MoBE

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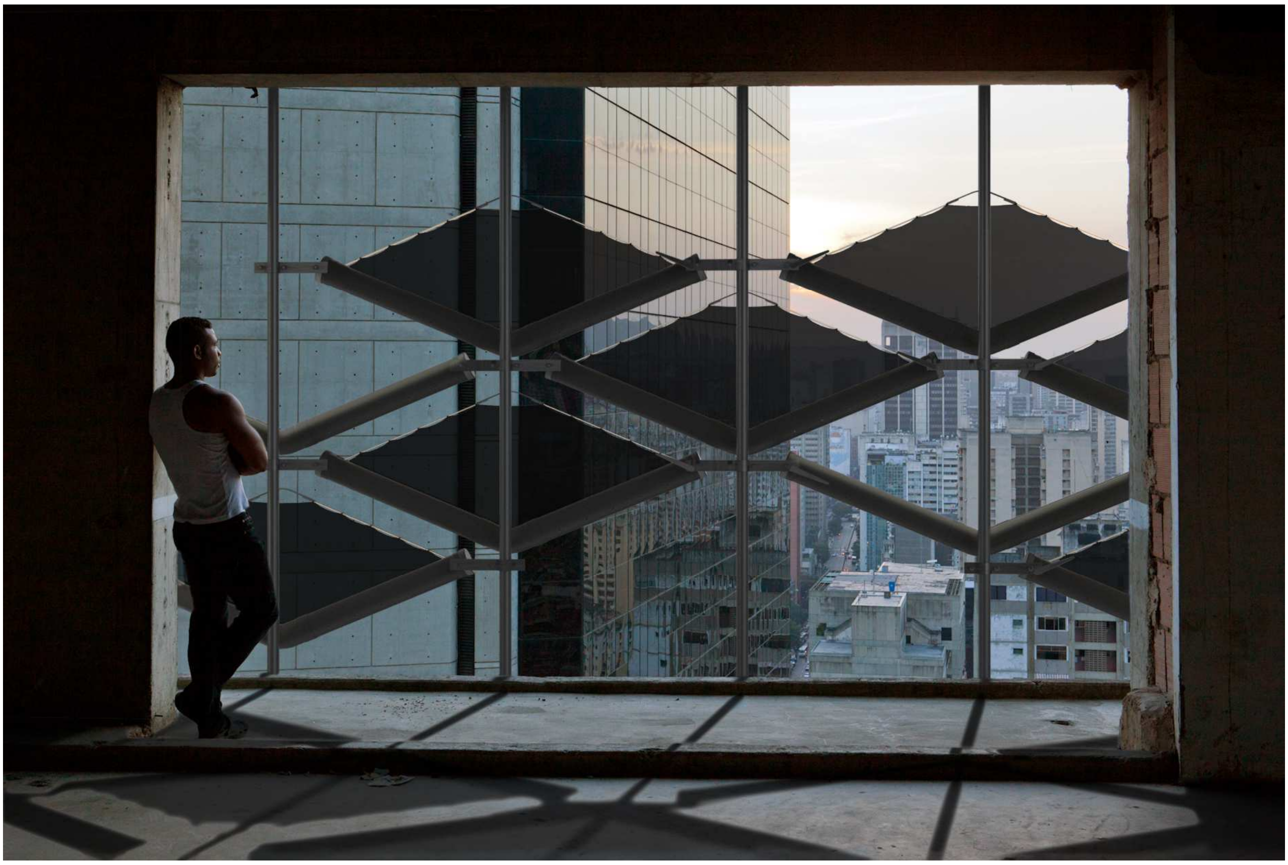
Executive summary

Climate change is one of the most significant challenges of our time. Due to the increasing energy consumption of a steadily growing world population, CO_2 emissions and greenhouse effect are continuously increasing. The building sector provides great potential to reduce CO_2 emissions, since 30% of the total energy consumption is to maintain thermal comfort in buildings. The lack of water is another major concern that troubles different regions of the world and is amplified by social inequality. This issue and similar ones are not limited only to rural areas, as even the current urban settings do not sometimes provide an adequate standard of living to their citizens. The lack of housing within cities has stimulated the growth of slums with limited or no access to basic commodities like potable water. A smart design of building envelopes can help tackling the previously described issues, since the impact of these elements, in spite of their limited cost (20% of the building), is multifaceted. The present work aims to design an adaptable, modular and multi-functional façade system to retrofit building envelopes in diverse geographical and social contexts. Nowadays, kinetic or smart façades are inclined towards sophisticated mechanisms and materiality. This comes at an economic expense that limits the usage to a privileged class and leaves a major social segment behind. Since the existing informal building stocks inhabited by the economically weaker sections of the society cannot afford this luxury, the environmental and social impact of such design solutions is limited. The goal of this project has been maximizing the affordability of the technology through informed design choices along with minimizing the energy required for achieving thermal comfort conditions. The design solution exploits the potential of dynamic building envelopes, broadening its application to existing informal communities, thus promising a greater positive environmental and social impact. In addition to the reduction of energy demand by exploiting a variable shading mechanism, the design provides an advanced water harvesting system based on fog collection, which would further improve the standard of living of the users. Innovation is achieved by scaling down technology, to enlarge the applicability field of an elite installation, thus fully exploiting its potential to solve worldwide spread social and environmental issues. Moreover, the application of a bottom-up approach innovates the method of kinetic façades design, which is usually design driven. The expected result of the project is the design of a morphable façade system, able to interact with the users to mediate the external environment conditions. Such a novel creation moves away from the paradigm of dynamic building skins and aims both to improve the life quality and to reduce the environmental footprint of disadvantaged communities.

Key Words

Morphable building skin; Modular design; Hand actuation; Affordable and Adaptable solution; Empowering informal communities



Interior view of the façade – open modules (image dimension 12,2x8,2 cm)

Interior view of the façade – closed modules (image dimension 12,2x8,2 cm)

Project description written by the Principal Academic Tutor

In the past, structures have been typically conceived with invariant geometries and mechanical properties to withstand the environmental excitations. The proliferation of the curtain wall as a typology of envelopes, the choice of standardized materials applied while ignoring the climatic context, and the mechanization of architecture with the total isolation of the internal environment, contributed to the increase in energy consumption and the worsening of the global climate system. For this reason, scientific and technological evolution combined with the ecological mentality of architecture has instigated the development of new alternative techniques to the façade with more dynamic and functional characteristics that can improve the internal conditions of the building and reduce the consumption of electrical energy. The burst in the design of dynamic skin façades could help decrease bulidings carbon emission and mitigate global warming. To self-adapt under a continuously changing external environment and to also monitor their health, bio-mimicking has been considered in the past. This resulted in a specific focus on polymeric films, stimuli-responsive smart materials and compliant morphing structures, also exploiting origami shaped folding paths.

This year's project moved away from such a trend, focusing on scaling down the technology of kinetic façades, in order to shift their field of implementation from smart cieites to informal communities, leveraging a social engagement component. Such an objective has resulted in a novel approach to the actuation of morphable envelopes. Exploiting the potential of bistability and of fog harvesting, the team focused on the development of a hand actuated system that can provide both interior shading and air-water collection. Such a system has been designed to retrofit existing building envelopes and to be maintained by the buildings' inhabitants, under the key criteria of affordability and modularity. The functionality of the proposed solution and its water harvesting performance have been assessed through digital models, and a small scale prototype has been built to verify practical aspects of the building process and functioning.

Team description by skill

The team is made up of four architects with different backgrounds, two engineers and a designer, thus being a clear example of multidisciplinarity. The former experience of architects in assessing and tackling the design of building's components and installation has been the most precious resource for the framing and the organization of the project. Architects played a principal role both in developing the design of the module and of the installation as a whole. Moreover, their proficiency in using CAD and 3D modeling softwares has been essential to produce professional drwaings and renderings. The technical background of engineers showed to be crucial in the development and analysis of the structure, mechanism and water collecting capabilities of the designed device. Their expertise in multibody dynamics and fluid dynamics allowed to prove the functioning and evaluate the performances of the module. In order to not lose touch with the human sided, aesthetical and user experience related side of the project the contribution of the designer has been priceless. His competencies have been precious for the production of all the needed documentation and for the effective communication and diffusion of the project. All the synergic efforts of such different professional figures have been fundamental to develop a functioning and functional retrofitting installation with both shading and air-water harvesting capabilities.

Goal

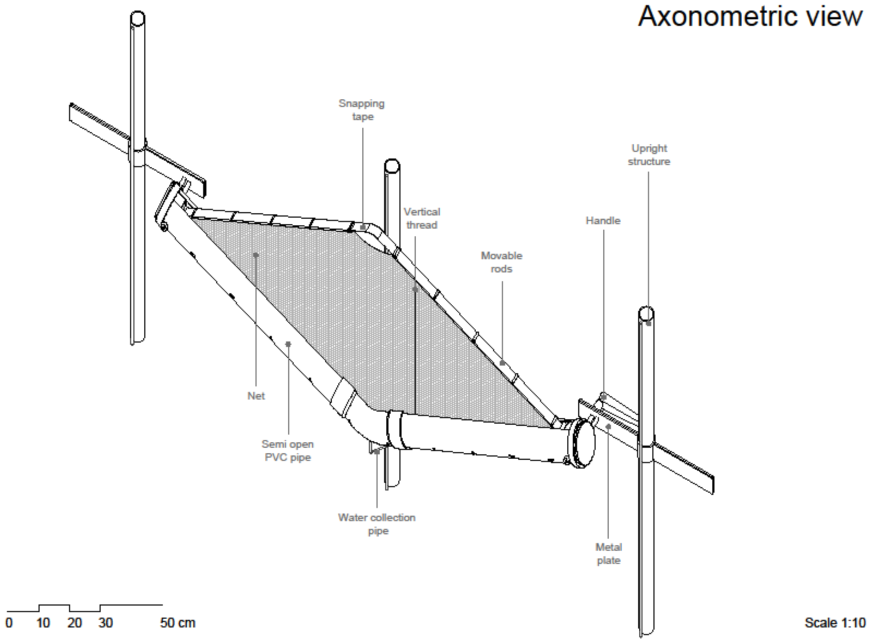
The assigned objective of the project was to design a morphable or kinetic building façade, able to passively or adaptively react in realtime to changing external/internal environments. The main goal was to reduce the energy footprint linked to the attainment of the indoor comfort, usually intended as shading. Such a statement is both general and multifaceted, thus it could have been possible to tackle the design task following a broad range of approaches. In order to create an original device that moves away from the trend of last years' projects, which usually were focused on high-tech solutions exploiting origami-shaped modules and biomimicry to create shading responsive façades, we integrated the project with a social engaged component. Thus, the present work aims to design an adaptable, modular and multi-functional kinetic façade system to retrofit building façades in diverse geographical, physical and social contexts. The main goal of this project is maximizing the affordability of the technology through informed design choices along with minimizing the energy required for achieving thermal comfort conditions. Multifunctionality is achieved by creating a module that is not only able to shade the interior spaces, but that also displays air-water collection capabilities. In fact, the final goal of the project is to improve the life quality of informal communities' inhabitants, by providing internal thermal comfort along with an essential and often rare resource as potable water.

Understanding the problem

The developed project tackles two of the most relevant issues of our time: climate change and proliferation of informal communities. Both these problems derive from the rapid growth of the world population in the last decades. This results in the steady increase of CO_2 emissions, that are the main cause of climate change and greenhouse effect. To curb global warming to a maximum of 20°C, CO_2 emissions worldwide must be dramatically reduced, resources must be managed in the best possible way and new renewable energy sources must be developed. The building sector provides great potential to reduce CO_2 emissions since it has more than twice as much CO_2 and energy saving potential as, for example the transport sector. More than 30% of total energy consumed is used to maintain thermal comfort in the buildings. There is thus an urgency to respond to this need with research, innovative technology, and efficient systems in the form of architecturally sophisticated façade.

Moreover, the construction sector cannot face such an incessant growth in the number of people, hence the proliferation of slums and informal communities. Such abitative stocks seldom lack the most basic resources, such as energy and water, and they are becoming more and more diffused also in the developed country. Prospects predict that in 2040 two billions inhabitants will live in slums. Although it is always necessary to reason about these numbers, what is quite certain is that they will certainly grow, as there are no alternatives or inversions of trend. Thus, the solution is rather to make slums liveable more than hindering their proliferation, which is actually impossible.

A further issue come along with the previous two, and its inherent to the current nature of kinetic façades. Nowadays, such elements are elite products, implemented in a limited set of developed cities around the world, since they implement cutting edge technologies and expensive materials. Thus, even if they reduce the carbon footprint of the building they are implemented into, their reduced application environment results in a negligible effect on the global scale. Moreover, beside the limit in the diffusion, kinetic façade are also narrow in the function they carry out, usually limited to the interior shading. Needless to say, the problem of kinetic façade is that they do not exploit their great potential: their application could be much broader and their functionality more multifaceted.



Axonometric view of the module (image dimension 12,2x8,2 cm)

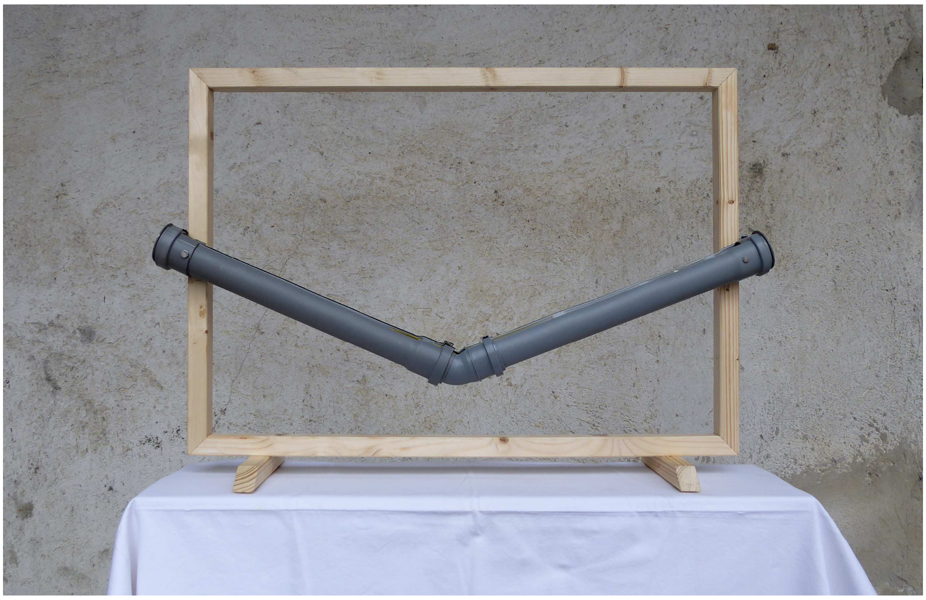
Exploring the opportunities

The design started by formulating the concrete definition of the project, followed by conception and further planning and design of the building envelope. An affordable and adaptable system was thought of to amplify the positive impact that the design would have on existing environmental and social issues. The idea was reinforced by the limitations of the state of the art kinetic façades that have a restricted applicability as well as user segment. In the conception phase an interdisciplinary team prepared several basic approaches to a solution, with which the project specific parameters and requirements defined in the project objectives could be achieved by exploiting the latest engineering and functional possibilities as well as taking design aspects into account. In this phase, the study of the state-of-the-art in the field of adaptive structures and specifically of morphing, kinetic building envelopes, was essential as it allowed to highlight the strengths and weaknesses of each approach and the attainable results. Diverse priorities dealing with economic, ecological and socio-cultural aspects were explored during this phase. Efforts were made for decoupling of functions and specialization of individual components for the benefit of not just planners and component suppliers, but also for later users.

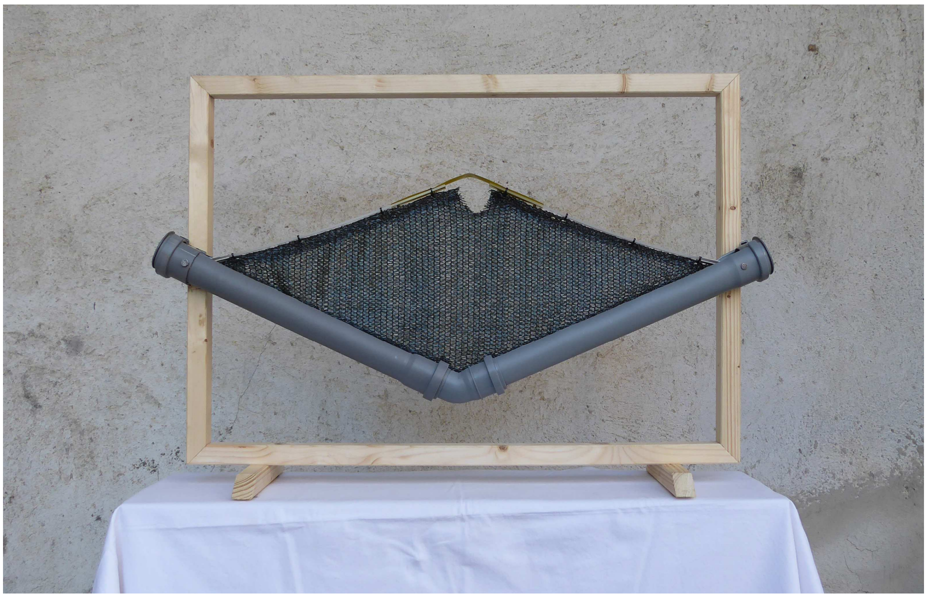
Generating a solution

After the identification of the problems to tackle and having explored different possibilities, in terms of physical phenomena, materials and functionalities, the project focused on the development of what seemed to be the more original and promising solution. As stated, the focus was to develop an adaptable, user friendly, modular kinetic façade system with special attention to the issue of social discrimination instilled by un-affordability, providing a particularly low cost design solution to retrofit existing building façades in diverse contexts. Multifunctionality was imparted by embedding variable shading and water harvesting systems, with a minimal additional cost. The possibility to harvest energy was discarded due to the high cost of such a solution, incompatible with the need of socially disadvantaged communities. An hand-actuated system, that exploits the potential of snapping bistable shapes to reduce the required actuation force, is chosen as it perfectly fits the driving criteria of the project (defined by the stakeholders' needs). Different materials for the design of the module components are studied and compared in terms of cost, efficiency and resilience. A trade-off among these criteria is obtained by also selecting the materials that are easily available, standardised and durable in harsh environments.

The functioning and efficiency of the proposed solution has been studied through digital models and a 1:2 scale prototype of the module has been created to assess and discuss relevant technological details.



Closed mockup (image dimension 12,2x8,2 cm)



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