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SUSTAINABLE RENOVATION OF RESIDENTIAL BUILDINGS IN SUBTROPICAL CLIMATE ZONE

Ph.D. Thesis booklet of Theories- 2018

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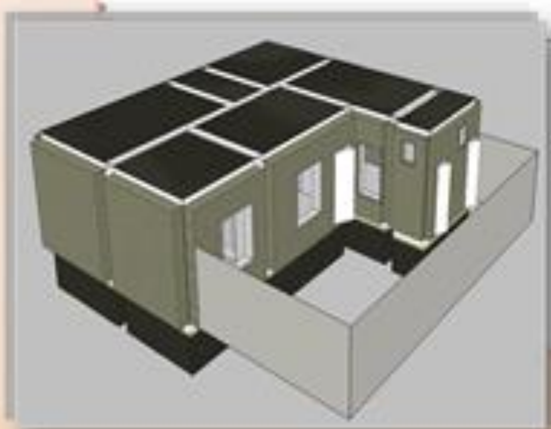

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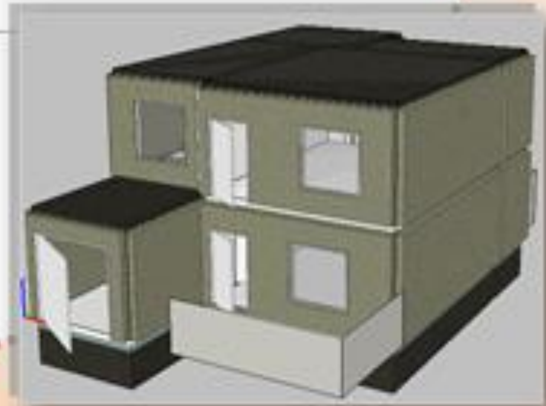


1. The Aims of the Research.

Climate has a major impact on the thermal comfort and energy consumption in the buildings. Traditional buildings have been a good example of responding to the local climates, which were the results of centuries of materials construction techniques and climate considerations that achieved through a trial- and error process. In current buildings, some technologies and building materials used were inverted from western countries without careful consideration for the local climates in the region. In addition, most of the new building envelopes made of a thin layer of high thermal mass, such as cement block, which include no overhang or any shading devices, resulting in easy solar radiation penetration into inside the building. As a result, buildings were very hot without the assistance of an air-conditioner; this caused an excessive energy consumption of the built environment.

The building sector is known to be the largest energy consumer, based on the analysis of previous studies, the residential building is the first largest energy consumer. In Sulaimani governorate, the consequences of high-energy consumption in residential sectors are becoming a major concern. According to the annual report of the Ministry of Electricity and Energy in Kurdistan Region of Iraq in 2014, the residential buildings consumed 70% of the total energy consumption. One of the best opportunities to improve the energy and thermal comfort performance in the existing buildings can be attained through the renovation of buildings in a sustainable manner. Thus, the main goal of sustainable renovation is improving the thermal comfort, increasing the indoor air quality, while minimizing the energy consumption .

The main objectives of the research are:

-Finding a comprehensive strategy for sustainable renovation of residential buildings in order to be able to fulfill the requirements of their occupants.

-Trying to take advantage of natural ventilation to improve indoor air quality, reduce energy consumption, and develop passive ventilation systems for residential buildings during the refurbishment process.

-Trying to propose models of energy and thermal comfort efficient in the renovation of the residential building typologies using appropriate passive and active strategies.

2. New cientific Results

2.1 1st Theory

Creating typology is a comparative method to investigate the physical or other characteristics of the built environment. It can also be a useful instrument in the existing residential buildings to reduce energy consumption during the renovation process. The best opportunities for improving energy efficiency, indoor air quality and thermal comfort performance in the existing buildings are sustainable renovations. Therefore**, the first step of my study was identifying five types of existing residential buildings in the study area, through field surveys based on their compositional and morphological characteristics analysing.**

To investigate the energy efficiency in the existing residential typologies, there is a need for an accurate numeric analysis and modeling tools, the dynamic simulation IDA ICE 4.7.1 has been applied for feasibility purposes. The models have been simulated. During the results analysing **I have found that the building materials and construction techniques have a significant impact on the energy performance. Consequently, I investigated that the houses that have better thermal mass, have lower energy requirements.**

It is worth to mention, the IDA ICE software, for calculating supplied energy has been used up the whole area into account during the calculating procedure. To find out the actual delivered energy for each type, it will better to count on the energy that required per square meters instead of the total energy for the whole building, in this way, the first type is actually the best among others in terms of energy efficiency requiring only 225.5 kWh/ m^2. While worst type is Type 3, which required 554.7kWh/m^2.

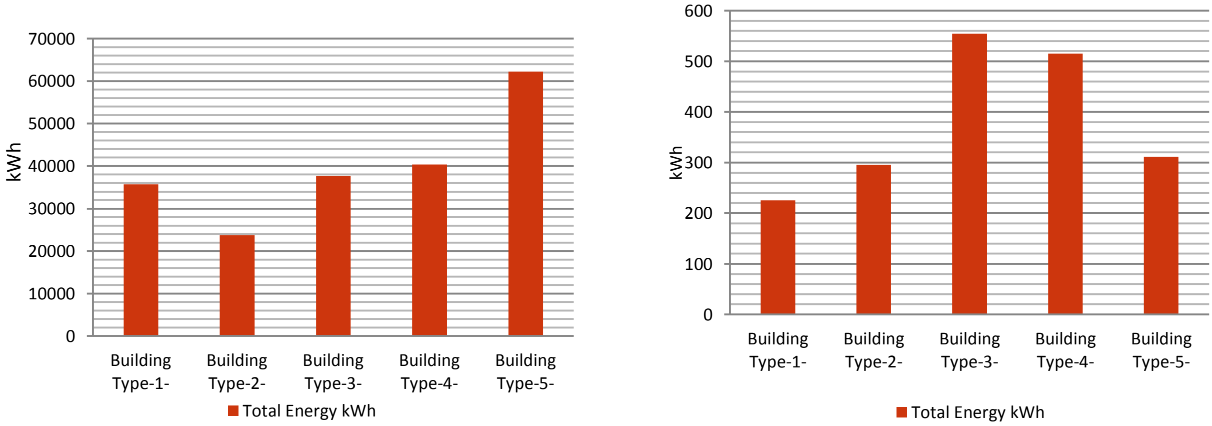


*Fig.1.*The total supplied energy (left), the energy required per meter square (right), in the building types.

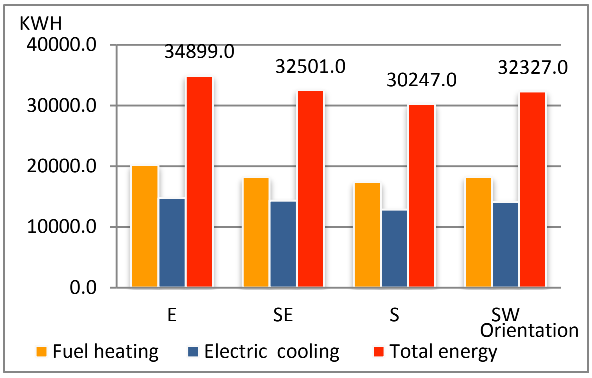
2.2. 2^{nd} Theory

The Passive design responds to the local climate and site conditions. It is one of the most effective strategies for reducing energy consumption and improving indoor air quality in the building. Therefore, the key for designing passive building is to take the best advantage of the local climate. **The most important factors must be addressed when designing or optimizing passive buildings, including; building shape, building orientation, thermal insulation, air infiltration, shading device control, and window to wall ratio (WWR) for the building and its different orientations.** In addition, the natural ventilation can take away the indoor heat and humidity and provide fresh air to improve indoor thermal comfort conditions when the outdoor climate is uncomfortable. Furthermore, for centuries, wind tower as a passive cooling strategy had been used for ventilation and cooling the buildings in the hot- arid or hot- humid areas.

The study focused on passive cooling, heating and ventilation as an integral part of architectural elements which mainly influenced by the local climates. These strategies could provide part of the cooling requirements in hot dry climates, reduce the continuous reliance on common active cooling systems and promote for energy and carbon emission savings since they depend on natural energy sources in the surrounding environment. However, in hot and dry climate it is important to consider the sun's path and the position and axis of shading device during the renovation process, to prevent extra solar gain in summer and allow it to enter in winter.

2.3 3^{rd} Theory

Optimization is a technique which used to obtain the best results from a system or process. In essence, the importance of optimization lies not in trying to find out all about a system, but to find out, with the least possible effort, the best way to adjust the system. Furthermore, international studies confirm this conjecture, according to which 30% more energy savings can be achieved by optimization of the building. The first factor that took into consideration for optimization was building orientation. To find the best orientation for energy efficiency in the existing buildings, fourth alternative orientations were selected for each type including East, South-east, South-west, and South. Moreover, the IDA ICE was used for simulation. Based on the alternative orientation simulation, the best orientation for all the models was south orientation.



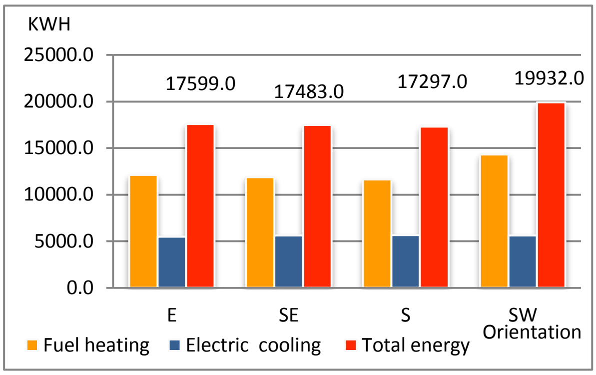


*Fig.2.*The annual delivered energy comparison in four different orientations based on IDA ICE Simulation

2.4. 4th Theory

Passive Strategies Optimization

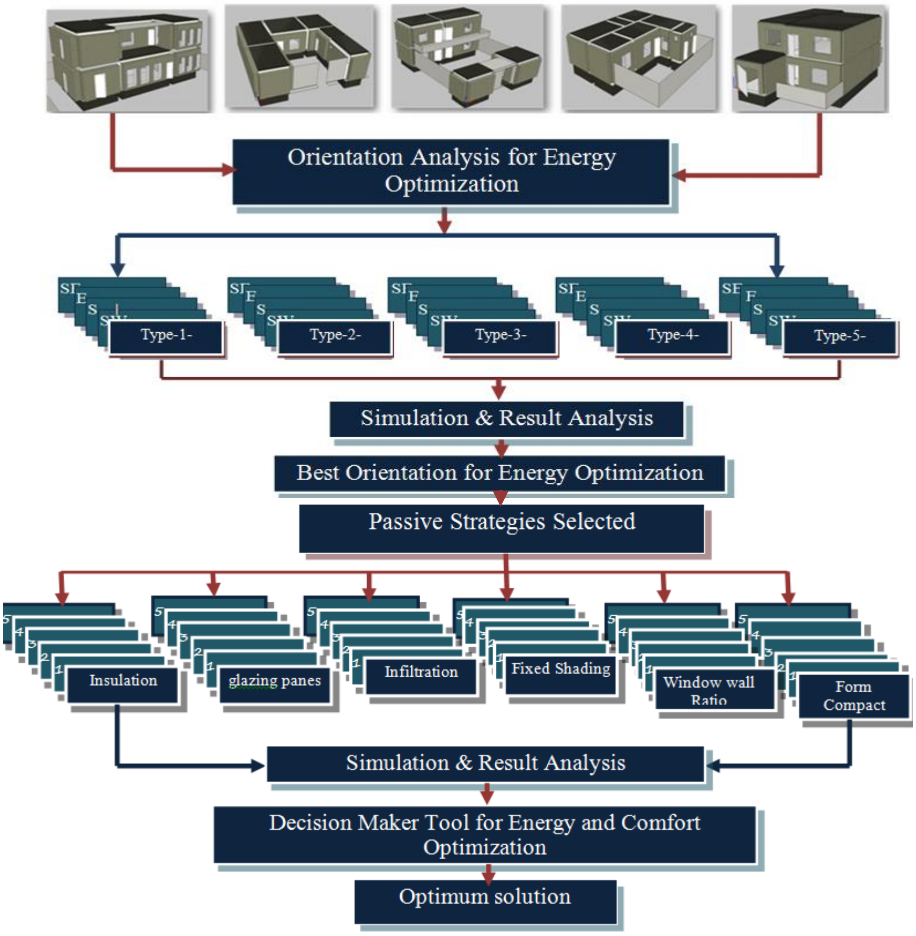
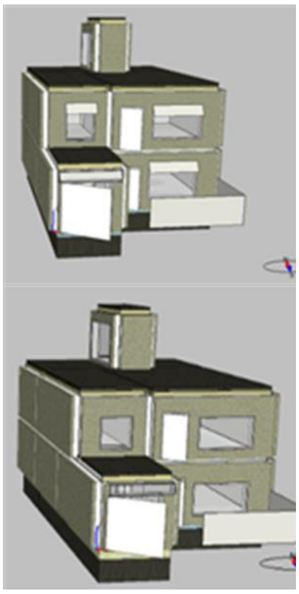


Fig.3. The optimization process for getting optimum models based on the passive strategies.

Based on the passive strategies optimization for the residential building typologies, several scenarios were selected and all selected scenarios have been simulated. The simulation results have been analysed and compared with the base model to identify the most appropriate passive strategies for getting an optimum mode for each type. The approaches are supported by the Excel decision support tool was used to complete the optimization process.

Table.1. The percentage of reduction and increased energy consumption and thermal comfort in all scenarios.

Residential building Type - 5 -			Passive strategies					
Zone: kitchen Orientation: South			1	2	3	4	5	6
		Basis	Insulation 20cm	3 pane glass	WWR 25%	Infiltration	Wind Catcher	Fixed shading
Max. Heating load	W	0.0%	-67.6%	-3.7%	4.4%	- 0.2%	- 3.4%	0.6%
Max. Cooling load	W	0.0%	35.4%	-10.5%	-1.2%	- 6.3%	-12.7%	-7.5%
Heating demand	Kwh	0.0%	-72.3%	-1.6%	0.0%	- 0.9%	- 0.9%	7.4%
Cooling demand	Kwh	0.0%	-52.3%	-11.6%	- 3.8%	- 9.7%	-19.1%	-14.1%
CO2	Ppm	0.0%	-36.6%	- 35.1%	-37.8%	2.3%	- 47.9%	-35.1%
Daylight	Lux	0.0%	-0.2%	-17.5%	26.8%	0.0%	-6.4%	-35.1%
Thermal comfort (Acceptable hours)	Hour	0.0%	1.1%	-1.1%	-1.4%	-1.4%	- 1.4%	- 2.8%



Residential building Type-5-			(Passive strategies)	
Zone: Guest room		Basis	Optimum model	
			with shading	Without shading
Max. Heating load	W	0.0%	- 70.9%	- 68.4%
Max. Cooling load	W	0.0%	- 66.1%	- 63.1%
Heating demand	kWh	0.0%	- 72.1%	- 71.4%
Cooling demand	kWh	0.0%	- 58.9%	- 51.6%
CO2	ppm	0.0%	-51.1%	- 51.3%
Daylight	Lux	0.0%	-6.6%	7.7%
Thermal comfort	Hour	0.0%	1.57%	1.8%

Fig.3. The proposed optimum model from IDA ICE (left), The percentage of energy and thermal comfort reduction in the optimum model (right).

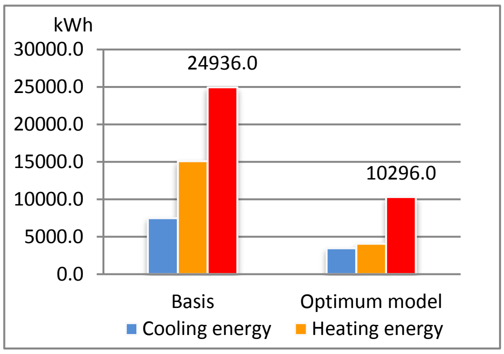
Through the cases studies, one thing **I can be stated here is despite differences of the residential building types, there are some common passive strategies have a significant effect which includes thermal insulation, glass pane, window to wall ratio, that play a big role in increasing thermal comfort and energy performance.**

2.5. 5th Theory

Generally, passive strategies alone are insufficient to meet heating, cooling, ventilation, and lighting that need in the buildings when the ambient temperature is too high or too low, in the winter and summer seasons. Therefore, the conditioning buildings need active systems to supplement passive systems. **The hybrid strategies system attempts to combine the benefits of both passive and active strategies in an optimal way to provide better indoor climate and lower energy use.**

Table 2. Comparison the hybrid strategies results with the base model.

Residential building Type - 5 -			Hybrid strategies					
Zone: kitchen Orientation: South			1	2	3	4	5	6
		Basis	External Shading	Heating/ Cooling Floor	Heating/ Cooling Floor +HP	Heating/ Cooling Floor +HP+ Solar Th.	Water Rad.	Water Rad.+ AHU
Max. Heating load	W	0.0%	-0.2%	-38.8%	-37.9%	-38.1%	-0.5%	5.5%
Max. Cooling load	W	0.0%	-11.2%	-21.7%	-21.9%	-21.9%	-1%	1.8%
Heating demand	Kwh	0.0%	0.1%	5.9%	5.9%	5.8%	-8.4%	12.3%
Cooling demand	Kwh	0.0%	-39.5%	26.8%	25.9%	25.8%	1.4%	3.9%
CO_2	Ppm	0.0%	0.4%	0.0%	0.0%	-0.1%	-0.4%	-53.6%
Daylight	Lux	0.0%	-14.2%	2.3%	2.3%	2.3%	0.0%	0.0%
Thermal comfort (Acceptable hours)	Hour	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%



Optimum model-5- Hybrid strategies			
		Basis	Optimum model
Cooling energy	Kwh	0.0%	-53.8%
Heating energy	Kwh	0.0%	- 73.1%
Total energy	Kwh	0.0%	- 58.7%

Fig.4. The delivered energy for the optimal model and its comparison with the base model in the hybrid strategies.

During aforementioned, **I came to the result that both passive and hybrid strategies are promising strategies to optimise the building more sustainable with low energy use and good indoor air quality.** I have also established that the hybrid strategy usage more efficient in the indoor air quality and thermal comfort, compared to the passive strategy. While passive strategies are more efficient in terms of energy savings. Therefore, this issue should be addressed carefully in the buildings renovation process.

In summary, **I have established that in the optimization phase, when simulations serve as a means to compare different scenarios of negative and hybrid strategies, this simulation can predict that the optimal model reduces 85% of total energy consumption per year compared to the base model. While the improved model is more efficient in terms of acceptable thermal comfort hours and indoor air quality performance.**

3. The results, usability and practicality of the research

- The results analysis in considerable iterations undertaken during the scenarios' simulation is very important because time is one of the most reported barriers during design or renovation stages. Therefore, it is essential that architects receive a sufficient knowledge in sustainable environmental building to use the tools for quick evaluation of design or optimization concepts. Thus, evolution has to take place in the academic field and consulting engineering offices by introducing new classes of building simulation tools.
- Today, the building sector in Kurdistan suffers from lack of electricity in daily life. Since the residential buildings are the first electric energy consumer during the past four years. Therefore, sustainable renovation for the residential building may be directly involved in reducing energy consumption. Hopefully, this study can contribute a bit to research in this area focusing on sustainable renovation and providing knowledge and experience for similar projects in the future.

4. Further perspectives of the research

The research, in its various aspects, opens up new horizons for future research on the sustainable renovation of existing buildings, considering that the research carried out in this field suffers from the knowledge gap in this field. The research allows for future research to deepen the dimensions of sustainability, so trends in future research comprise:

- Sustainable Renovation in the non-Residential Buildings in hot and dry climates.
- Energy Performance in the non-Residential Buildings in hot and dry climate.
- Improvement Indoor Environment in the Existing Buildings in hot and dry climate.
- Studying and Development the Dynamic Simulation Tools