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Improving Environmental Performance Indicators (KPIs) of Contemporary Iraqi Housing through Simulation-Based Reuse of Traditional Shenashil with Integrated Smart Technologies

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ABSTRACT

High solar radiation and high temperature that would be predisposing factors for discomfort have taken their toll on performance pressure added to the already mounting environmental performance pressure on modern housing in hot, arid regions. The Baghdadi Shenashil were one of the traditional architectural elements that responded well by providing shading and other means of environmental control; however, their use has been aesthetically lost in new residential designs. The recent literature has its force directed towards smart façade systems and belongs to the simulation wave based on the performance, which left inquisitiveness around studies exploring reusing traditional Shenashil through integrated smart techniques toward improving environmental performance indicators in contemporary Iraqi housing.

The study was based on an exploratory attempt to understand the effect of re-applying traditional Shenashil through simulation-based smart approaches towards environmental performance for modern Iraqi residential units. Digital tools for simulating the environment were used in measuring major indicators such as Solar Radiation Exposure, Direct Sun Hours, and Daylight performance under hot arid climatic conditions. Several facade scenarios have been created in the study that would reveal the potentiality of static and smart-adaptive Shenashil configurations, weighing their effectiveness against unshaded facades.

Results indicated that applying Shenashil with an adaptive shading strategy significantly reduced the excess amount of the sun and improved the total environmental performance. Results proved that maintaining the architectural identity, comfort thermal and environmental can be achieved by merging traditional elements with smart simulation-based techniques. Based on results received, this study is also going to provide a new sustainable design approach which can support climate responsive housing as well as enhance environmental quality in hot arid urban contexts.

1. Introduction

Climate change is one of the most important global challenges of recent decades. The increase in temperatures is one of its most significant impacts comprises hot arid regions [1]. In the cities of Iraq, contemporary residential environments face increasing exposure to high intensities of solar radiation and extreme thermal conditions during the summer months. High energy consumption for cooling, high levels of thermal stress, and low

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levels of environmental comfort result in such conditions. Therefore, improving the environmental performance of residential buildings has consequently emerged as a fundamental aspect in the design of climate-responsive urban areas.

Building façades play a vital role in determining overall energy consumption and thermal performance, as they are continuously exposed to outdoor environmental conditions [2,3]. Traditional Iraqi cities historically demonstrated better adaptation to local climatic conditions compared to many contemporary urban developments [4]. Baghdadi Shanashil regulates the solar exposure control of daylight penetration and enhancing thermal comfort by shading and ventilation strategies.

Recent studies extensively discussed the role of shading elements and urban geometry in the improvement of thermal comfort and environmental performance in hot climates. Several researchers numerically investigated the effect of Shading devices, which include urban canyons and facade configurations on outdoor-indoor thermal comfort tools and thermal comfort indices. These studies prove that shading elements reduce radiant temperature by a great extent and thus improving thermal comfort. It does not always have a major effect on the air temperature, however. Also, simulation-based approaches are applicable to successfully test environmental performance indicators for different design scenarios.

Even though research work on smart facades and shading strategies is increasingly mounting, there has hardly been any work that discusses the reuse of traditional elements through simulations in modern Iraqi houses. Previous works discuss shading at an urban scale or technologically advanced facade systems, but not much work tests the environmental performance of traditional Shenashil when reinterpreted with smart and adaptive techniques at the residential scale. More importantly, quantitative studies are missing that could be based on environmental performance KPIs such as solar radiation exposure, direct sun hours, and daylight availability, etc., and comparative simulation scenarios.

Based on the review of previous literature and studies addressing the climatic challenges of Iraqi cities [8–10], this study intends to examine the effect caused by the reuse of traditional Shenashil with integrated smart techniques toward improving the indicators for environmental performance in modern Iraqi houses. The study hereby assumes that the use of adaptive shading elements inspired by traditional Shenashil will be able to improve the environmental performance and achieve thermal comfort in hot arid climatic conditions. They are tested in this paper through digital environmental simulations that serve as a performance-based framework bridging typical architectural knowledge with contemporary, simulation-driven design strategies.2.

2. Methodology

This study used simulation as the methodology to test how much integration of smart adaptive Shenashil would affect environmental KPIs for a modern Iraqi villa in hot-arid climatic conditions. It used a controlled comparative approach whereby the same residential model was simulated two times so that the environmental effect of the smart Shenashil system could be isolated.

2.1 Case Study Description

A contemporary Iraqi villa was selected as the case study model. The villa represents a typical residential typology commonly used in Iraqi urban contexts in terms of spatial configuration, façade orientation, and building envelope characteristics. The model was developed digitally using parametric modeling tools to ensure accuracy and consistency during simulation processes.

Figure 1. Case study model of the contemporary Iraqi villa.

Table 1. Environmental performance indicators (KPIs) used in the simulation-based analysis.

Simulation Tool	Description	Unit	(KPI)	No.
Ladybug (Grasshopper)	Measures the average amount of solar energy incident on the building façade surfaces to evaluate the effectiveness of shading systems in reducing solar heat gain.	kWh/m²	Average solar radiation on façade	1
Ladybug (Grasshopper)	Indicates the maximum recorded solar radiation on façade surfaces during peak summer conditions.	kWh/m²	Peak solar radiation on façade	2
Ladybug (Grasshopper)	Calculates the duration of direct solar exposure on façade surfaces to assess shading efficiency before and after applying Shanashil.	hours/day	Direct sun hours	3
Honeybee (Grasshopper)	Evaluates the availability and distribution of natural daylight within interior spaces to assess visual comfort and lighting performance.	%	Daylight availability (main spaces)	4

2.2 Simulation Scenarios

Two simulation scenarios were defined using the same villa model and identical climatic conditions:

• Scenario A: Villa without Shenashil (baseline model)

• Scenario B: Villa with smart adaptive Shenashil integrated into the façade.

The only variable between the two scenarios was the presence of the smart adaptive Shenashil system, allowing a direct comparison of environmental performance before and after its integration.

a)

b)

Figure 2. Simulation scenarios: (a) villa without Shenashil, (b) villa with smart adaptive Shenashil.

2.3 Environmental Simulation Tools

Rhino–Grasshopper is the platform of choice for environmental performance simulations, with Ladybug tools plugged in. It allows an assessment of solar radiation, direct sun hours, and daylight availability based on climatic data used as input for simulations representative of the hot-arid region. Thus, quantitatively assessing facade performance under consistent environmental conditions is made possible by this simulation setup.

2.4 Environmental Performance Indicators (KPIs)

The evaluation focused on key environmental performance indicators relevant to residential comfort and sustainability in hot climates. These indicators included:

- Solar radiation on façade surfaces
- Direct sun hours
- Daylight availability within interior spaces

2.5 Simulation Procedure

The simulation runs were fed with the same climatic data and analysis parameters. For each KPI, environmental performance outputs were extracted and compared to see the difference made by the smart adaptive Shanashil system. Such a comparison would duly bring out objectively any environmental improvement that can be attributed to using smart shading elements inspired by traditional Shanashil in modern Iraqi residential design.

3. Results and discussion

This part shares the simulation results seen from checking the green performance marks (KPIs) of the modern Iraqi home under two front looks: without Shenashil (Scenario A) and with smart changing Shenashil (Scenario B). The results focus on sun light contact, straight sun hours, and day light supply giving a number comparison between the two setups.

3.1 Solar Radiation Analysis

The results of the simulation showed a clear reduction in solar radiation after the smart adaptive Shenashil system had been integrated. In Scenario A, the average solar radiation striking the villa facade was about 5.20 kWh/m²;

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reduced value in Scenario B was 3.30 kWh/m². The difference is close to about 36.5%.

Also, maximum sun power went down from 7.10 kWh/m² in the open case to 4.40 kWh/m² after using the smart Shenashil setup, giving a drop of close to 38.0%. These facts show how well fitting shades can control too much solar heat gain on the building cover.

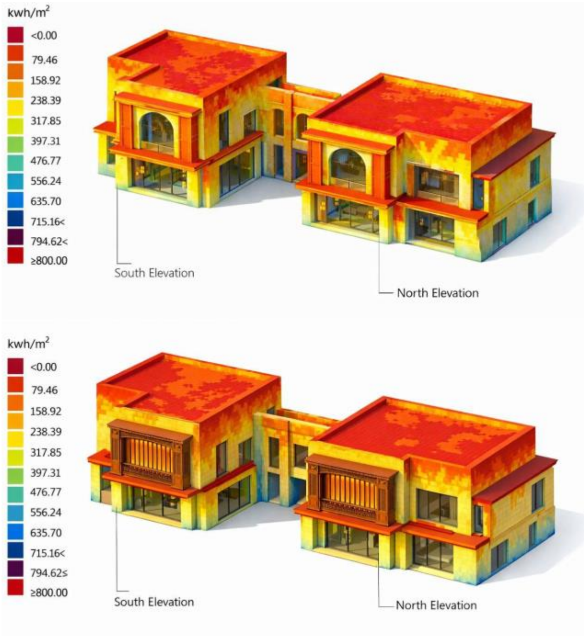

Figure 3. Solar radiation distribution for the two simulation scenarios.

3.2 Direct Sun Hours

More evidence of the increased performance that would be achieved through the introduction of a smart Shenashil system is found in the direct sun hours. Facade surfaces under Scenario A were subjected to exposure to direct sunlight for an average of 6.5 hours a day while under Scenario B shows reduced exposure to about 3.8 hours per day. This comes out as close to a 41.5% reduction in direct sun hours.

The significant decrease in prolonged solar exposure highlights the role of smart adaptive Shenashil in enhancing façade protection during peak solar periods, particularly in hot arid climatic conditions.

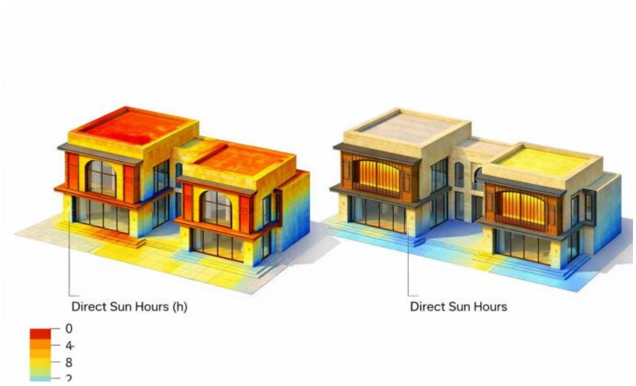

Figure 4. Comparison of direct sun hours with and without smart Shenashil.

3.3 Daylight Availability

In terms of daylight performance, integrating smart adaptive Shanashil kept balanced indoor daylight conditions with control over excessive solar penetration. Average daylight availability inside the main interior space rose from about 58% in Scenario A to reach 64% in Scenario B, which reflects a difference of approximately 10.3%.

This improvement indicates that the smart Shenashil system not only reduces solar heat gains but also enhances visual comfort by regulating daylight distribution and minimizing glare within interior spaces.

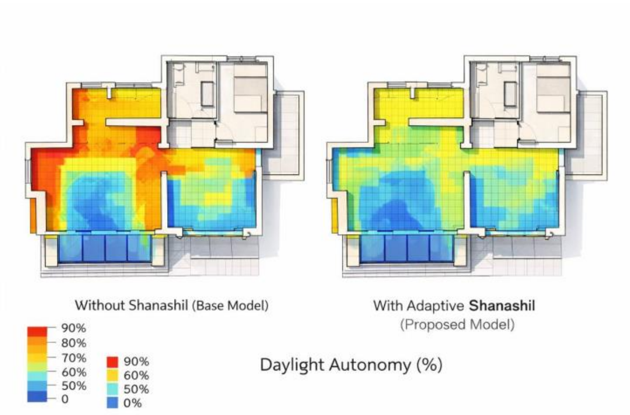

Figure 5. Daylight availability results for the simulated scenarios.

3.4 Comparative KPI Evaluation

A comparison of the environmental performance indicators proved the villa with smart adaptive Shenashil to be leading. This system successfully reduces solar radiation and direct sun hours while improving daylight availability inside the house. Smart Adaptive Shanashil can, therefore, be inferred as having great potential to offer an effective climate-responsive facade strategy for contemporary Iraqi residential buildings.

Table 2. Comparative KPI results for the two simulation scenarios.

Improvement (%)	Villa with Smart Shanashil	Villa without Shanashil	(KPI)
36.5 ↓	3.30	5.20	Average solar radiation on façade
38.0 ↓	4.40	7.10	Peak solar radiation on façade
41.5 ↓	3.8	6.5	Direct sun hours
10.3 ↑	64	58	Daylight availability (main spaces)

4. Conclusions

This paper tested the potency of inculcating smart adaptive Shenashil as a shading strategy responsive to climate for contemporary Iraqi residential architecture under hot arid climatic conditions. A simulation-based comparative approach in two scenarios evaluated the environmental performance of a contemporary Iraqi villa: one without Shenashil and the other with smart adaptive Shenashil.

The results of the simulation verified that the application of smart adaptive Shenashil can effectively improve key environmental KPIs. There were high reductions in solar radiation and direct sun hour on façade which directly relates to reducing thermal stress and cooling demand as well as maintaining balanced daylight availability inside spaces by setting the shading system thus making visual comfort without causing any type of glare or heat gain problems.

The results prove that smart adaptive Shenashil has the potential to fuse the eco-friendly benefits accrued from traditional shading components with the niceties brought about by present day intelligent design strategies. The adaptive setup, unlike the usual fixed sun control devices, gives a chance for dynamic regulation of solar ingress based on climatic situations which makes it more applicable in hot arid climates like those found in Iraqi cities.

The study has therefore highlighted just how much potential there is for bringing back traditional architectural elements through performance-based simulation and smart adaptation as a sustainable design strategy for contemporary housing. What it offers, essentially, is a practical framework that allows an interaction between cultural heritage and today's environmental performance requirements to take place. Future studies can widen the scope of this work by applying other, additional thermal comfort indices as well as energy consumption analysis or real-time adaptive control mechanisms aimed at even more optimization of the performance of the intelligent Shenashil system.

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