ACTA SCIENTIAE

ISSN: 2178-7727

The Effect of Climate Considerations in Generating House Façade in Erbil City

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Erbil-Kurdistan-2024

ABSTRACT

Many factors affect the architectural design process and the building's overall design including culture, location, economy, religion and others. climatic factors are one of the most influential which have a significant impact on building design. Purpose: Due to the rapid urbanization and housing projects, the role of the effect of the climatical factors has been neglected during the design process, which makes the householder intervene in the house façade. Therefore, this study aims to investigate the kind of interventions that have been done to reduce the negative impact of climate factors and then to evaluate the efficiency of each type the intervention. Subject This research is limited to the investment housing projects in Erbil City, and it was conducted in the Andaziyaran project which is located in the north part of the city. Design: This study conducted a pilot study and demonstrated a post-occupancy evaluation POE questionnaire to identify the climatical factors which lead to these innervations, then, the most influential factors were identified which were solar radiation, rainfall, and dust storms. analysing models were created for six houses using Rhinoceros which is 3D modelling software, one model before the change and the other after the change. Measure: To obtain data from the analyzing models, the Grasshopper plugin, ladybug tools, and butterfly were applied. Result: The result indicated that the façade interventions significantly reduced the negative impact of climate factors and contributed to a more climate-considerations facade. Therefore, climate considerations should receive more attention in the early stage of the design process.

Keywords- Climate Considerations, Façade Generation, House façade, POE.

INTRODUCTION

Since the political changes in Iraq and the Kurdistan Region in 2003, the region has experienced significant transformations, including an improved financial situation and an increasing population, leading to a surge in demand for housing units. To meet this demand, the Kurdistan Regional Government initiated the construction of housing units through investment, focusing on housing options for low-income individuals. However, despite these efforts, houses built for the low-income population have encountered numerous challenges, often leading to replacement shortly after construction.

The research will address essential questions such as the extent to which climate influences facade modifications in investment projects, and how architects and policymakers can design house facades that align with climate considerations, ensuring better adaptation to local weather conditions. By shedding light on these crucial aspects, this study aims to contribute valuable insights that will improve the design and construction practices of low-income housing units, ultimately enhancing the living conditions and wellbeing of the residents in Erbil.

An increasing amount of scientific data indicates that climate change is happening quickly and that human activity is the primary contributor. (Regmi et al., n.d.) as affecting urban planners, architects, and developers. Public knowledge is influencing buying habits and purchase decisions more than ever. Air pollution can cause damage to structures. Due to the consequences of climate change and air pollution on various places and activities, both societal and ecological, it has grown to be a significant issue (Santamouris, 2016) The research will primarily focus on the effects of climate change on building façades since building envelopes shield occupants from outside threats. This is because climate change has an impact on structures. Consider the

DOI: 10.2563/acta.sci.2024.1.1

ISSN: 2178-7727

location of the building, the energy problem, the cost, and any potential or current climate changes when selecting a building facade (Santamouris, 2016).

The main objective of this research is to learn how climate considerations generate house facades and examine methods and procedures for house facade sustainability.

LITERATURE REVIEW

Climate and Design

The impact of climate considerations on architectural design is a significant area of research, particularly in hot and dry climates. In such regions, the effective management of solar heat and the implementation of shading techniques are crucial for creating sustainability. This literature review aims to explore existing research that delves into the relationship between climate considerations and house facade design in hot and dry climates. The review specifically focuses on shading devices, openings, orientation, and roof shaping studies.

The location of windows and openings should be carefully planned, wind deflectors should be used, and wind towers should be redesigned, among other recommended design solutions. These include techniques for improving ventilation in the building's open spaces and corridors, paying attention to the orientation of the building's site, and optimizing the building's orientation relative to the desirable and undesirable winds(Agharabi & Fard, 2021).

The natural way to cool a building is to minimize the incident solar radiation, proper orientation of the building, adequate layout concerning the neighboring house, and by using proper shading devices to help control the incident solar radiation on a house effectively(Ajmera, 2020).

Generally, optimizing daylighting requires considering an extensive set of architectural design parameters, including building compactness, building orientation, configuration, depth of external shading devices, and WWR. Amongst these factors, building compactness, WWR, and building orientation in all cases were assumed as constant, and the configuration and depth of external shading devices were investigated(Mohsenzadeh et al., 2021).

The relationship between the spaces in the house, and the bioclimatic design should be perceived beyond just being a low-energy building design scheme or constructed with renewable materials to meet the sustainable development certification system(Samuel et al., 2019).

House Façade

A house's facade refers to one of the House envelopes, usually the front one. It plays a significant role in the overall layout of a house. It makes it possible for a building's personality and character to grow.

Even though facades are usually associated with older, more well-known buildings, any construction can have a distinctive appearance. Many listed buildings and constructions in conservation zones may have restrictions on facade alterations. This demonstrates their importance to the structure as well as the nearby populations and ecosystems(Kaluarachchi et al., 2005).

The significance of a house facade lies in its ability to highlight design elements. Too many buildings use traditional designs that meet structural standards but lack individuality. This damages the environments we live in since every building is the same. In addition to being aesthetically pleasing, a house facade connects the internal and external architecture of a structure. Thanks to breakthroughs in materials, concepts, and design, a house facade may unleash a multitude of alternatives for construction (Bodach et al., 2016).

DOI: 10.2563/acta.sci.2024.1.1

ISSN: 2178-7727

Climate responsive Design Methods for High-performance Facades High-performance

Excellent performance sustainable facades are external enclosures that consume the least amount of energy to provide a warm interior atmosphere that enhances occupant productivity and well-being (John Wiley & Sons, 2013). This indicates sustainable facades serve as energy-saving barriers in addition to serving as a building's exterior wall. Designing high-performance building enclosures requires considering climatespecific criteria (Regmi et al., n.d.). The strategies that perform best in temperate or hot, humid settings are not the same as those that perform well in hot, dry climates. The facade impacts a building's energy budget and occupant comfort more than any other system. A facade must, among other things, allow daylight into interior spaces, block unwanted solar heat gain, shield occupants from outside noise and temperature extremes, resist air and water penetration, resist wind loads, support its dead-load weight, and provide views to the outside to provide occupants with a comfortable environment(John Wiley & Sons, 2013). Some of the most fundamental methods for designing high-performance building facades are summarized below: • Orienting and developing geometry and facades of the house to respond to solar radiation.

- Controlling and improving thermal comfort by providing sun shading.
- Using the most natural light and external wall insulation to minimize the energy needed for artificial lighting, mechanical cooling, and heating.

THEORETICAL FRAMEWORK OF THE RESEARCH

Based on the type of research and the information presented, the study aims to investigate and analyze the residential architecture of Erbil city in Iraq, specifically focusing on the relationship between the region's climate and the design of low-income housing units. The research is set to explore the challenges faced by these low-income housing units, leading to their replacement or renovation by their owners shortly after construction.

The residential architecture under examination is part of a larger initiative by the Kurdistan Regional Government, which involves the construction of housing units through investment. These units are categorized into three income groups: low, medium, and high-income residents. However, the study will specifically concentrate on the housing units built for low-income individuals The objective of this research is to identify the various reasons behind the problems experienced by low-income housing units in Erbil. By conducting an in-depth analysis of the challenges faced by low-income housing units, the research aims to provide valuable insights that can inform future architectural design decisions and urban planning in Erbil. The findings could be instrumental in developing more climate-responsive, resilient, and sustainable lowincome housing solutions that better cater to the needs of the residents and mitigate the issues faced shortly after construction (Figure 1).

DOI: 10.2563/acta.sci.2024.1.1

ISSN: 2178-7727

Figure 1. The factor affected to renovation of houses in Erbil city.

The pilot study and questionnaire in the project (Andazyaran City), Andazyaran City in Erbil. It consists of 816 houses, 496 of which are two-floors and 320 are one-floor, we have taken only one-floor houses as an example, which has 320 two types of houses, corner houses, and normal houses in four directions, the result of questionnaire 30.5% of changes in house 24.4% due to climate considerations. This article focused on three factors affecting the architectural form of the Erbil house: solar radiation, Wind and dust, and Rainfall. (Figure 2).

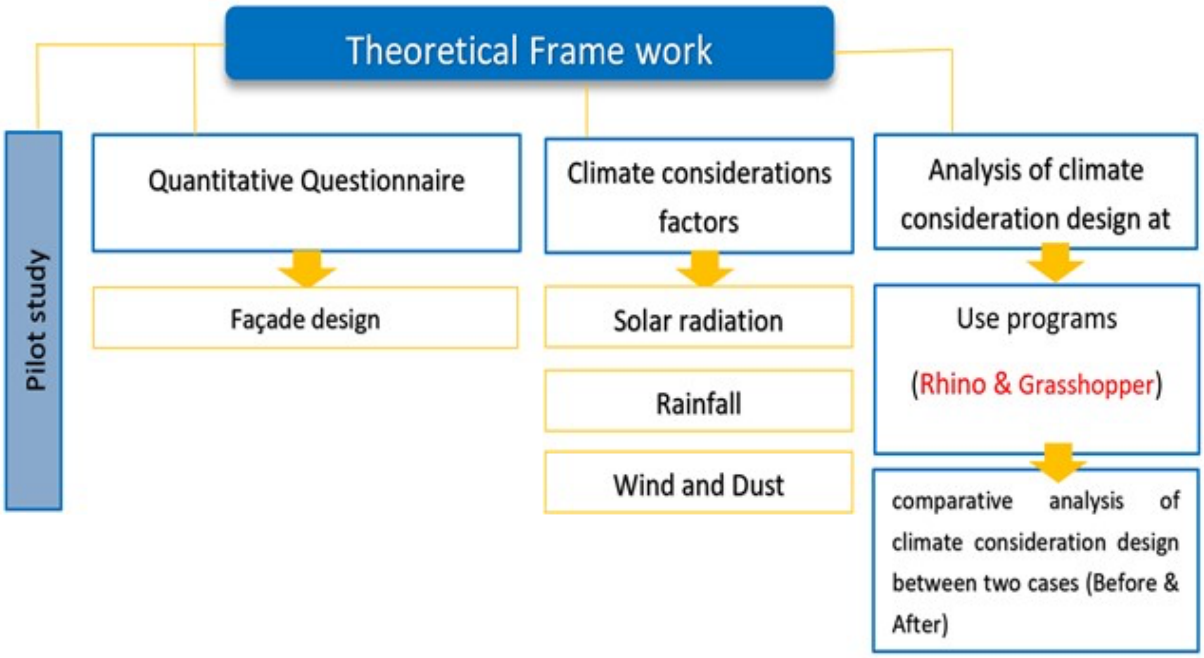


Figure 2. Theoretical Framework of the Research.

Effect of Climate Considerations on House Façade

The mass and shape of the building:

A well-massed building maximizes the free energy from the sun and wind and minimizes the amount of energy needed for cooling by utilizing the shape and scale of the structure. When designing a structure, massing it properly takes into account daylighting, passive heating, and cooling (Bassiouny, 2021). Buildings with compact forms and minimal east and west walls limit heat input in hot and dry areas. Increasing a building's depth would help it have more thermal capacity (Kamali, 2014).

Orientation of the building

The process of determining a building's direction is known as building orientation. It is essential for providing passive thermal comfort to buildings and aids in the utilization of solar energy by designers to lower cooling demands. Depending on the climate, the building's orientation needs to be changed. It might be positioned to keep the interior of the building comfortable and to prevent unwanted solar gain. For instance, long façade structures in hot and dry climate zones are ideally oriented north and south to make use of indirect light from the north without glare and to control direct solar heat gain from the south by shade. Furthermore, the building should be oriented towards the prevailing cool wind direction to provide maximum cross ventilation at night.

Building materials

The insulating property has an impact on the choice of construction materials. To reduce heat movement between the interior and outside rooms, good insulation is crucial (Atlan, 2016). The materials used in a building's construction have a significant impact on the amount of heat that enters the structure. As a designer,

DOI: 10.2563/acta.sci.2024.1.1

ISSN: 2178-7727

it is critical to recognize the importance of material selection and to employ locally sourced materials that reduce energy consumption and, hence, building costs.

Building openings

Large openings let in more sound; therefore, naturally ventilated buildings tend to be noisier even though they are better for it. Naturally ventilated structures should therefore be avoided in noisy locations and their location is important. When windows are positioned correctly, the amount of sunshine that enters the building will be maximized, provided that the building is aligned with the sun. Because of this, a structure should be designed with windows on sides that are distinct from one another to maximize natural ventilation (Khatami, 2009). In hot, dry conditions, windows should be smaller and the use of glass should be kept to a minimum to limit heat gain within the building (Majumdar, 1997). Furthermore, the most important passive design strategy for buildings is shading, particularly shading around openings. WWR, or the window-to-wall ratio, shouldn't be higher than 60%. Thus, a somewhat lower WWR can still result in effective daylighting(Afreen, 1997). Sun entering through windows is frequently a significant component of a building's heat gains. Effective shading can be achieved through a variety of techniques, including the use of devices that create shade next to buildings, plants, and unique kinds of glass. As they block solar radiation before it enters the interior space through the building exterior, external shading systems are thought to be the most effective(Chenvidyakarn, 2007).

The main Environmental factors Affecting the House Façade

The quality level of individual residential buildings is determined by their functional, architectural, constructive, hygienic, aesthetic, economic, and many other indicators. In this regard, the main goal of the design and construction of individual housing is to achieve only comfort. The greatest influence on a private house design is exerted by atmospheric conditions(Zakieva et al., 2021).

Climatic elements are air temperature and humidity, wind, solar radiation, and precipitation. Temperature, relative humidity, and wind make it possible to compile the climatic characteristics of the territory(Zakieva et al., 2021).

Solar radiation:

The sun's path is one of the primary factors to determine the house design(Ismail et al., 2021). solar radiation is today specifically oriented to the possibility of adapting shape, colour, dimensions, superficial finishing, type of material, etc (Frattolillo et al., 2020).

The effects of solar radiation on the wall surface temperature of a modern terrace house by determining the minimum and maximum temperatures recorded on the exposed surfaces and establishing the heating and cooling rates of different materials on the exposed surfaces(Ismail et al., 2021).

Heating-dominated climates benefit from increased solar radiation collection, passive heating, heat storage, improved insulation to reduce heating demand, and daylighting to reduce lighting demand(Regmi et al., n.d.). In colder climates, protection from the sun and direct solar radiation becomes more important. In mixed climates, combination strategies that strike a balance between sun exposure and daylight availability must be used(Nady Faragallah, 2022).

Wind and Dust:

The dust itself is made up of repairable dust with a size range of 1 to 10 microns, inhalable dust with a size range of 10 microns, and total dust, which comprises all airborne particles, the existence of airflow or the wind that carries the dust has a significant impact on how it spreads. Windows and vents on the windward side of the house may be smaller than those on the opposite side due to the zone of enhanced pressure created by the

ISSN: 2178-7727

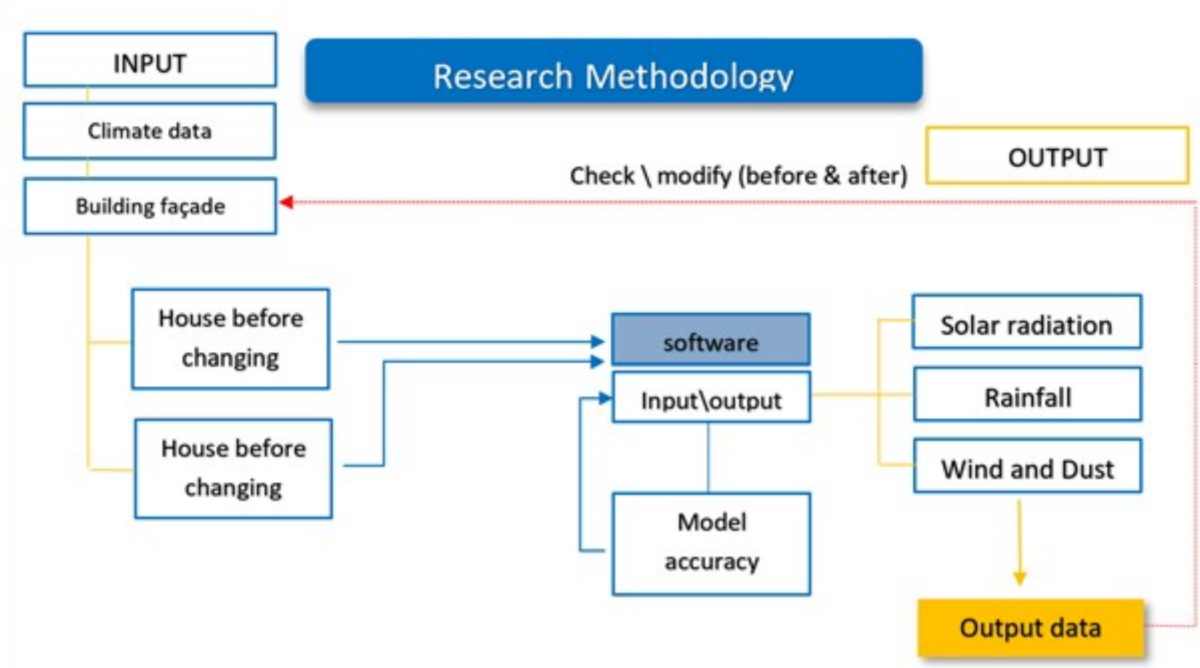
wind. When creating a master plan for a complicated estate development that includes a residential building and outbuildings, it is crucial to consider the wind regime(Zakieva et al., 2021).
According to a recent study, limiting the generation and distribution of dust, developing a dust-collecting system, or protecting occupants from exposure to risks by constructing a closed space system with clean, fresh air are all examples of ways to control the spread of dust.

Rainfall:
When wind and rain combine, it's practically referred to as "wind-driven rain" (WDR), which happens when raindrops are forced horizontally by the wind, causing the rain to fall obliquely. WDR-induced moisture intrusion frequently has a detrimental impact on the hygrothermal performance and longevity of building facades, resulting in surface material deterioration, frost damage, salt efflorescence, structural cracking, and inside damage (Erkal et al., 2012).

Rain with a horizontal velocity component given by the wind is called wind-driven rain (WDR) (Erkal et al., 2012). which is one of the main factors being responsible for surface erosion. Erosion here means the detachment of material from a masonry building façade due to the physical impingement of WDR.

RESEARCH METHODOLOGY

To study the effect of CCs on hose interface generation, the present study adopted facade observation and experiments. This study is limited to the investment housing project in Erbil city. The site observation was to collect the actual site information related to changes and interventions in the houses. The collected data were about the type, location and size of the facade interventions. A post-occupancy evaluation questionnaire was demonstrated with the householders to identify the reason for intervention. Current research adopted six houses as a case study, and then Rhinoceros software, which is a 3D modelling software was adopted to create the models of each type of the selected houses, two models were created one before and one after the changes. To evaluate the efficiency of the interventions, several software programs were utilized to analyse the most types of intervention and to obtain numerical data and analyse the climatic factors, the software programs were Grasshopper, Eve Rain, ladybug and Butterfly. The climatical and weather data were obtained from EPW files (Energy Plus Weather) which are available at the Erbil Airport data center (Figure 3).



(Figure 3) illustrates the research methodology and tools utilised to achieve the study's objective.

DOI: 10.2563/acta.sci.2024.1.1

ISSN: 2178-7727

THE CASE STUDY: ERBIL CITY

This paper first examines the climate of Erbil and the principles of designing investment residential house projects for low cost and then analyzes the architectural features of housing in this city in light of climatic conditions.

Selecting a case study

In this section of the study, they conducted a thorough examination of two types of houses: one before changing the facade and the other after changing the facade. By analyzing these two scenarios, they have extracted and documented the properties and characteristics of each house. The objective is to compare the houses' features before and after the facade alterations to identify any differences or improvements resulting from the changes.

Andazyaran City Project one of the projects, is located in the east of Erbil, 10 km from the city center. It consists of 816 houses, 496 of which are two-floors and 320 are one-floor, we have taken only one-floor houses as an example, which has 320 two types of houses, corner houses, and normal houses in four directions (Figure 4).

Figure 4. Case studies location

RESULT AND DISCUSSION 6.1. Analysis and Results

This section presents thirty-six sample analyses of the performance of solar radiation, rainfall, and wind with dust around the shapes of the houses before and after the renovation, and their possible existence in reality (Figure 5).

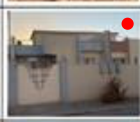
case	House befor changing	House after changing	floor	type	direction	case	House befor changing	House after changing	floor	type	direction
1			1	cornner	NORTH-EAST	4			1	cornner	SOUTH-WEST
2			1	cornner	NORTH-WEST	5			1	normal	EAST
3			1	cornner	SOUTH -EAST	6			1	normal	WEST

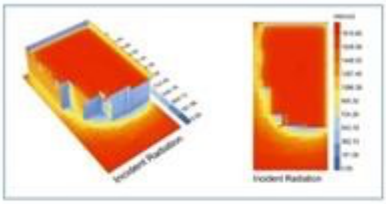
Figure 5. List of case studies.

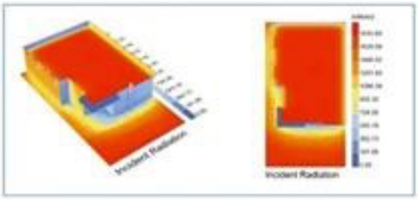
DOI: 10.2563/acta.sci.2024.1.1

ISSN: 2178-7727

Solar radiation analysis

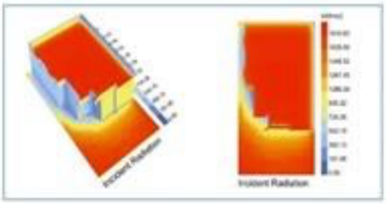
Case 1: after analysis of the effect of solar radiation for both conditions, The result shows that the impact of solar radiation on W&W is **(362 kWh/m2-543 kWh/m2)**, and becomes **(161 kWh/m2-362.19 kWh/m2)** in the second condition.

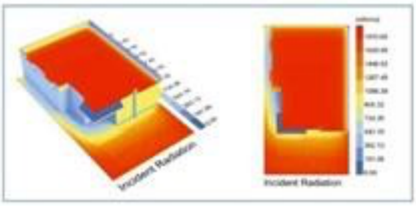




Before changing **After changing**

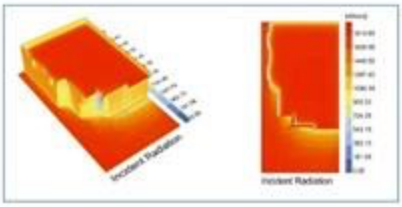
Case 2: after analysis of the effect of solar radiation for both conditions, The result shows that the impact of solar radiation on W&W is **(543 kWh/m2-724 kWh/m2)**, and becomes **(362kWh/m2-543kWh/m2)** in the second condition.

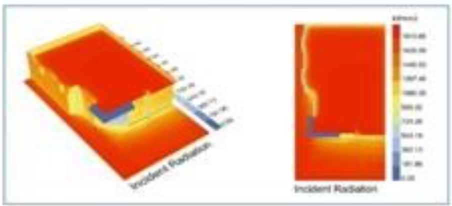




Before changing **After changing**

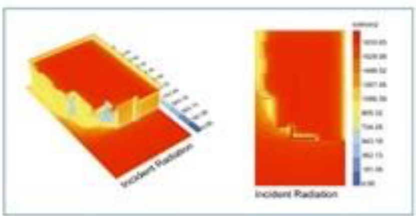
Case 3: after analysis of the effect of solar radiation for both conditions, the result shows that the impact of solar radiation on W&W is **(905 kWh/m2-1086 kWh/m2)**, and becomes **(362 kWh/m2-543 kWh/m2)** in the second condition.

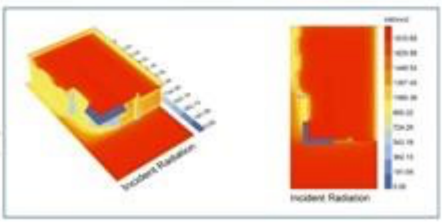




Before changing **After changing**

Case 4: after analysis of the effect of solar radiation for both conditions, the result shows that the impact of solar radiation on W&W is **(543 kWh/m2-905 kWh/m2)**, and becomes **(362 kWh/m2-543 kWh/m2)** in the second condition.



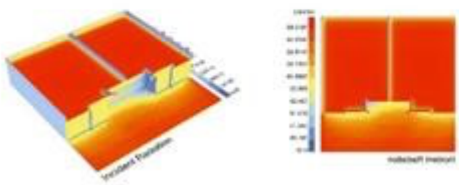


Before changing **After changing**

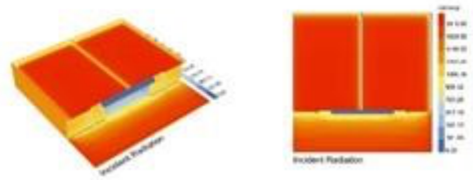
Case 5: after analysis of the effect of solar radiation for both conditions, the result shows that the impact of solar radiation on W&W is **(543 kWh/m2-724 kWh/m2)**, and becomes **(362 kWh/m2-543kWh/m2)** in the second condition.

DOI: 10.2563/acta.sci.2024.1.1

ISSN: 2178-7727

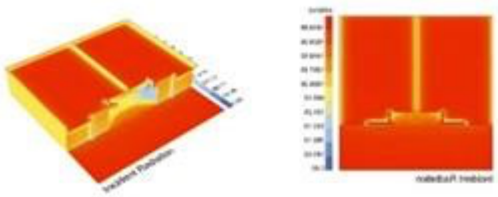


Before changing



After changing

Case 6: after analysis of the effect of solar radiation for both conditions, the result shows that the impact of solar radiation on W&W is **(724 kWh/m2-1086 kWh/m2)**, and becomes **(362kWh/m2-543 kWh/m2)** in the second condition.



Before changing

After changing

The result of the analysis of solar radiation by a plugin in the Rhino - grasshopper program was found that changing the shape of the house reduced the impact of solar radiation on the walls and windows in the house of the changed area, depending on the direction of the houses, the reduction is more effective in the south and west directions than in the east and north directions (Figure 6).

case	effect solar radiation House befor changing	effect solar radiation House after changing	floor	type	direction
1	(362 -543 kWh/m2)	(161-362 kWh/m2)	1	cornner	NORTH-EAST
2	(543-724 kWh/m2)	(362-543kWh/m2)	1	cornner	NORTH-WEST
3	(905-1086 kWh/m2)	(362 -543 kWh/m2)	1	cornner	SOUTH -EAST
4	(543 -905 kWh/m2)	(362 -543 kWh/m2)	1	cornner	SOUTH-WEST
5	(543-724kWh/m2)	(362-543kWh/m2)	1	normal	EAST
6	(724-1086 kWh/m2)	(362-543 kWh/m2)	1	normal	WEST

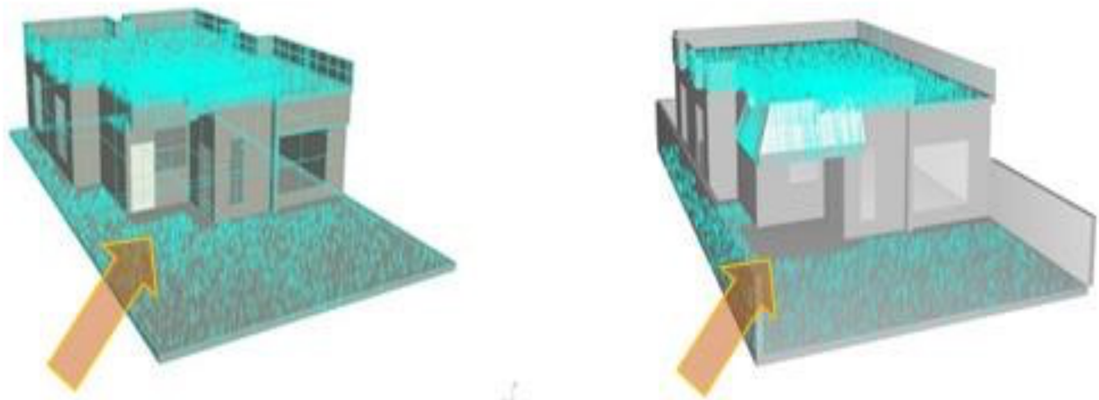
(Figure 6). Comparative List of analysis solar radiation for the house.

Rainfall analysis

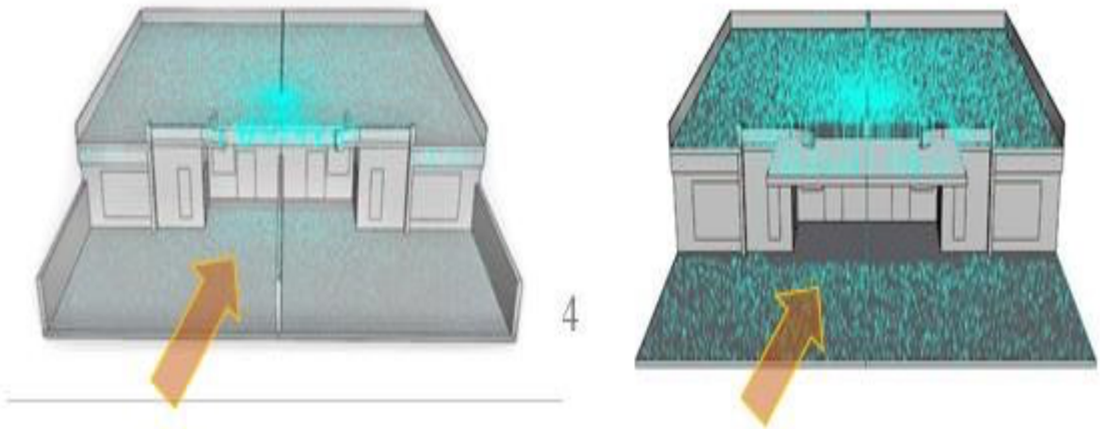
Case 1: After analysis of the rainfall for both times (before and after) changing by Both Rhinoceros, Grasshopper plugin and Ladybug which is visual programming.

DOI: 10.2563/acta.sci.2024.1.1

ISSN: 2178-7727



Case 2: After analysis of the rainfall for both times (before and after) changing by Both Rhinoceros, Grasshopper plugin, and Ladybug which is visual programming.



The result of the analysis of the rainfall, (Case 1) the shading above the window and the entrance of the house protect the 3m2 floor area and 7.5m2 wall, but in the second analysis mass after changing the shading above the window and the entrance of the house protect 8.75m2 floor area and 15m2 wall. (Case 2) in the first analysis the shading above the window and the entrance of the house protects 2.2 m2 floor area and 7.5 m2 wall, but in the second analysis mass after changing the shading above the window and the entrance of the house protects the 8.4 m2 floor area and 15m2 wall.

Wind and Dust

Case 1: In the first mass before changing the wind speed on the house shape it is between **(7.98 m/s-9.40 m\s)** (Figure7), but in the second mass after changing the wind speed on the house shape it is between **(2.30 m/s-7.27 m\s).**

Case 2: In the first mass before changing the wind speed on the house shape it is between **(6.56 m/s-9.40 m\s)** (Figure7), but in the second mass after changing the wind speed on the house shape it is between **(4.30 m/s-9.40 m\s).**

DOI: 10.2563/acta.sci.2024.1.1

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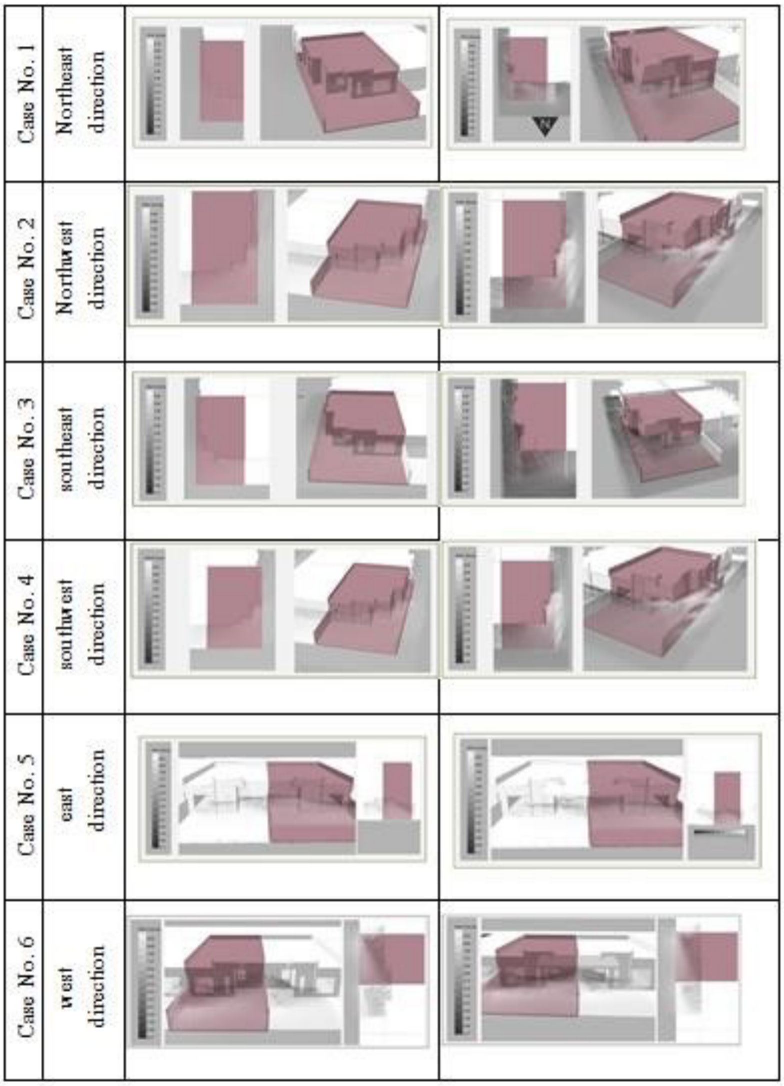
Case 3: In the first mass before changing the wind speed on the house shape it is between **(4.43 m/s-9.40 m\s)** (Figure7), but in the second mass after changing the wind speed on the house shape it is between **(1.59 m/s-3.72 m\s).**

Case 4: In the first mass before changing the wind speed on the house shape it is between **(6.56 m/s-9.40 m\s)** (Figure7), but in the second mass after changing the wind speed on the house shape it is between **(3.72 m/s-9.40 m\s).**

Case 5: In the first mass before changing the wind speed on the house shape it is between **(6.56 m/s-9.40 m\s)** (Figure7), but in the second mass after changing the wind speed on the house shape it is between **(1.59 m/s-4.43 m\s).**

Case 6: In the first mass before changing the wind speed on the house shape it is between **(1.59 m/s-6.56 m\s)** (Figure7), but in the second mass after changing the wind speed on the house shape it is between **(1.59 m/s-4.43 m\s).**



(Figure 7). Comparative List of analysis wind for the house.

The velocity contours of all the cases explain how the wind moves around a building, oriented differently. Part of the wind streamlines hit the house at the centre of its windward surface to have low velocity. In all cases before changing the form of houses, a squared corner element faces the wind, allowing its streamlines to escape

ISSN: 2178-7727

the surface with an increasing velocity, but not as high as the velocity produced by the normal element in the previous case (represented in a white colour gradient). But in all cases after changing, this leaves the changing area and the leeward surface surrounded by motionless air (represented in black). The procedure is demonstrated. It can be observed that this case results in the greatest dust accumulation. As in the other cases, dust particles tend to move with the wind streamlines until they escape to the spaces. Dust particles manage to approach side two due to the existence of the corner house element instead of the normal one. Existing in high concentrations in those areas, dust particles will accumulate on the building sides' surfaces, especially the recessed portions(Figure 8).

case	wind speed House befor changing	wind speed House after changing	floor	type	direction
1	(7.98 m/s-9.40 m\s)	(2.30 m/s-7.27 m\s)	1	cornner	NORTH-EAST
2	(6.56 m/s-9.40 m\s)	(4.30 m/s-9.40 m\s)	1	cornner	NORTH-WEST
3	(4.43 m/s-9.40 m\s)	(1.59 m/s-3.72 m\s)	1	cornner	SOUTH -EAST
4	(6.56 m/s-9.40 m\s)	(3.72 m/s-9.40 m\s)	1	cornner	SOUTH-WEST
5	(6.56 m/s-9.40 m\s)	(1.59 m/s-4.43 m\s)	1	normal	EAST
6	(1.59 m/s-6.56 m\s)	(1.59 m/s-4.43 m\s)	1	normal	WEST

(Figure 8). Comparative List of analysis wind for the house.

CONCLUSIONS

In hot dry climate zones, climate factors need to be carefully studied during the design process otherwise there will be an intervention and change in the building component after it has been implemented. Therefore, the main of this study was to identify the most utilized interventions and to investigate and evaluate the effect of them. This study conducted a post-occupancy evolution to identify the most influential climate factors from a householder's viewpoint. This research analyzed and simulated several case studies following different house typologies. To determine the level of efficiency of each intervention in terms of Solar radiation, rainfall and dust, this simulated each case using a 3D software program, then several software

plugins were utilized to analyze and obtain numerical data on climate factors. The study revealed that the alterations in the houses were directly influenced by climate-related factors. Based on the POE questionnaire, this research identified three main climate factors that played a crucial role in shaping the decisions of homeowners as follows:

- Solar Radiation: The intensity and direction of sunlight in Erbil influenced homeowners' choices regarding features such as window orientation and shading devices. The number of walls and floor surface exposures decreased after the intervention, this indicates a successful intervention which optimizes energy efficiency and indoor comfort.
- Rainfall: The amount and frequency of rainfall in the region affected the type of intervention too. After the intervention, the amount of rainwater decreased in the window and patio area.
- Dust Storms: The susceptibility of Erbil to dust storms prompted homeowners to take measures to minimize dust infiltration and potential damage to their properties.

The results of this study indicate that the negative climate factors are underestimated by the designers during the design process. This article shows that utilising a building simulation model during the design process can aid and predict the designers to have a better result and improve building performance. In conclusion, the research successfully investigated the façade interventions in the investment projects in Erbil due to climate considerations.

DOI: 10.2563/acta.sci.2024.1.1

ISSN: 2178-7727

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