besides the already stated benefits of providing links in green infrastructures on a local scale, interior vertical gardens improve the overall quality by balancing temperature and humidity, purifying air, while enhancing aesthetics and occupants` psychological comfort.

- The variety of vertical vegetated systems shows great adaptation capacity to both location and financial power of the owner.
- Expanding the studies on this field and the applications in different architectural contexts leads to optimization in production, implementation and maintenance process and costs, transforming the system from an idyllic, isolated solution, to a feasible option.

To become feasible and reach the maximum potential, several issues involved in the decision process must be considered when integrating a vertical planting system in design. Location is highly important, as it implies aspects of bi-directional interaction: from the wall to the environment and users and vice versa, from the environment to the green wall.

The position of the vertical garden determines different qualities on the space in which it develops: environmental quality enhancement, psychological benefits, aesthetical and functional aspects. Moreover, the environment in turn impacts the state and well-functioning of the assembly: location within building and interior space (Mohora 2019), air pollution, natural and artificial light, irrigation (manual or automated), human presence and interaction. As a partly natural, partly anthropic system, the vertical garden interacts with its environment sending and receiving various stimulus.

Location is an important factor in differentiating typologies of living walls, as position relative to the building envelope determine distinctive characteristics. A classification made by the authors is illustrated in Figure 1 and is theoretically founded by the studies on vegetated building skins of Dr. Marc Ottele who argues that "Vertical green is the result of greening surfaces with plants, either rooted into the ground, in the wall material itself or in planter boxes attached to the wall in order to cover buildings in vegetation" (Perini, Ottelé, Haas, and Raiteri 2011). Thus, substrate condition and location determined the main categories.

"Living walls" function based on vertically positioned natural or artificial substrates (Gunawardena and Steemers 2019) that imply a certain level of sensitivity and dependence on humans or automated alimentation systems for essential features. Consequently, living walls are mainly used in protective environments that facilitate monitored irrigation and growth. In opposition, "green facades" or "green walls" are based on a more naturalistic approach, with plants rooted in horizontally arranged soil or planters that involve more space for plant development both vertically and horizontally. The second typology is exposed to natural factors like precipitation, temperature variations, direct sunlight, changing weather and fauna, which lead to less human dependence and a naturally functioning ecosystem.

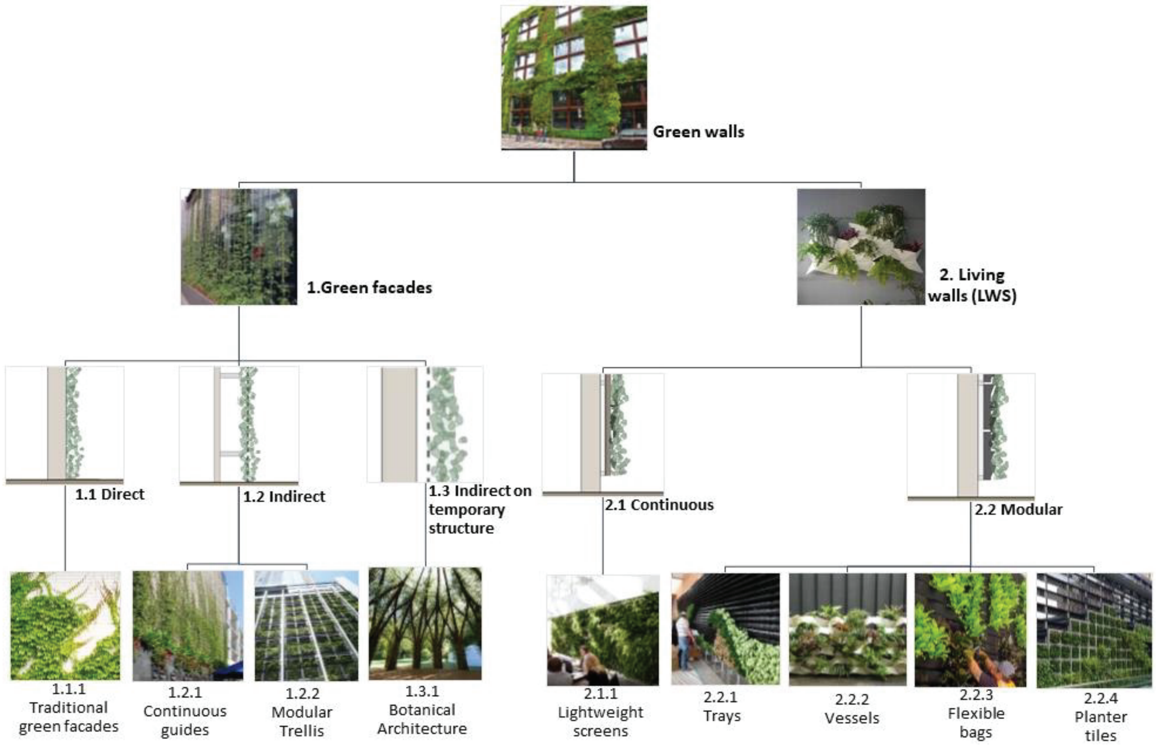
2.1 Exterior vertical vegetation—Green facades

The substrate, either natural soil or planters, is situated at the base of the wall and hosts plant roots as any natural green space. Not all vegetation species are appropriate for green facades, but those with potential of organic expansion for coverage of large vertical surfaces. The grip is either direct on the wall surface or indirect, using supporting and guiding trellises attached to the building structure.

Depending on the final appearance, building status, desired effect and the characteristics of the geo-climatic location, the decision process of green facade implementation is complex and must fall into one of the described typologies.

2.1.1 *The direct greening method* (Figure 1/ 1.1.1), implies obtaining a rather traditional facade type using climbing plants (Pérez, Coma, Barreneche, Alvaro de Gracia, Urrestarazu, Burés and

FIGURE 1. Classification of vertical green systems—study made by the authors.



Cabeza 2017). Fundamentally based on the natural growth and attachment capacity of the aerial parts of certain plant species, this technique is the first known in facade vegetalization and has occurred in either architectural or natural settings.

2.1.2 *Indirect greening* uses secondary supporting structures for plant growth and guidance (Figure 1/ 1.2.1 and 1.2.2), set directly on the facade or as a second layer. Plants are either rooted directly in the ground or in strategically positioned planters on the lower floor and/or the upper levels.

Considering plants specificities and the supporting structure, these systems are optimized for outdoor use and bring a certain ecological contribution, creating connections to other green systems and the biosphere. Green facades provide shelter for insects and small local fauna, interact with the outdoor environment reflecting season and climate changes, hence transforming the building into a living system rather than an inert construction.

The above described systems can be incorporated in the initial building architecture or subsequently added. Green facades maintenance presents similarities to the techniques applied for classical gardens, grooming frequency and fertilization depending on the planted species and climate conditions.

2.2 Interior vertical vegetation—Green facades

Unlike outdoor vegetation systems where light, irrigation and climate are naturally provided, indoor vegetation assemblies involve fulfilment of these requirements artificially, simulating natural conditions through various methods. Therefore, one of the reasons for relatively limited implementation of indoor living walls is the high cost (Table 1) of creating these conditions sometimes through complex systems that require specialized personnel both for installation and maintenance.

Living wall systems (LWS) represent a relatively recent innovation that involves placing the substrate on the vertical plan (Gunawardena and Steemers 2019).

Depending on the typology of the planting area, the living walls can be designed in continuous or modular systems (Figure1/ 2.1 and Figure1/ 2.2), that involve in turn different installations and implementation challenges.

2.2.1 *The continuous system* (Figure 1/ 2.1.1) involves a relative rigidity in employment, by individually inserting the roots into a flexible support made of textiles, natural woven, mineral wool, etc. Both installation and planting are carried out on site, and the resulting assembly functions as a compact unit, making local interventions difficult in case of damage, replacement, degradation of plants or support.

2.2.2 *The modular system* (Figure 1/ 2.2.1–2.2.4), on the other hand, is composed of independent elements such as a planting container made of plastic, metal or composite materials. Standard modules contain substrate already treated with the necessary nutrients, are pre-planted to facilitate installation. The modular system has the advantage of allowing partial disassembly, replacement or other interventions, on isolated areas without affecting the whole living wall.

Planting material for living walls in both continuous and modular systems is much more varied and permissive than in the case of green facades. The use of plants in vertical gardens is largely based on the research of French botanist Patrick Blanc, who draws attention on the importance of vegetation in the urban environment by creating natural compositions of exotic and local species, according to their humidity and light requirements (Lambertini 2007). Thus, depending on the placement and role of the plant wall, there is a variety of perennial, decorative, edible plants, succulents, ferns, exotic plants, that can be used to create both aesthetically and ecologically pleasing ecosystems.

TABLE 1. Greening the building envelope, facade greening and living wall systems.

Planting system	Growth support	Average cost
Direct greening system	grown climbing plants	30–45€/m2
Indirect greening system	grown climbing plants + supporting material	40–75 €/m2
Indirect greening system with planter boxes (LWS)	zinc-coated steel (galvanized steel)	600–800 €/m2
	coated steel	400–500 €/m2
	HDPE	100–150 €/m2
Living wall system based on foam substrate	Foam substrate; modular or blocks	750–1200 €/m2
Living wall system based on felt layers	Lightweight flexible felt layers	350–750 €/m2

Ambiental conditions are among the essential aspects to consider in living wall design and maintenance, as they are sensitive living organisms with complex requirements, dependent on artificial nutrients, humidity, ventilation and lighting, compared to green facades in natural environments. Albeit the advantages and high resilience of vertical greenery, it is currently the least used planting system due to difficulties in installation, maintenance and significant costs: specialized personnel for plant maintenance and periodical replanting, automated irrigation systems, replacement of damaged areas of the substrate or support. Modular solutions aim to isolate damage to smaller areas, facilitating replacement (Wagemans 2016). Modern systems are being optimized for wider and cost-effective use. The average cost of various vertical vegetation typologies is represented in the following table and is based on research undertook by dr. Marc Ottele from the Technical University of Delft, Netherlands.

3. PREVIOUS PROJECTS/EXPERIENCES

The knowledge acquired by the team during their previous research period has been a solid background in defining new solutions and concepts for a typical green living modular wall and its possible response to external stimuli. All these study directions are in addition to previous projects/experiences of the authors, regarding the interior and exterior spaces environmental design with vegetal elements, interactive surfaces, constantly changing and resulting in the "living" organisms, adaptable to external inputs. These projects were elaborated or are currently taking part of master and doctoral studies of the UPT (Politehnica University of Timisoara) team members.

3.1 Revitalization Proposals for Green Interior Courtyards in the Historical Centre of Timisoara, 2018, *(Mohora and Anghel 2018/ 2019)*

Team members: arch. Irina Mohora, arch. Anghel Anamaria Andreea

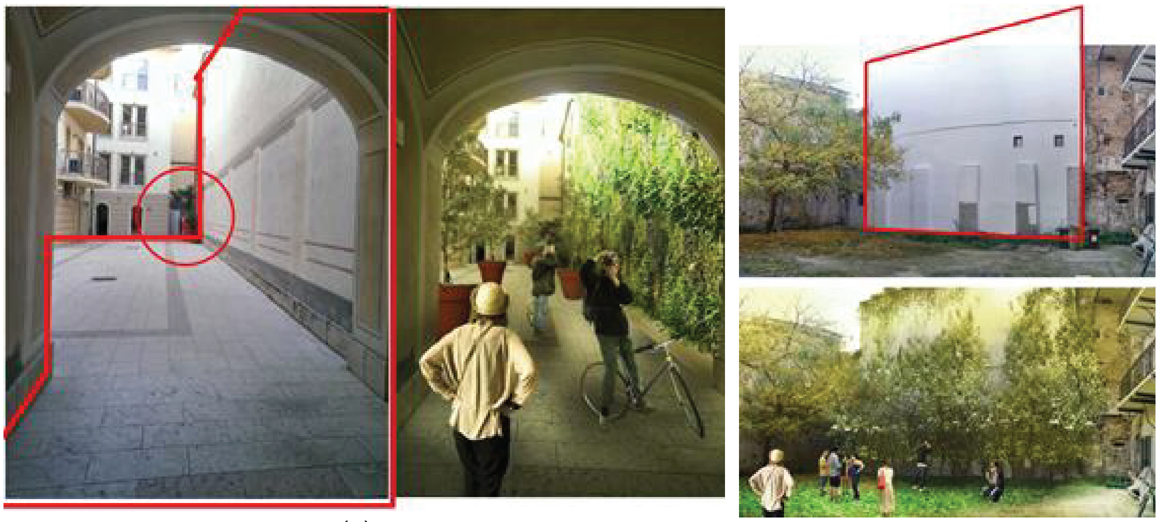
As a result of previous studies, we will further approach four different cases of interior courtyards belonging to the historical area of Timisoara, Romania. Each case is individually subjected to analysis (depending on size, shape and its potential to accommodate various green systems) and proposal. The main reason was to observe the positive influence of greenery when facing visual or legislative approaches.

By applying a simple Biotope Area Factor method of calculation for a projected situation and comparing the obtained results to a local green areas percentage demand, we could decide whether the struggle of proposing and implementing living modular walls or other type of green vertical systems in interior historical courtyards would have positive outcome. In each example, with minimum intervention, encouraging results can be obtained which raise the level and quality of life. (Mohora and Anghel 2018/ 2019)

3.1.1 *Case 1: Proposal of wall covering vegetation with soil substrate and potted trees* (Mohora and Anghel 2018/ 2019)

The first example of a courtyard, Figure 2a), is used as an exterior access area belonging to several offices. Although the courtyard is in a good existing state because of recent rehabilitation, the design is somehow to mineral and impersonal (pavements and empty blind walls without any treatments). The design lacks an essential part, as vegetation is only present isolated, by using a small potted tree. As the space is quite narrow, we used green systems that cover the blind wall. This living wall considerably increases the ecological impact as compared to the simple use of

FIGURE 2. (a) Case 1: Narrow patio without vegetation (Mohora and Anghel 2018/2019); (b) Case 2: Rectangular patio with existing vegetation (Mohora and Anghel 2018/2019)



(a) (b)

potted plants. Also, the proposed green wall serves as a psychological restoration motor for all the users that interact with it. It becomes present in everyday life activities being seen from all the interior spaces.

3.1.2 *Case 2: Proposal of horizontal and vertical wall covering vegetation* (Mohora and Anghel 2018/ 2019)

The second courtyard, Figure 2b), has a rectangular shape. It belongs to the Museum of Arts in Timisoara, in the historical area with poor connection to the surrounding building or the street. Although suitable, medium sized, the courtyard is not valued in any way. By simply replacing the deteriorated horizontal pavements with plants and greening the existing blind wall we could obtain the required percentage of green area that is so needed in Timisoara's mineral historical areas. This simple solution could ensure a better connection to the surrounding museum which could host workshops, art exhibitions, relaxation spaces or meeting areas followed by a guided tour of the museum.

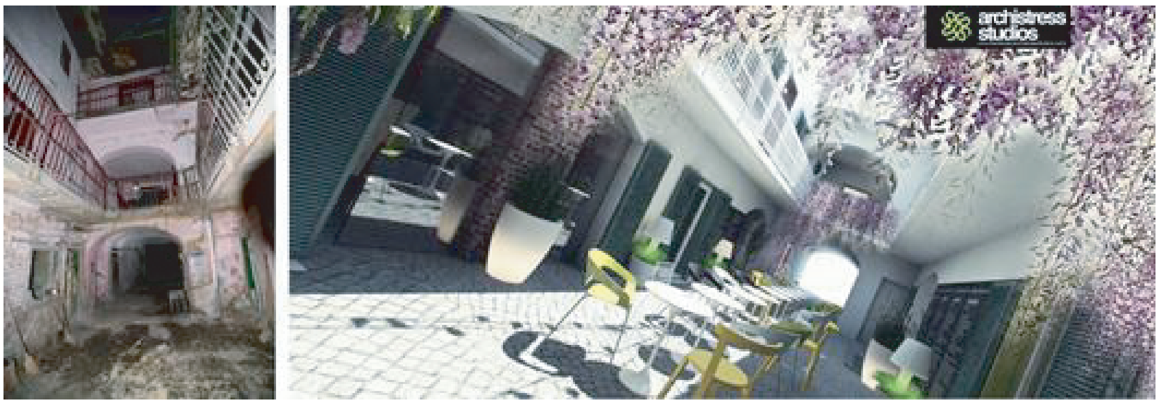
3.1.3 *Case 3: Proposal of vertical central vegetation* (Mohora and Anghel 2018/ 2019)

Figures 3 and Figure 4 (third and fourth cases) focus on the spatial and also functional potential of the interior patios by implementing more complex systems. These chosen situations are completely mineral with no vegetation and are in different levels of degradation. As compared to the semi-public courtyard in Figure 3, the private, residential patio in Figure 4 is in an advanced state of abandonment and deterioration.

A central position vegetal/green installation simple system is the main idea proposed for the first situation. Inspired by Agnes Daval`s project made in Strasbourg, this green oasis creates focal interest in the core part of the interior yard. The neoclassical architectural style mix of wooden structures and facades are transformed by the cascading greenery that changes completely the atmosphere of the building. The ground floor restaurant now functions as a continuation of the urban space through this open gangway which opens up to the public.

FIGURE 3. Case 3: Proposal of vertical central vegetation (Mohora and Anghel 2018/ 2019)

FIGURE 4. Case 4: Proposal of vertical surrounding courtyard vegetation (Mohora and Anghel 2018/ 2019)



3.1.4 *Case 4: Proposal of vertical surrounding courtyard vegetation* (Mohora and Anghel 2018/ 2019)

Very similar to the situation in Figure 2a), the residential interior courtyard from Figure 4, has a narrow and elongated shape. We emphasized interior-exterior correlation by opening the proposed new functions towards the yard using a concept united by colors and animated by the simple presence of natural vegetation.

3.2 Study of natural models: Hidden nest pavilion and Static pulsation wall

The type of top-down approach involves the existence of a problem and the identification of one or more examples that have the capacity to solve the problem from the spectrum of natural models. The two temporary architecture installations exploit the possibilities of formal and functional expression starting from the problematic topic (design theme) followed by the study of natural models, namely in the first bird nest with the project Hidden nest and second in the dynamics of the birds flock within the project Static pulsation wall.

3.2.1 Hidden nest pavilion, Plai Festival, Banat Village Museum, Timisoara, 2015

Team members: arch. Diana Giurea, arch. Zoran Popovici

FIGURE 5. (a) (b) The entrance to the Banat Village Museum before the interventions

(a) (b)

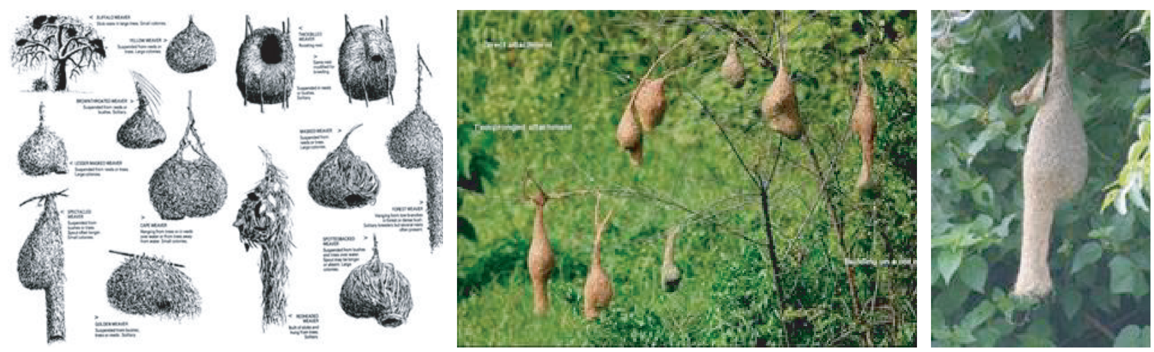
This project was developed during the elaboration of the doctoral thesis titled "The porosity of organic architectural forms" and was commissioned by Plai Festival under the design request of building an entrance gate (Figure 5) at the Festival 10th Edition of 2015. The aim of the project was to create a temporary architecture installation that would serve simultaneously as a gate, a medium object between exterior (the city) and the interior (the museum). The source of inspiration came from the weaver bird's nest (Figure 6) geometry which was reinterpreted in order to serve the purpose of the architectural proposed object.

Digital modelling played an important role in the design process as it allowed us to test several shape iterations as seen in Figure 7 with the objective of finding an optimal geometry which would guide and distribute the public from the entrance to the festival's main points.

Moreover, the pavilion had to be a discreet intervention in the context of the Banat Village Museum which is mainly dominated by an architecture of straight lines, and thus, we opted for inserting the organic mesh in a bounding box simulated by a three-directional grid (Figure 8 and 9).

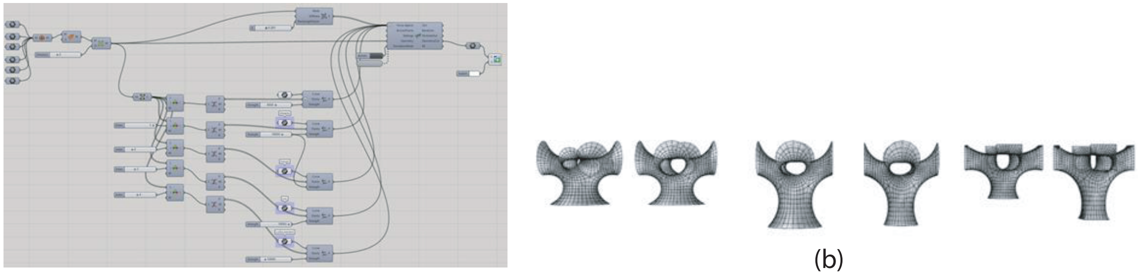
Hidden nest offered the festival's public not only a means of transit but a memorable transition experience. The pavilion's life span was three days, during which people of all ages (Figure 10) manifested curiosity and felt intrigued by the way one can experience a human

FIGURE 6. (a) (b) (c) The natural role-model—Types of weaver-bird nests



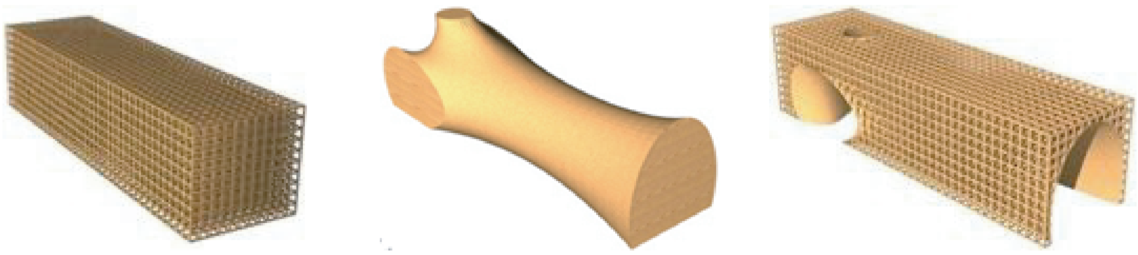
(a) (b) (c)

FIGURE 7. (a) (b) Parametric definition of mesh relaxation with different geometry iterations



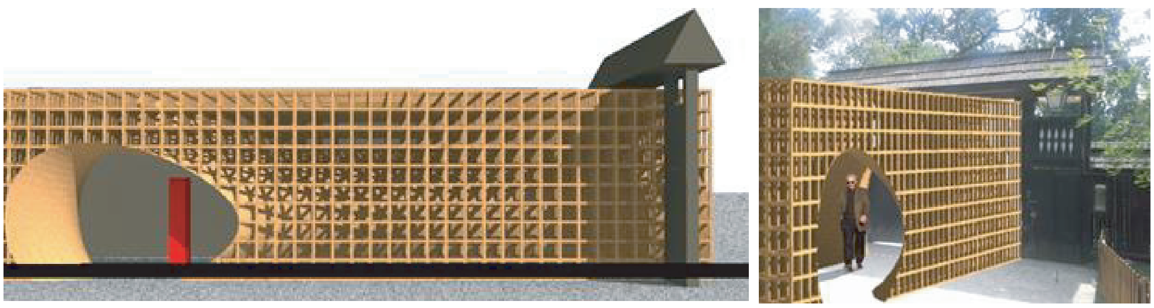
(a) (b)

FIGURE 8. (a) (b) (c) Shape generation through subtraction



(a) (b) (c)

FIGURE 9. (a) (b) 3d model with context insertion



(a) (b)

scale nest. Furthermore, we consider that temporary structures have the ability to determine a perception shift in one's mind given that it provides alternatives to how we interact with existing urbanscapes.

3.2.2 Static pulsation wall, Plai Festival, Banat Village Museum, Timisoara, 2017

Team members: arch. Diana Giurea

As in the case of the Hidden nest, for the 12th edition of Plai Festival, the client requested an architectural installation which would be more present on the street side of the museum and would serve as an attractor not only for the public but also for the passers-by. The idea of

FIGURE 10. (a) (b) Final result

(a) (b)

creating a pulsatory geometry was born after revisiting natural role-models which tackle with movement and dynamics. Thus, the focus remained on the bird flocks which are constantly reshaping their geometry throughout the flight. Another important characteristic of this natural role-model is that the whole spatial configuration of the flock is determined by the position of each bird which acts as a module to the whole group (Figure 11).

The use of parametric modeling (Figure 12 and Figure 13) in the process of finding the optimal shape of the sinuous pulsation of the wall and color palette, generated several iterations which could be easily tested.

FIGURE 11. (a) (b) (c) The dynamic geometry of bird flocks

(a) (b) (c)

FIGURE 12. Parametric definition of the Static pulsation wall

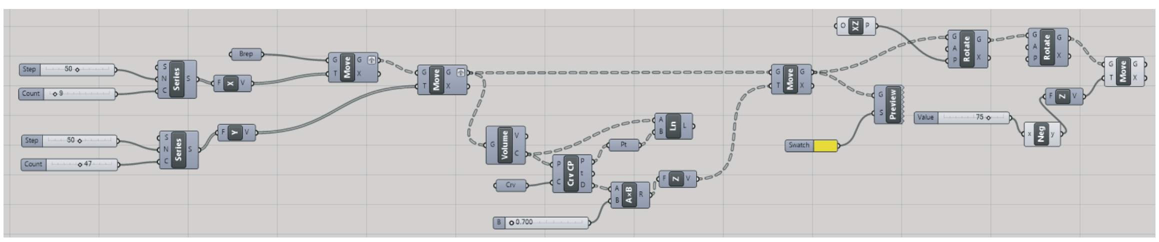


FIGURE 13. 3d model of the wall inserted in the Banat village museum entrance

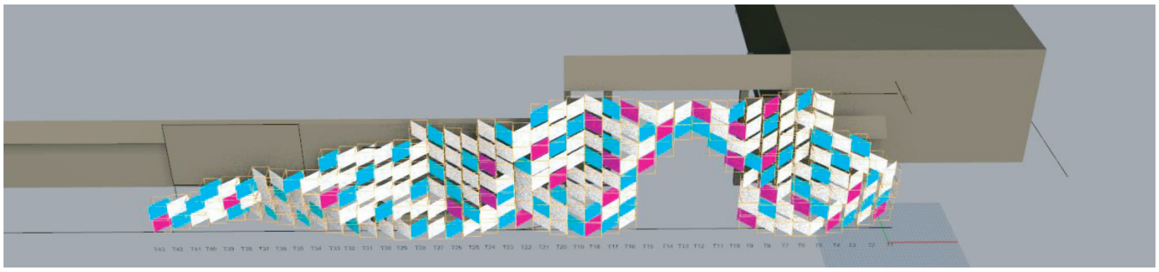


FIGURE 14. (a) (b) (c) Construction process with the help of the festival volunteers

(a) (b) (c)

FIGURE 15. Final result

The overall architectural installation consisted of 244 wooden frame cubes, where each cube functioned as a module unit and by its unique position determined the whole geometry of the wall.

3.3 "Breathing Prototypes" Workshop, Bucharect, Romania, 2013

Team members: arch. Alma Preda (Hapenciuc), arch. Oana Grecea (Banescu), Andreea Sima, Olivia Joikits, Adrian Mihai

The concept of this sentient (inflatable) white structure was based on the idea of a spiral as the physical reflection of the code of life. As an interactive decorative interior element, the spiral harnesses the human presence (Figure 16).

FIGURE 16. "Breathing Spiral" functioning diagram—study made by the team members

The complex geometry was created using computational design during the international workshop named "Breathing Prototypes," organized by "Parametrica, Digi Fab School" in Bucharest, Romania. Under the guidance of the tutors, Andrea Graziano, Alessio Erioli, Carlo Caltabiano, Horia Spirescu and Sorina Dumitru, we created an interactive, inflatable structure that was connected to an Arduino board and a proximity sensor (Figure 17).

The white spiral-like installation communicated a key message using the Morse code that was transmitted through red light flashes, as soon as a user approached it (Figure 18). The rhythmic "breathing" of the inflatable structure suggested its living pulse, while the message described by the red flashes created a dialogue with the user, thus implying the structure's responsivity to people's presence: "You Are In The Breathing Spiral."

FIGURE 17. "Breathing Spiral" digital model—study made by the team members

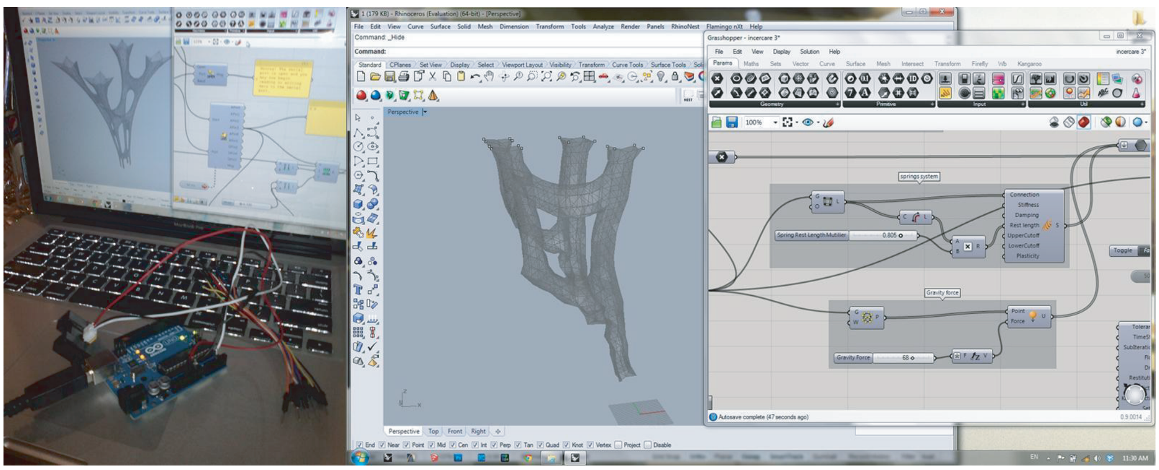
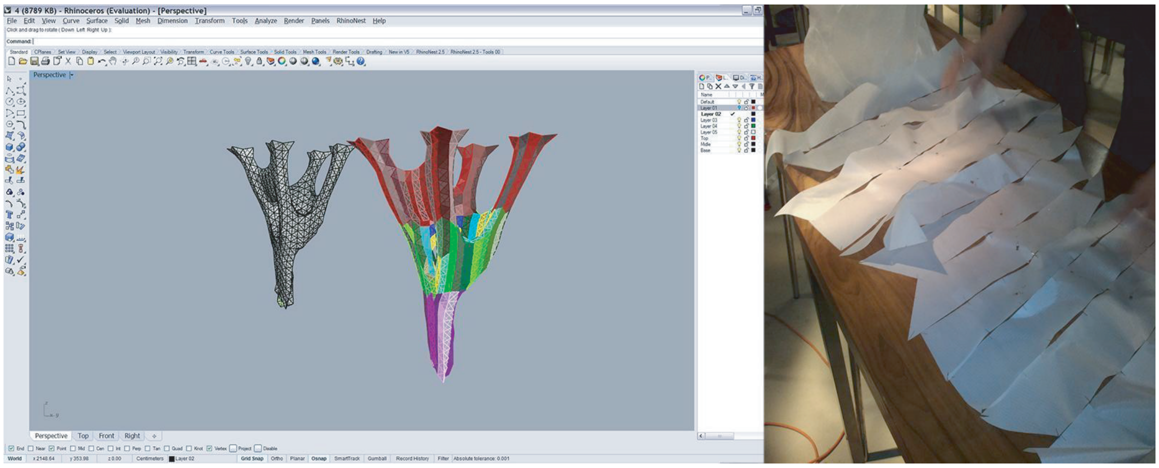


FIGURE 18. "Breathing Spiral" fabric sheets—sheet numbering and categorization, geometry for physical cutting, and white textile model made by the team members



3.4 "Interactive Responsive Surface" Project, Timisoara, Romania, 2015

Team members: Alma Preda (Hapenciuc), Adrian Mihai, Oana Grecea (Banescu), prof. dr. arh. Cristian Dumitrescu (coordinator)

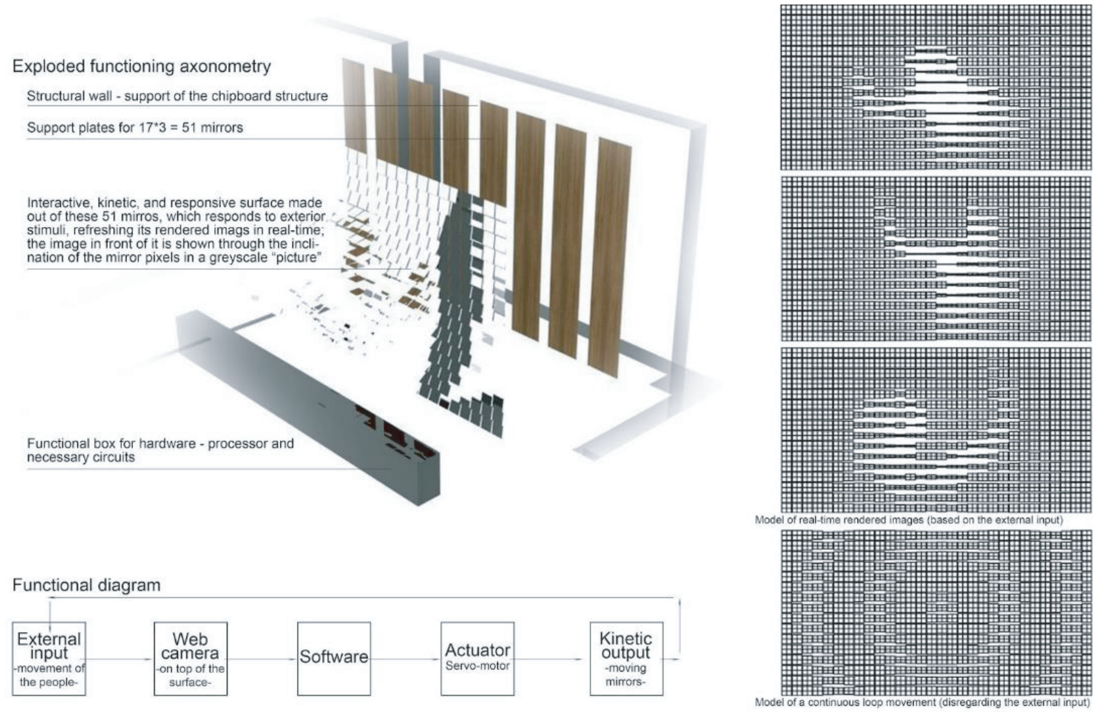
The aim of the Responsive Wall—as an experiment and an homage to Daniel Rozin's work—was to analyze the possible ability of an interior panel to interact with its users. It was intended for this unconventional piece of furniture to transform external influences into own language elements, which it would prefigure on itself, in a matrix of action-reaction, stimulus-response that would be open to communication in real time (Preda, Grecea and Mihai 2016).

Throughout the materialization of the concept, we also doubled the multidirectional relationship through the material we chose to use. The responsive wall was thus formed by a large number of small mirrors that firstly functioned as pixels, which mechanically conveyed the image in front of them and secondly, as a whole, an entire surface that reflected the environment due to the characteristic of the material itself.

The functioning diagram was characterized by the fact that the wall did not only perceive the notion of motion in its proximity, but also received the entire "moving" image, which it reinterpreted and then rendered through its constitutive elements—a matrix of small size mirrors (Figure 19).

At a first level of interaction, the mirrors reflected the movement around them. At the second level, a video camera captured the image, which was reinterpreted by the software and transmitted in real time through a pixelated picture of what was in front of the wall. This perceived image, consisting of a white-black gradient, was rendered by the mirrors through their angle: those that looked towards the ceiling represented the white "spots" of the image, reflecting the interior lighting, and the greys reflected the basis of the wall / the floor (a dark surface). All the intermediary nuances of grey had their afferent angles, depicting thereby, through a white-black painting, and at the same time in an abstract manner due to the double reflection, the continuously moving image from the wall's proximity and, thus, the dynamic breath given by users to this moving panel.

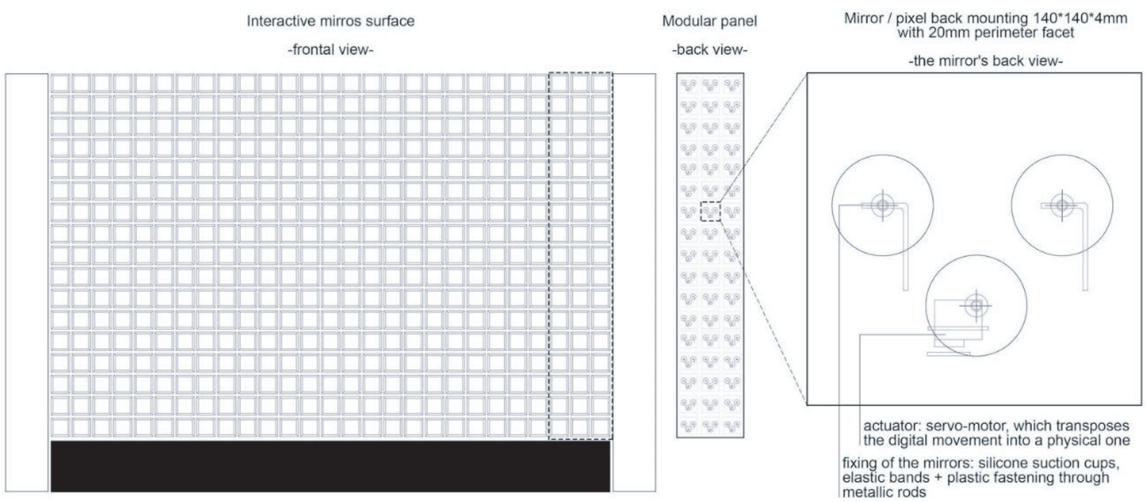
FIGURE 19. "Interactive Responsive Surface" mode of operation (Preda, Grecea and Mihai 2016)—model designed by the team members (Preda and Mihai 2018)



This way, the surface managed to capture stimuli from its exterior, reinterpreted them and transmitted a response in real time, in its own formal language.

Technically, all dynamic mirrors were fixed to servo-motors through elastic strips; the independent motors were stimulated by the software; it made them change their angle according to the reinterpreted grayscale image received from the web camera (Figure 20).

FIGURE 20. "Interactive Responsive Surface" display, back panels and pixels (Preda, Grecea and Mihai 2016)—model designed by the team members (Preda and MIhai 2018)



From a practical point of view, the responsive surface is an innovative piece of interior architecture, which may be used for representation and visual identity in welcoming spaces, for user-wall interaction purposes, patterns and their analysis and/or for decoration as a moving interactive sculpture. The types of responses offered by it can vary according to the software, the possibilities being endless: from rendering the surrounding image to different independent animations and static positions of the mirrors, representing the desired images or certain directions (Figure 21).

Through the dual scale of the reflection, by means of both the walls' pixels' movement and the material of the pixels (mirror), the experiment of a possible communication platform between an individual and interior architecture has been thus taken to an intriguing level by the reflective surface (Figure 22).

FIGURE 21. "Interactive Responsive Surface" renderings (Preda, Grecea and Mihai 2016)—model designed by the team members

FIGURE 22. "Interactive Responsive Surface" materialization—project supported by Flonta Lakeside Restaurant, Giroc, Romania; photo taken by the team members

3.5 "Transite" Competition—Honourable Mention, Timisoara, Romania, 2018

Team members: Alma Preda (Hapenciuc), Adrian Mihai, Oana Grecea (Banescu), Ovidiu Mihutescu, Radu Dorgo

The concept of the Kinetic Rail-Way of Interaction (Preda, Mihai, Grecea, Mihutescu and Dorgo 2018) was created during an architectural competition at the North Railway Station in Timisoara, Romania that aimed to raise awareness about existing insufficiently culturally exploited spaces.

The idea of the proposed dynamic installation was based on the railroad's ability of creating links, dialogue, communication. Therefore, the proposed structure marked the transitional motion in time between 1857 and 2021, and the continuous motion of travelers in space made possible by the first rail link, Szeged-Jimbolia-Timișoara, which included the city of Timisoara, where the installation was intended to be materialized. Sustaining this concept was the structure made of original train tracks that were proposed to be positioned parallel to the existing trains' directions. Some authentic sleepers were the protagonists of the scenario, as they had the power to influence it through their behavior and their type of movement. Thus, the more people gathered in the area marked on the floor beneath the structure, the more the frequency of their motion increased. Thereby, people were encouraged to interact with the installation and between themselves, to intuitively learn what it takes to change the movement of the sleepers (take a place inside the marked area and call other travelers to join them) and to feel that they have the ability of changing the installation's default type and speed of motion.

FIGURE 23. "Kinetic Rail-Way of Interaction" simulation—rendering made by the team members (Preda, Mihai, Grecea, Mihutescu and Dorgo 2018)

Based on the research undertaken by Reuben Margolin, the "Kinetic Rail-Way of Interaction" project placed a kinetic installation into a clear context and created a symbolic link between the rhythm of the sleepers and the continuous movement, which they supported.

Technically, the sinusoidal movement was designed to be generated through the spinning of eccentric levers, driven by an electric motor through a bicycle chain, which was meant to be sustained by an electric generator mounted on the rooftop. The movement frequency and speed were electronically controlled by a managing unit, depending on the degree of interaction influenced by the users (a web camera perceived the level of occupancy of the marked floor area). Furthermore, because the motion pattern of the sleepers was designed to never repeat itself, it created, through a simple mechanism, a complex movement through time, space and human interaction.

4. EXPERIENCE IMPLEMENTATION: PROPOSED CURRICULUM AT THE ARCHITECTURE AND URBANISM FACULTY, POLITEHNICA UNIVERSITY OF TIMISOARA

As involved former students and present researchers, the team members have introduced their findings and experiments to the Architecture and Urbanism Faculty (Politehnica University of Timisoara), developing several workshops and applications as part of the curriculum of the subjects they are teaching. Therefore, present students can get involved in various experiments with interactive, respectively green concepts both through some of their mandatory university subjects and through their annual summer practice workshops.

Firstly, the previously described workshops in Chapter 3.2 have been part of summer practice experiments, in which students were involved in the building process as volunteers. The academic novelty brought by the proposal was based on the responses received from students as part of half-yearly questionnaires regarding the attention given to practical rather than only theoretical ways of teaching. Therefore, these workshops were part of the practical approach given to mandatory summer practice, which is meant to compliment the academic year with a hands-on curriculum regarding actual built concepts. What we noticed during the implementation of the projects Hidden Nest and Static pulsating pavilion was that students felt challenged by the fact that they had to find optimal means of working with construction materials (wood and assembly parts), while dealing with a limited budget and fixed deadline. In addition, the summer practice at "Plai Festival" build-up process offered the volunteering students the opportunity to thoroughly understand a project workflow, from the design process to the final outcome, and, more important, its impact on the users experience at the festival through on-site feedback.

Moreover, the Computer Aided Design subjects the team members were part of (example: CAD at the 3rd Year of Interior Architecture) have been developed around the idea of teaching through examples of good practice. The acquired knowledge verification has not only been made by evaluating the answers to similar design problems as in class, but also by guiding students to create original designs that would also be materialized, such as interactive concepts for pieces of furniture or interior design surfaces.

Furthermore, some of the concepts have been reinterpreted as part of other complementary subjects held by the team members, such as Fashion Design (3rd Year of Interior Architecture), in which students would also sew their proposed garments.

The Form Study subject (2nd Year of Architecture), through experiments regarding the research of suitable forms and functional schemes for diverse programs (such as museums, pavilions, exhibition galleries, restaurants, etc.) is based on the study of natural forms and green mechanisms. Being a main academic subject that requires the materialization of each student's concept through drawn boards and physical models, Form Study is still the first encounter students have in our faculty with green, living inspiration for architecture.

Last but not least, the team members continue to encourage the introduction of fresh, up-to-date concepts into the curriculum, inspired by national or international competitions. For example, the 2nd Year Studio (of Architecture) has yearly been inserting the annual "CASA" competition in the curriculum, students being able to develop the concept at school and also enter it in the competition (that is independent of the university); thus, an increasing interest of students in the subject has been observed.

International projects at Atelier Basic Design subject (1st Year of Interior Architecture): In order to further develop the research of the projects presented in chapter 3.1, the team members transformed the subject into international workshops during the past years as seen in Figure 24. There were 3 stages of the project and the fourth is now being planned. The dissimulation started by presenting the situation and proposals for the rehabilitation of the interior courtyards from the historical center of Timisoara, to an audience formed by architecture students in Seville-Spain, a city based mostly on an urban layout with interior yards. Analyzing similar study cases from Andalusia and its potential, the team members felt the need to strengthen and further develop research on the topic.

The following phase was an international workshop in the Dominican Republic with the theme “Interior Courtyard Rehabilitation” following and highlighting the example and study cases from Timisoara. Together with students from Santo Domingo, guided by a team member and local teachers, they succeeded in having interesting, fresh, suitable ideas to implement in the old historical part of Santo Domingo city.

The third stage was another international workshop, this time in Timisoara, where Romanian students had to study and make proposals of revitalizing an abandoned building with an interior courtyard from Santo Domingo’s historical city. The green aspect in a mineral yard was efficiently implemented because most of the ideas were based on greening the area in order to create a more suitable and healthier environment.

The fourth stage will be held in Timisoara next year, 2020, as a preparation for the city’s title “European Capital of Culture” in 2021. An appropriate reason to continue the research on interior courtyards belonging to the historical part of the city, “the Citadel.” Thus, students from Naples, Italy, will join locals in order to search for suitable solutions for the climate and the area’s need. It is mandatory to involve students in the research. In this way they can mix theory with more practical projects necessary for their education, and we can obtain the feedback we need for constantly readapting and improve the curriculum for architecture students at the University of Architecture and Urban Planning, Politehnica University of Timisoara.

It is critical to highlight the importance of this applied curriculum, as one of the serious challenges for the contemporary educational system is creating connections between theory and practice in visual arts fields. Applied projects, as well as their presence on site, aids students to better understand real-life problems and find feasible sustainable solutions.

As architecture and interior design are highly collaborative domains, the above-stated workshops teach the significance of team work and inter-field communication, creating an important basis for skills that will further be developed in students` future careers.

FIGURE 24. Workshop in Santo Domingo and Timisoara: Interior courtyards

Teaching sustainability and responsibility towards nature in higher education systems is among the present-day challenges. The approach outlined in this paper aims to develop creative thinking by drawing inspiration from nature through shapes, patterns and systems, although Form Studies have been long stranded in pure formal exercises. By guiding architecture students to a better understanding of natural principles, young minds are induced to think in ways of protecting and working with the environment.

5. METHODS AND PROPOSAL: PROPOSED INTERACTIVE MODULAR GREEN INSTALLATION

As part of the research and hands-on experience and approach we have previously instilled into the team's interest regarding kinetics, naturalness and responsiveness, we aim to broaden our exploration by practically implementing our conclusions. Therefore, as a result of all previous praxis regarding modular, flexible, interactive installations and team designs inspired by natural structures, and their imposing ways of sustaining life through continuous reinterpretations of present states, a means to facilitate sustainable external environments and desired evolution is achieved. Our proposal would be a living mechanism capable of developing itself in numerous ways, in order to raise awareness of environmental phenomena, but also to improve daily urban life. Therefore, the concept is based on multiple premises.

Firstly, as the installation would be generated by interweaving the identified two main approaches regarding living walls (ecological and artistic), it would rely on both environmental, natural, energetic aspects, and on human interaction and closeness to vegetation.

Secondly, the proposal would improve urban life in a crowded city, through its "living" features and abilities. By extrapolation, it would have to be a present and frequently seen element, that would also improve the toxic effect our city has on the environment. Therefore, what better way is there to achieve these goals than by heading towards public transportation with a “green,” innovative panel?

Lastly, in order for the design to be of actual biomimetic influence, it would have to be able to physically "live," therefore transition through different states. These would be influenced by both external, natural stimuli and by the human factor. Thus, the desirable installation would be a moving, dynamic, interactive structure.

Following the above described premises, our project would consist of a green installation concept made out of interactive modular systems, while having the unique feature of consciously developing every piece of the structure in order for it to also function individually as an urban, ornamental design piece. However, when these pieces communicate with each other through a modular system algorithm, they work as a whole, responding to external influence.

As part of Timisoara's innovative, growth mindset (see first European town with streets illuminated by electric light, first Romanian town with electric trams, first European city with three theaters in three languages, first free city in Romania following the Revolution of 1989, etc.), and its present multifaceted development due to its title of European Capital of Culture in 2021, this innovative concept could be a chapter in the evolution of the municipal strategy.

So, the interactive green structure would be materialized through a modular, decorative and functional panel (4 x 3 x 0.6m—estimated dimensions, which can support further change resulted by its hands-on implementation), as part of public transport stations in Timisoara. It would include the following uses: protected (from the weather) resting space, public lighting module, public advertisement and information area, urban vegetation, ludic artistic installation, that moves and responds to people’s presence, environmental awareness symbol, and a civic involvement example as seen in sketch Figure 25.

Therefore, as a "living," responsive mechanism, the green structure including patterned modules with small and medium-sized colorful vegetation, would firstly respond to external stimuli, as seen in Figure 26. Thus, due to a humidity sensor, it would signal passers-by to water the plants, respectively power on its own irrigation system (made possible by smartly collecting rainwater); due to light intensity sensors, the mechanism would physically rotate its green components towards optimal lighting, by directing the plants towards the sun when necessary, respectively protecting them from damaging, strong light through movement towards shaded directions or in-built shutter systems; due to motion sensors, the structure would react to different degrees of agglomeration in the stations, by changing the position of the panels, the shading stages of the shutters, the shown advertisements or the colors of its lights directed towards its sitting areas, in order to comfort people who may be stressed in their hectic schedule.

All these abilities and dynamic responses will be possible by using adequate sensors connected to the proposed PLS, that would run a personalized software sequence, designed by the team. Possibly operating both on-grid and off-grid (existing urban network versus an 800 W

FIGURE 25. Interactive green structure sketch proposals and details of the interactive module—plants, motion and light responsive

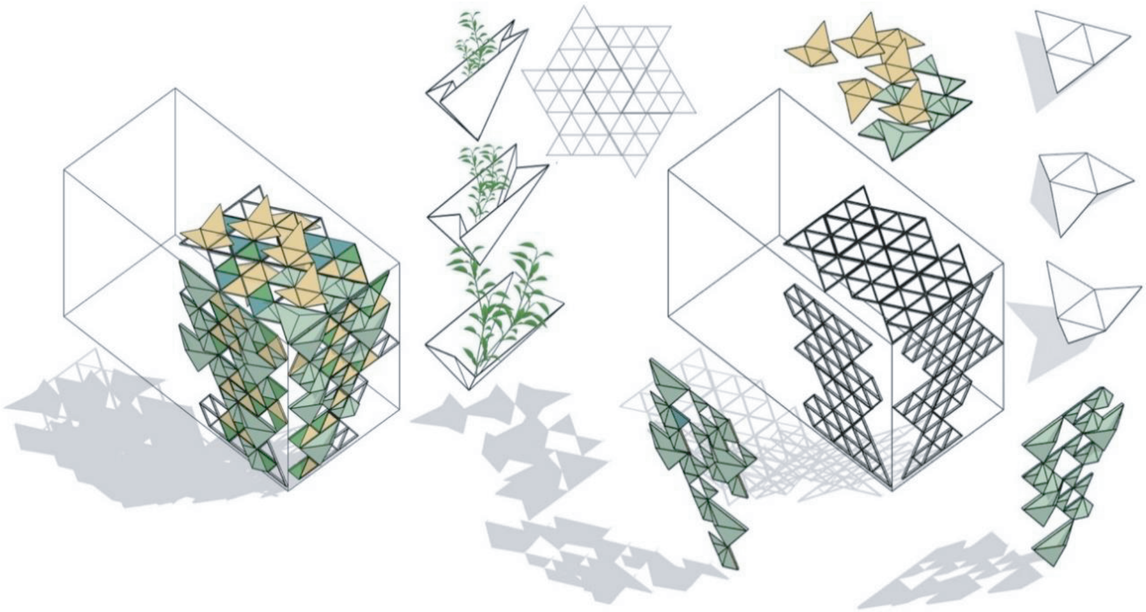
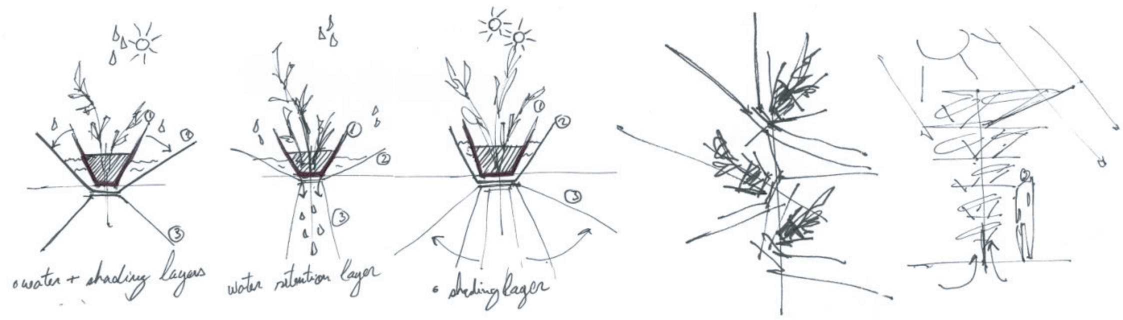


FIGURE 26. Response principle of a layer-based module. Sketches of dynamic behavior in response to light, humidity and motion external stimulus.



photovoltaic panel), the necessary sensors, micro-motors or actuators would be all connected to the PLC's main unit.

6. CONCLUSIONS

The purpose of this article is to gather all the previous experiences and knowledge in order to materialize the proposed new project—a green living, interactive installation made out of different modules. The concept of interaction, which also defines the originality and freshness of the proposal, consists in its physical response to certain external stimuli (motion, light, sun, sound, etc.) that causes it to change its shape and orientation by individually managing each component piece. Therefore, the form of this ensemble is constantly changing, resulting in a living organism, that is adaptable to the conditions it is subjected to. Novelty will result from the innovative concept of the modular interactive wall, the research of the factors that transform it into a living organism, the conception of a functioning algorithm for its constant dynamic and from some realistic simulations / experiments, respectively from the way of processing the resulting data and the drawing of personalized conclusions and dedicated recommendations regarding the concept, hereby, complementing few existing applied studies in Romania and abroad.

This project is currently under design by the authors involved having an estimation of its completion by the early 2020. Without the support and assistance given by the Politehnica University of Timisoara, and all the previous experience gathered by the authors, this interactive installation could not have been further developed.

Author Contributions: A.A.A. and I.M wrote the initial draft of the manuscript including the final abstract, introduction, chapter 2 and conclusions, chapter 3 was done by all team members: A.A.A., I.M, A.P., D.G. and F.F.

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