Urban Smart Shading Devices based on Traditional Gulf Design. Case study located in a district on a hot-arid climate city (Abu Dhabi).

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Abstract

In a city with hot arid weather such as Abu Dhabi, creating outdoor shading is a main concern. This not only a strategy to improve the outdoor comfort but also a very efficient solution to mitigate the urban heat island effect. In previous studies, we analyzed the extensive deployment of shading devices in 5 different districts in the main island of Abu Dhabi.

In the present study, our aim is to show how innovation and tradition can be merged. Innovation is all encompassing concept but in our case the basis of innovation is its tradition. In the past, the Gulf countries built cities with narrow streets covering some of them partially. The Mashrabiya is a well-known concept used in the traditional architecture. If an innovative intervention is made in an urban context it has to be connected to the culture of the city and its roots.

A system of smart shading devices based on traditional geometric design is a sustainable solution and also contributes to the education of younger generations. The proposed smart shading devices are made of tent with Photovoltaic (PV) cells integrated in it. This choice stems from the flexibility in shape that such a material can offer. We will establish a comparison between current commercially materials and our solution in terms of efficiency and life-cycle energy/cost. The market offers mainly tent made of PTFE with steel structure. A random design used in specific parking lots and small parks areas downtown Abu Dhabi. In this paper we bring alternative solutions in terms of efficiency and flexibility and also describe the different design options that we tested and how the optimal design was selected.

Keywords:

Smart shading devices, traditional passive design, urban energy modeling, short-wave, radiation.

1. Introduction

The Middle Eastern Cities have had a high speed development in terms of construction with few possibilities to make the necessary tests before applying. Like other cities in other parts of the world, they are experiencing an unprecedented wave of urbanization. For the next 10 years is expected that the number of citizens will reach over 40 million.

The speed of growth brings out a great challenge for all those involved in the design, planning, construction, and the case study taken into consideration will make a difference into this critical analysis. The Main Island of Abu Dhabi has had a growth that didn't take into consideration many aspects contributing the increase of the UHI levels. There must be interventions in order to make the city more sustainable, such as: cool roof, innovative pavement materials, shading trees and urban shading fixtures. Technically, analyzing such proposals takes a long time, but thru new software's it can be possible to monitor the suggested intervention. From the economical point of view there should be an analysis if such suggested intervention is sustainable cost wise.

Environmental impact of the integration we are talking about in this research is crucial as the energy efficiency is a sensitive topic in the today building environment. The results of the research will show if the planned project of this suggested and the applied one are correlative.

The real challenge of this development is controlling the sustainability in all the aspects. The challenges are also so diverse that sustaining cities will not be possible without external multidisciplinary interventions. The complex process of city transformation has to take into consideration problematic topics connected to a better life quality for the citizens, green solutions for the reduction of the CO2 levels and in this research also strategies of mitigating heat island as a way of contributing in a direct and indirect way to a higher life quality.

The building cooling in Abu Dhabi can be reduced by referring in different points such as, introduce to the community energy saving benefits, replacing non efficient energy management systems with innovative ones etc, and indirectly by proposing strategies to mitigate the heat island.

Different papers and studies have proven that by painting in white the roofs of the buildings, changing the old materials used for the pavements and the asphalts even by making minimal interventions in them, by increasing the trees quantity the temperatures can be decreased. This approach is quite wide. In a city like Abu Dhabi with hot arid climate an interesting point is to look back into the history of the emirates and other countries of the region. The old generation approach in the urban planning point of view gives practical lessons in cooling the cities. Narrow streets, the use of the solar chimney, the Mashrabiya, the ventilation system. Some of this strategies can be used by being modified and redesigned as a strategy in mitigating the UHI. The focus in this case is in the urban shading devices.

There are several projects applied in the past in small settlements in the area near Abu Dhabi as well as in Yemen, Oman, Iran etc. that proves that such interventions bring down the temperatures by 2-3 degrees.

This are valuable lesions for a developing country with a vision of sustainable urban planning and goals to be achieved by 2030. If the authorities are willing to achieve this goals than there is an important force in making this changes happen. Small changes at a neighborhood scale can help achieving the final points at a city scale.

The strategy has to be well defined and sustainable cost wise also. In this area there is space for a long research as due the fast development many issues connected with UHI are overpassed and the city suffers the consequences. And by the city is understood the inhabitants of each neighborhood.

Two types of design are taken into consideration in this study. The elements are to be installed in a residential district of downtown Abu Dhabi. The similarity with the traditional design, beside the geometry, is also the 3D layering. The traditional mashrabiya design is characterized by openings that allow to create shading and make an easy air flow passing thru the openings. This is the concept that mainly describes the mashrabiya here. So basically there are 2 layers overlapping at a certain point for the wind to go thru and inclined toward the sun so we can have the energy savings that will bring to the city grid.

Not only shading is provided for the people to walk under but the wind can easily flow through the device. The optimization concentrates on the height and the geometry. A life-cycle assessment based on the Net Present value is provided in order to assess which one is the optimal design.

2. The case study

In our previous publishing's there was done an energetic analysis showing the impact of the shading devices in the 5 different districts of Abu Dhabi, with a saving of 0.32% of the cooling load. Another important conclusion referring to the paper was a reduction on the average of 0.328 degrees after using the shading devices in the different district. It was shown that the shading devices are more efficient in the districts with middle rise buildings, because of their geometry and their height. Of course we don't refer only to the outdoor comfort but also to the energy savings in the buildings.

The tools used in this 2 papers unable to detail each shading device at the scale we are detailing them here.

In the below image are shown the area in each district covered with the shading devices proposed in a type of intervention. The districts that we are studying before the proposed intervention had few shading and few areas with trees or any type of vegetation. Even though here the vegetation is not an object of study (it's part of a future paper), in our previous simulations we were concentrated in the shading devices.

As it can be seen there is combination of the tradition with the modern devices in each district, being based in the architecture of the buildings and the population leaving in it. The shading are covering mostly the parking lots, the walking paths, the play areas etc. White the trees are concentrated in the small parks in the specific free areas.

Each district has a different physiognomy and different building typologies, different streets pattern, but in all the cases it was shown that the shadings help in reducing the temperatures.

The models of course had a margin of error but in this paper our focus in optimizing two main typologies.

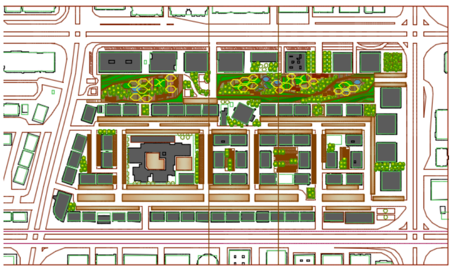

Figure 1: The case study district in Abu Dhabi.

3. Background

The main roles of a Mashrabiya are: the regulation of light, heat, humidity, airflow and privacy. For centuries it has been used in the gulf region and not only. From Morocco to India there are many cities having conserved even today the mashrabiya partitions. It was helping the decoration of the house with the different geometry. And because it was creating shade inside the house the temperatures were reduced.

The privacy obtained from the screens was also connected to the culture of each country.
The openings of the mashrabiya or so called porosity can be determined from the length and the width. Depending on this it was possible to control the light inside the rooms, the privacy and the wind passing thru the openings. In our study this parameter has an important function, as in our case we are interested to have the maximum shaded surface with the maximum flexibility of the wind movement.

Airflow improvement

The desert climate houses from the architectural point of view have such placement in plan and 3dimension to improve the airflow in the building. In such way with all the shading created all around the external openings was possible to cool the environment. The wind catchers had a major role in creating this airflow. There are many examples taken from the historical cities such as Yadz in Iran until the modern use of the Linz City in Austria, so-called solar city.
The porosity of the mashrabiya used in different desert areas is adapted to the specific climate. A porosity of 80% seems to have still a positive impact. In our study this porosity is important to define the number of louvers we would like to use. Also the position of the windows was important in improving the airflow. The windows were in opposite walls or L shape walls, in this way the breeze could continue and take the hot air outside. All this windows had the mashrabiya screens that would filter the airflow thru the openings and blocking the direct sunlight, reducing is such way the solar gains. In many cases as mentioned above, the water was another element that was added in the court that helped improving the humidity in the dry season. The wind flow would spreaded it in a natural way in all the rooms. The screens were part of this process.

The openings and the shape of the mashrabiya used in Fes (Morocco), in Cairo (Egypt), in Jeddah (Saudi Arabia), in (Sanaa) Yemen, in Punjab (Pakistan), in Isfahan (Iran) are different from each other.

In some cases there are geometric forms and in some others straight and simple lines. In the eastern part of the Arabic countries there is a major use of the floral design. Crossing all over to Morocco where the geometry takes place. All of them used for the same purpose, to reduce the solar gains, improve the temperatures and the airflow.
In the case of our study, the model A is more connected to the central part of the region, using straight lines of woos. This due to more flexibility, cost, performance and maintenance. Maintenance is a very important part of the life cycle of a device. Since what we are proposing is a massive use than the cost of each element and the maintenance cost must be considered carefully.
Below are shown some images connected to the geometry of the mashrabiya use in different countries where we were based inn for our analysis.

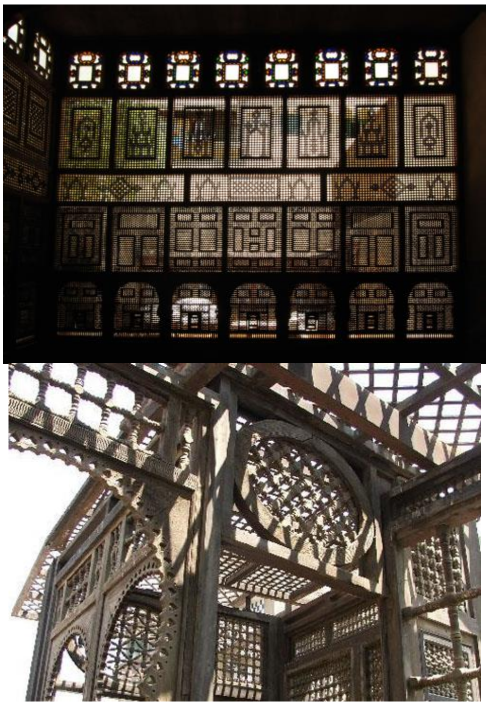

Figure 2: Mashrabiya traditional design for shading.

4. Previous shading, city structure.

The street pattern the urban planning.
In the old cities such as Sanaa, Fes, Jeddah etc. The street pattern is pretty simple, straight lines connecting in intersections. Since in the time that this cities were build the car was not yet in use and the city physiognomy was very different, the streets have a main characteristic they were narrow. The height of the buildings was enough to give shadow and cool the walking path. Even though the social life was evolved in the internal courts and not in the external parks as in countries with a colder climate conditions, the walking paths were cooled due to this blocking of the solar gains.
This is a concept that Fosters and Partners brought at Masdar City. Walking in the narrow streets of Masdar, there is no direct sun coming down to the pavement. People walk around and feel comfortable in comparison to the streets in the city. The same ide should be used in the new neighborhoods but this varies and depend on the development plan designed and approved.

In the modern cities of this region, with a hot arid climate, due to the use of the cars and other means of transport, the requirements of the citizens the change of the lifestyle, the streets are wide. The shading of the buildings doesn't cover the pavements. In our study only one district, with buildings of 20 floors in average has its streets shaded most of the time.

The conclusion is that there should be taken additional measures to create a sustainable city, in the direction of the outdoor comfort and in our case, as per our study the improvement of the outdoor comfort due to the temperature reduction. The sustainability of a city is a very large concept and can be achieved in many levels. In the urban planning point of view it can start by requalifying each district at a time.
Our proposal is to place shading over the parking lots, the main walkways and in the play areas inside the districts. The wide streets and walkways can have this type of solution to reduce the temperatures and to improve the airflow. In the main island of Abu Dhabi where the UHI has a major effect bringing such solutions that can be applied at a large scale.

The new neighborhoods being build all around the main island of Abu Dhabi towards the desert have a different typology of housing from the downtown Abu Dhabi, but also in the main island there are some districts in the entrance of the island that are mostly villas. Also in this type of areas we give some proposals, the typology A is the one we give as the best alternative. A connection with the past and an improvement of the outdoor life of the citizens

5. Proposed shading devices

The following shading devices were developed following the traditional principles.

5.1 Model A

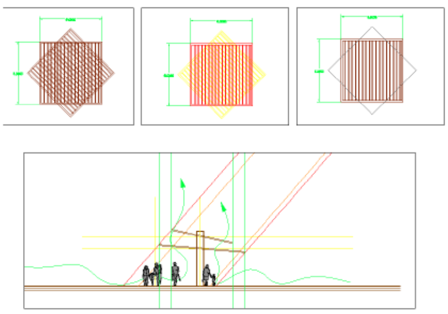

Figure 3: Drafts of the proposed shading devices in a CAD program.

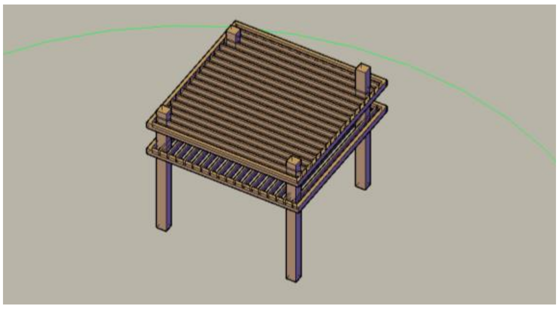

Figure 4: 3D model of the shading device.

Geometry
In this section will be focused on the characteristics of the firs model, A. We started with the geometry in our analysis. As the literature suggests, there are many different geometric patterns of the mashrabiyas for the several functions that they were covering. And even though they are typical for the full region, in different countries the design varies in accordance to the particular culture. For example, For example, as mentioned above, the openings and the shape of the mashrabiya used in Fes (Morocco), in Cairo (Egypt), in Jeddah (Saudi Arabia), in (Sanaa) Yemen, in Punjab (Pakistan), in Isfahan (Iran) are different from each other.
Material
In this Model the material we propose is wood. There are different types of wood for external use. Beach wood and merandi are the most used ones.
First analysis – Radiation
In this case there are taken two samples in analysis. And for this purpose is used Grasshopper.
Second analysis – wind flow
The wind flow analysis is used to show that the solution coming from Grasshopper is the most effective one, as it allows the wind to flow within the district.

5.2 Model B

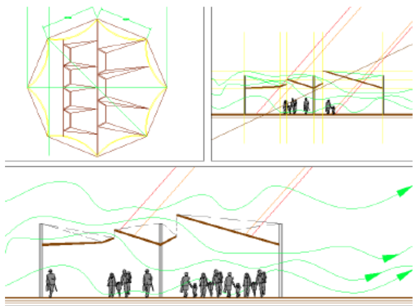

Figure 2: Shading devices that prevents the modification of the wind flow.

Geometry

In this section will be focused on the characteristics of the second model, B. We started with the geometry in our analysis. In this case, the element that we got from the traditional design is the wind flow. The PTFE material allowed to the device to take different shapes. Of course we proposed the photovoltaic cells as an alternative to recover energy from this process. Beside the mashrabiya concept another inspiration building using the same philosophy is the library at Masdar city that is already built with the same concept, to catch and bring at a human level the wind flow at a certain height. In a single unit the concept might not have the same feedback as it can have applied in many units. Furthermore, in cities like Abu Dhabi such structures are not applied and such optimization shows that a particular attention must be paid to the geometry.

Material

The material we propose is a type of PTFE but integrated photovoltaic cells. It's a material that recently has been opened to the market after a military use.

First analysis – Radiation
In this case there are taken two samples in analysis. And for this purpose is used Grasshopper.
Second analysis – wind flow
The wind flow analysis is used to show that the solution coming from Grasshopper is the most effective one, as it allows the wind to flow within the district.

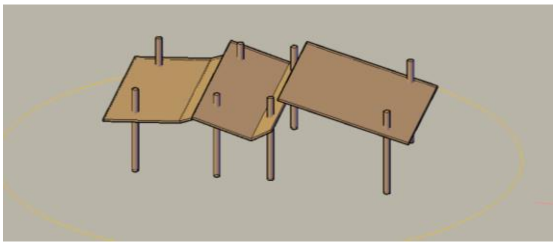

Figure 3: CAD representation of the model B

The double layer concept.
In both devices is used a double layer concept.
In the first case the second layer has the same surface as the firs layer but in the second device it covers it partially. In the first case we proposed such solution as by having 2 layers we can put les elements in each one in order for the structure to be lighter and allow the windflaw.
On the second case, it's partially covered as we want to take advantage of the solar energy with the photovoltaic cells but also increasing the shaded area with the optimal distance to allow ventilation.

6. Methodology.

The main tools we used in this research are AutoCAD, rhino and grasshopper.

AutoCAD
The full area of the districts was modulated in AutoCAD. Also the single elements were based in the base files of the districts in order to keep the same dimensions and pattern. The base of the traditional device has dimensions of 5x5 meters. Also the smart device is modeled in AutoCAD. A tool designed for architects and engineers but not only. From there the files were exported to rhino in order to modify the format of the file.
Rhino
Rhino is used as a transit tool to prepare the 2 working models for the Grasshoper. Converting the file to modify the openings of the louvers and the height is an important step for the optimization.

The one we used for the optimization is grasshopper. In this case the files taken from rhino are further modified. As shown below, the tool has different inputs for our purpose, the radiation analysis. The location, the weather file are the ones to calculate the solar gains in the analyzed surface. A similar analysis like Ecotect.

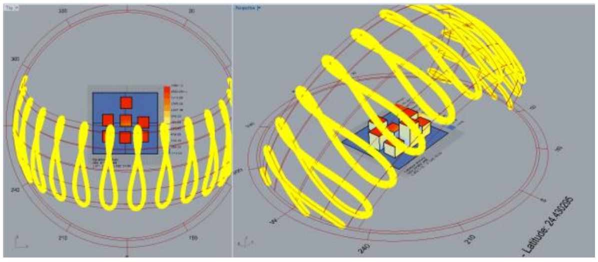

Figure 7: Radiation tool used for the analysis of the effectivity of each proposal.

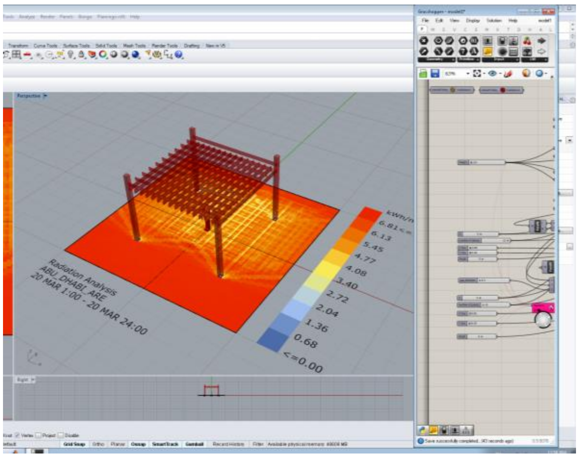

Figure 8: Axonometric view of the traditional device in Grasshopper.

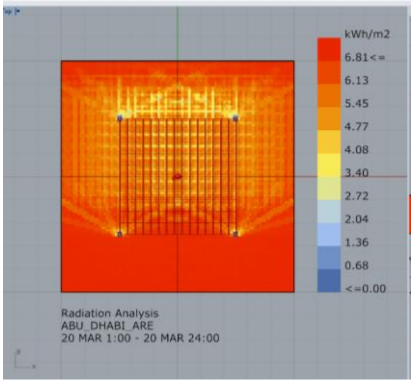

Figure 9: Plan view of the traditional device in Grasshopper.

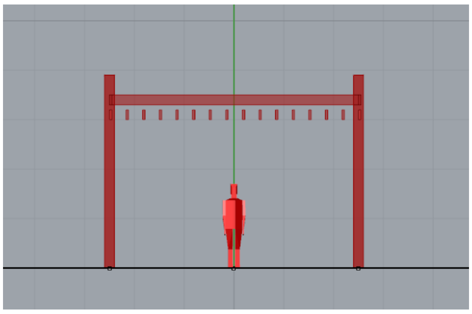

Figure 10: Section of the traditional device in Grasshopper.

2. Conclusions

Part 1.

(The results are still under revision as the optimization analysis is ongoing).

Simulations and results
As it will be shown results from the radiation and ventilation analysis the traditional and smart shading devices can be improved in dimensions and geometry. The first case is the one that is closer to the historical use of mashrabiyas and we designed it to recall their use. Optimizing the height of the louvers to have both maximum shading but also the necessary ventilation was the main aim of the research for this typology. Moreover the idea is that the role of this openings is to improve the wind flow within the districts.
In the case of the smart shading device, what is taken as a base line is the traditional concept of ventilation that we try to improve. Even though in a single device the impact might be very low at a higher scale the impact is very important as the wind flowing in the district can be improved. In additional this devices integrated with the photovoltaic cells helps saving energy that can be used to bring light to the district.

Part 2.
Sustainability as an alternative.
By the analyzed cases there can be a lot of learned lessons. There are many shading devices already placed in the city but the contractors are focused only in the cost. There is this possibility that with a similar cost can be obtained a better performance of the shading. The owners that order them or the public institutions must pay attention to the performance of the devices as a strong mean to improve sustainability.

Acknowledgment

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