IMPROVING INDOOR COMFORT THROUGH FAÇADE IMPROVEMENT FOR RESIDENTS IN BASRA, IRAQ

By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

August 2023

FRSB 2023 16

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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August 2023

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Indoor thermal comfort is key to residents' comfort in the dry and hot regions. In Iraq, the climate has changed due to several factors such as wars and economic crises. This led to extremely high temperatures. This phenomenon has resulted in significant energy use and discomfort for the residents 'of Basra. In a hot, arid country like Iraq, the residents' thermal comfort is still the main problem, especially during summertime resulting a high energy usage. Therefore, this research aimed to determine the optimum façade improvement that Basra people can use to attain indoor thermal comfort. This study employed an experimental design based on Fanger's model to analyse variables that may impact indoor comfort and determine a balance between air quality and indoor comfort. Vi suit and 3D blender software were used in the simulation to examine the impact of thermal on the residents' façade. The experiment result indicated that double-glazing typologies and double-skin façade materials could increase inhabitants' indoor thermal comfort by 50 % and enhance air quality by 40%. Using these façade materials and typology could potentially improve indoor comfort for the residents. This study is limited to understanding the effect of double glazing and double skin materials on residents in arid and hot climates particularly in the Basra City, Iraq. The development of façade improvement could formulate future guidelines and policies for façade treatment in hot and arid countries.

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Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

MENINGKATKAN KESELESAAN DALAMAN MELALUI PENAMBAHBAIKAN FASAD BANGUNAN KEDIAMAN DI BASRA, IRAQ

Oleh

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Keselesaan terma dalaman adalah kunci kepada keselesaan penduduk di kawasan kering dan panas. Iklim di Iraq telah berubah disebabkan oleh beberapa faktor seperti peperangan dan krisis ekonomi sehingga menjurus kepada suhu yang sangat tinggi. Fenomena ini telah menyebabkan peningkatan penggunaan tenaga yang ketara dan ketidakselesaan kepada penduduk Basra. Di negara yang panas dan gersang seperti Iraq, keselesaan haba penduduk masih menjadi masalah utama, terutamanya semasa musim panas hingga mengakibatkan penggunaan tenaga yang tinggi. Oleh itu, penyelidikan ini bertujuan untuk menentukan penambahbaikan muka bangunan yang optimum yang boleh digunakan oleh penduduk Bandar Basra untuk mencapai haba dalaman yang selesa. Kajian ini menggunakan reka bentuk eksperimen berdasarkan model Fanger untuk menganalisis pembolehubah yang akan memberi kesan kepada keselesaan dalaman dan untuk menentukan keseimbangan antara kualiti udara dan keselesaan dalaman. Perisian VI-suite dan pengadun 3D digunakan dalam simulasi untuk mengkaji kesan haba kepada muka bangunan yang dihuni penduduk. Hasil kajian menunjukkan bahawa tipologi kaca dua lapis dan bahan muka bangunan dua kulit boleh meningkatkan keselesaan haba dalaman penghuni sebanyak 50% dan meningkatkan kualiti udara sebanyak 40%. Penggunaan bahan muka bangunan dan tipologi ini dapat meningkatkan keselesaan dalaman penduduk. Kajian ini terhad kepada usaha memahami kesan kaca dua lapis dan bahan dua kulit untuk bangunan kepada penduduk di kawasan beriklim gersang dan panas terutamanya di bandar Basra, Iraq. Perkembangan penambahbaikan muka bangunan dapat merumuskan garis panduan dan dasar masa depan untuk penambahbaikan muka bangunan di negara-negara yang gersang dan panas.

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ACKNOWLEDGEMENTS

I am grateful to my wife Noor and my family for their ever-ending love and support during my Master's journey. I am grateful to my supervisor Ts Dr Maszura Abdul Ghafar for her time and support for me to finish my Master. I also would like to say thank you to Associate Professor Dr. Mohd Fakri Zaki Ja'afar for his contributions to this study.

I would also like to thank the editors and reviewers for their constructive comments.

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LIST OF ABBREVIATIONS

PMV	Predicted Mean vote
PPD	Predicted Percentage of Dissatisfied
IDQ	indoor air quality
°C	temperature
WWR	Window to wall ratio
h	Hour
CO_2	Carbon dioxide

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CHAPTER 1

INTRODUCTION

In this chapter, an overview of the background of the study from past studies is presented. This is followed by the study's problem statement, research hypothesis, research questions, and research objectives. Additionally provided are the study's limitations and research framework. Finally, the organisation of the thesis outline is introduced.

1.1 Background

There is an urgent need to satisfy residential demands for saving energy and thermal comfort. This has become one of the major global aims the world has today. Many countries have been working on providing sufficient energy and comfortable housing for their population (Fattah et al., 2018). In arid and hot countries like Iraq, the demands for comfortable and energy-efficient housing have increased rapidly due to climate change. Unfortunately, in the Middle East, people suffer from a shortage of housing and/or poor residential conditions (Fadhil & Burhan, 2021). This has resulted in instability and problems due to the high temperature and war crisis (Ramezani et al., 2021).

The shortage in housing in Iraq represents 25 per cent of the total residences, which is estimated to be around 1 million dwellings. Iraq's housing is dealing with a weak building construction and infrastructure services sector, inefficient housing production and finance system, lack of available materials, and spreading of slums in many parts of the country (Haraty et al., 2019). Iraqi government have taken several measures to reverse the situation such as the introduction of a National Housing Policy in 2010 which defines the current problems and suggests framework solutions (Ministry of Construction and Housing, 2010). The most important measure in the National Housing Policy is providing energy-saving features and thermal indoor comfort for Iraq's residential housing (Ministry of Construction and Housing, 2010). This is because of the summer's high temperatures and the inadequate availability of electricity.

In general, the Iraqi population prioritises having a thermally comfortable indoor condition as most of the time the residents stay inside the building. However, the main challenge with comfort and energy conservation in houses is the lack of energy in southern Iraq, particularly in Basra (Ramezani et al., 2021). Based on the World Bank (2018) (refer to Figure 1.1), the city of Basra in the west and south has the most sun radiation during the entire year, particularly during the summer months of May through September. Haraty et al. (2019) said that the insufficient supply of electricity is the reason for the excessive summer temperatures. Salman et al. (2017) and Istepanian (2020) discovered that when summer temperatures reach above 50 °C, the electricity demand increases as

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well as the discomfort among the residents. According to Fadhil and Burhan (2021), the situation is comparable to the war and economic crisis faced by the Iraqis in the 1980s. Hence, Basra was chosen because it offered a typical case of an extremely hot climate zone in Iraq.

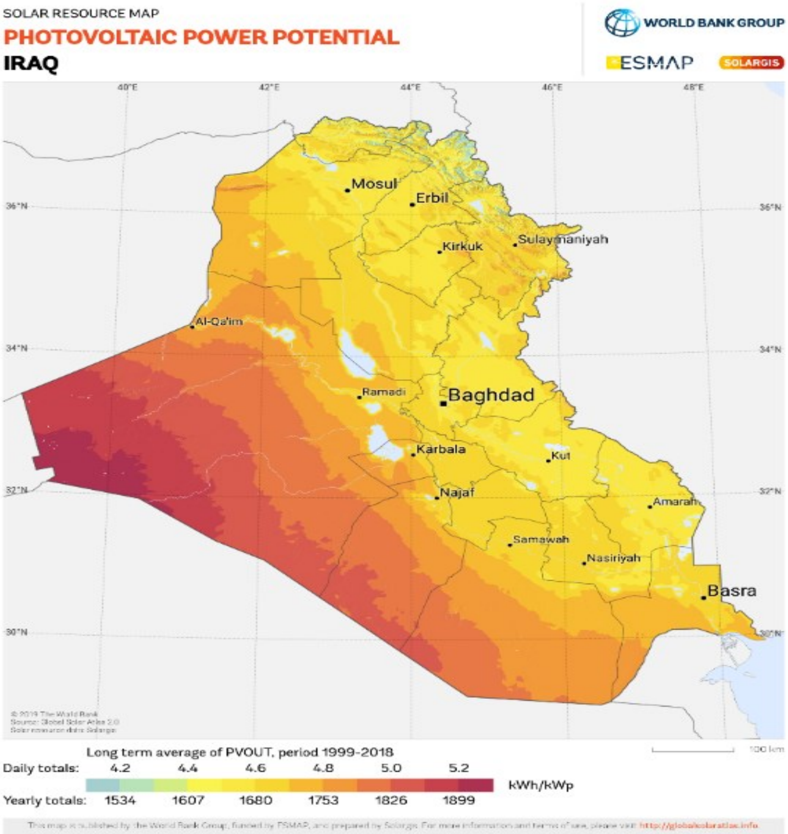

Figure 1.1: Solar Radiation for a Whole Year in Iraq and Basra
(Source: World Bank, 2018)

According to a World Bank assessment from 2018, Iraq’s housing shortage, particularly in Baghdad and Basra, accounts for 25 per cent of all residential stock. The shortage has been a result of inefficient building and infrastructure services, including housing production and financial system, as well as weak construction, lack of available materials, and the spread of slums around many parts of the country (Haraty et al., 2019). This research agrees with Mohammed and Jasim (2017) that in order to solve energy consumption and the comfort issues, low-cost solutions are very necessary. Additionally, this study also agrees with Al-Hafith et al. (2018) and Kamal et al. (2019) in that current residential designs and deteriorating energy supplies are significant barriers to achieving the best possible indoor comfort for Iraq's hot and dry climate. This study believed that comfort for Iraq's residential buildings is urgently needed, especially during the summer.

1.2 Problem Statement

Indoor thermal comfort for residences in Iraq is the key challenge for Iraq’s housing as Iraq is located in an extremely hot climate zone. In 2010, Iraq's Ministry of Construction and Housing set the National Housing Policy to guarantee that Iraq’s residents are provided with indoor thermal comfort. However, Rawaf et al. (2014) highlighted the lack of economic capacity, continuity, and independence to handle the execution of this policy. Accordingly, Al-Shaibani and Popov (2019) suggested studying and evaluating Iraq's housing typology using the existing materials and policies to improve the poor housing policies.

Studies have revealed a significant connection between health, long-term and short-term illnesses, and thermal comfort (Bueno et al., 2021). This study supported Hussein and Uzunoğlu (2020), which prioritises achieving indoor thermal comfort for the summer, as they remain inside the building most of the day during the season. Thus, thermal comfort and energy-saving solutions for residents could be provided by establishing housing policies based on the economic conditions, demographic characteristics, and normative settings of Iraq, as noted by Alkindi (2016). With this in mind, this research anticipated a need to advocate for effective façade features in residential housing through programmes and sustainable policies to provide optimal thermal comfort living environment and air quality for residents.

Basra, the second-largest regional state of Iraq, is located in the far south and has been suffering from uncomfortable thermal conditions for many years (Jasim et al., 2018). According to scholars (e.g., Kamal et al., 2019; Homod et al., 2021; Jasim et al., 2018), Basra has the highest temperature and solar radiation during summer compared to other regional states in Iraq based on its annual temperature collected from Iraqi meteorological organisation and seismology (IMOS), as shown on Table 1.1. In addition, the houses in Basra topologically vary from historical structures. For example, they use dried bricks and modern construction materials such as flat slabs and precast foundations for their *Shanasheel* houses (Hussien et al. 2021). *Shanasheel* houses are old houses in Basra built with brick and wood (Hussien et al. 2021). This information convinced academics (e.g., Salih, 2019; Homod et al., 2021; Al-hafith et al., 2017) that the materials, façade form, and housing topology in Iraq are the important factors in reducing the discomfort caused by heat.

Table 1.1: Description of the Annual Temperature Collected from IMOS Iraq Meteorological Organisation and Seismology for Iraq States

Station No.	Station name	Elev. (m)	period	Annual Avg. Max Temp	Annual Avg. Min Temp
1	Sinjar	583	1965-2021	35	4
2	Tallafer	373	1965-2021	40	5
3	Mosul	223	1965-2021	46	8
4	Kirkuk	331	1965-2021	44	5
5	Khankhin	202	1965-2021	44	4
6	Bagdad	32	1965-2021	47	10
7	Karbala	29	1965-2021	44	8
8	AL-hai	17	1965-2021	43	7
9	Najef	53	1965-2021	44	9
10	Diwaniyah	20	1965-2021	44	10
11	AL-Samawa	12	1965-2021	47	15
12	Nasryah	5	1965-2021	49	14
13	Amarah	9	1965-2021	50	14
14	Basra	2	1965-2021	52	15
15	Rutba	631	1965-2021	44	9

The building envelope's façade controls the building's thermal comfort and has an impact on the sustainability of the house's construction (Kalús et al., 2021). Nonetheless, a large number of Iraqi building façades do not adhere to standards, including energy and thermal comfort as well as social, economic, and environmental considerations (Krajčík & Šikula, 2020). According to Mirshojaeian Hosseini et al. (2020), conventional façade systems could benefit from improved façade performances and functionalities. This is aligned with Pastore and Andersen (2022), who have highlighted two elements that have an impact on the functionality of façades, namely: 1) technology; and 2) design.

Hosseini et al. (2019) emphasised that the façade design was misgauged due to the poor standard performance required by residents. The poor standard performance mentioned by Hosseini et al. (2019) is interpreted as lacking building components and poor thermal characteristics (Pujadas-Gispert et al., 2020) that increase thermal discomfort and energy consumption. Several studies on façade components adaptation for short- and long-term weather fluctuations have been initiated to guarantee that the best technical façade satisfies the thermal needs of the residents (Hu et al., 2017; Zhang et al., 2016).

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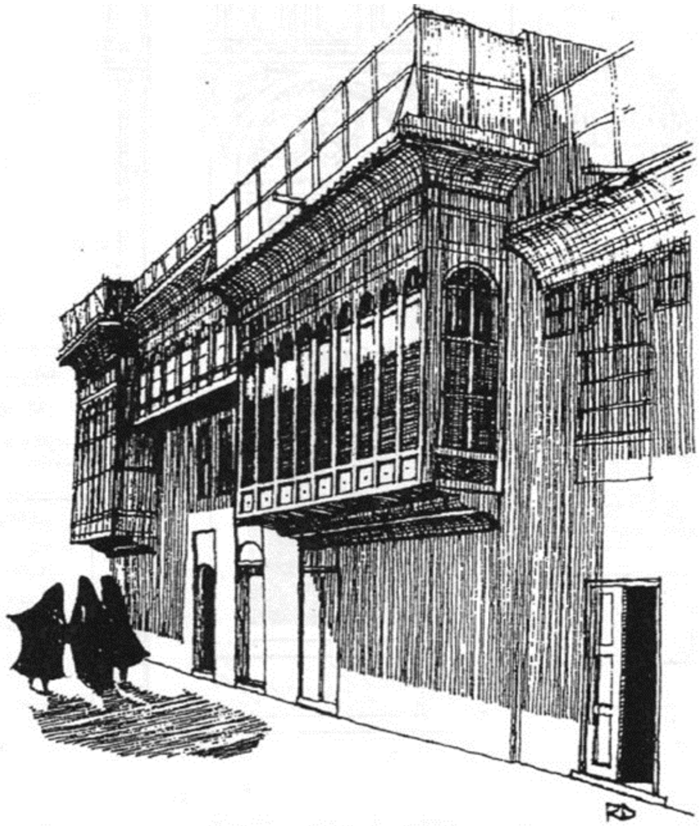

شكل (١)
بروز كتلة الشناشيل في فضاء الزقاق وتغطيتها بالاقنعة والمزخرفات(٨)

Figure 1.2: ***Shanasheel*** **House Arrangement**
(Source: Historical of Basra. 2021)

Investigations need to be carried out in a moderately hot temperature, aligned with Iraq's hot and dry climate conditions. This is because, in hot and arid climates, residences may have worse thermal comfort and a weak energy supply. Selective material usage, such as dry bricks and façade shapes (Hasan, 2018; Hassan et al., 2019; Homod et al., 2021), poor material qualities (Al-Qaraghuli & Alawsey, 2016; Rashid & Voelker, 2019; Abaas, 2020), and inappropriate building materials (Al-Yasiri et al., 2019) may cause surface temperature increase as a result of solar radiation. Voelker and Rashid (2019) recommended a layered double skin façade to control thermal comfort performance. It is clear from the literature above that façade component technology and housing policy could enhance Iraq's indoor thermal comfort environment. As part of the housing policy needs, the policy might be improved by focusing on the economic conditions for thermal comfort while taking into account the topology of the façade and the climatic conditions of the residents.

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Dissatisfaction is primarily caused by the poor façade designs and inappropriate façade elements. Hence, to achieve thermal comfort, it is necessary to develop a strategy and establish a set of criteria for choosing suitable façade technologies that satisfy both the needs of the occupants and the climate's problems. Therefore, the current study examined the barriers to improving thermal comfort in residential buildings in Iraq and made recommendations for the most effective façade improvement typologies for residential structures in Basra.

1.3 Research Questions

The main research question of this study was: what are the best façade improvement techniques to improve indoor comfort for Basra's Residence?

The other research questions were as follows:

1. What are the current challenges faced by Basra's residents in terms of residential comfort?
2. What are the current façade improvement techniques to be used for the hot climate of Basra?
3. What are the best façade improvement techniques to improve indoor comfort for Basra's Residence?

1.4 Research Objectives

This study had the following objectives:

1. To identify the current challenges faced by Basra's residents in terms of residential comfort.
2. To document the current façade Improvement to be used for the hot climate of Basra.
3. To propose the best façade improvements to improve indoor comfort for Basra's residence.

Table 1.2 presents the flow process used to address the study's research objectives, research questions, research method, and problem statement.

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Table 1.2: The flow between Research Questions, Research Objectives, Methods, and Problem Statement

Title : Improving Indoor Comfort through Facade Improvement for Basra's Residence				
Main RQ: What are the best Facade Improvements to Improve Indoor Comfort for Basra's Residence?				
Problem: there is a need to advocate for effective façade features in residential housing through programs and sustainable policies in order to provide optimal thermal comfort living environment for residents				
RQ constructs RQ Construct	Description of sub-RQ	Strategy of Inquiry	Expected Output	Expected Knowledge Contribution
Who Basra's residents (Basra City)	**RO 1:** To identify and understand the current challenges faced by Basra's residents in terms of residential comfort. **Sub RQ 1:** What are the current challenges facing Basra resident in terms of resident comfort?	LR	• Challenges and barriers to Basra residents' comfort • Basra residents' preferences toward comfort.	• Documentation of policy etc.
What façade Improvement techniques	**RO 2:** To identify the current façade Improvement techniques to be used for hot climate of Basra. **Sub RQ 2:** What are the current façade Improvements techniques to be used for hot climate of Basra?	LR	• Basra's current facade topology • façade Improvement preference/ factor for improving comfort for residents	• Document the variables for simulation for the best façade Improvement • Document the variables for façade Improvement that can improve residential comfort
How Improve Indoor comfort	**RO 3:** To propose the best Facade Improvements to Improve Indoor Comfort for Basra's Residence . **Sub RQ 3:** What are the best Facade Improvements to Improve Indoor Comfort for Basra's Residence?	**Test-** (Simulation) i.e. simulation and compare i.e. (thermal indoor, heat gain, heat loss, air temperature, and thermal comfort)	• Propose the best façade Improvement for Basra City to improve residents' comfort	• Application for the best façade Improvement for Basra City

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1.5 Research Framework

This research is organised and summarised in Figure 1.3. It starts with a literature review in which the independent and dependent variables are defined. Then, the concept of the façade design components, indicators, and building thermal performance concept are presented. The study variables are transformed into measurable indicators for quantitative analysis in the form of comparable figures and tables.

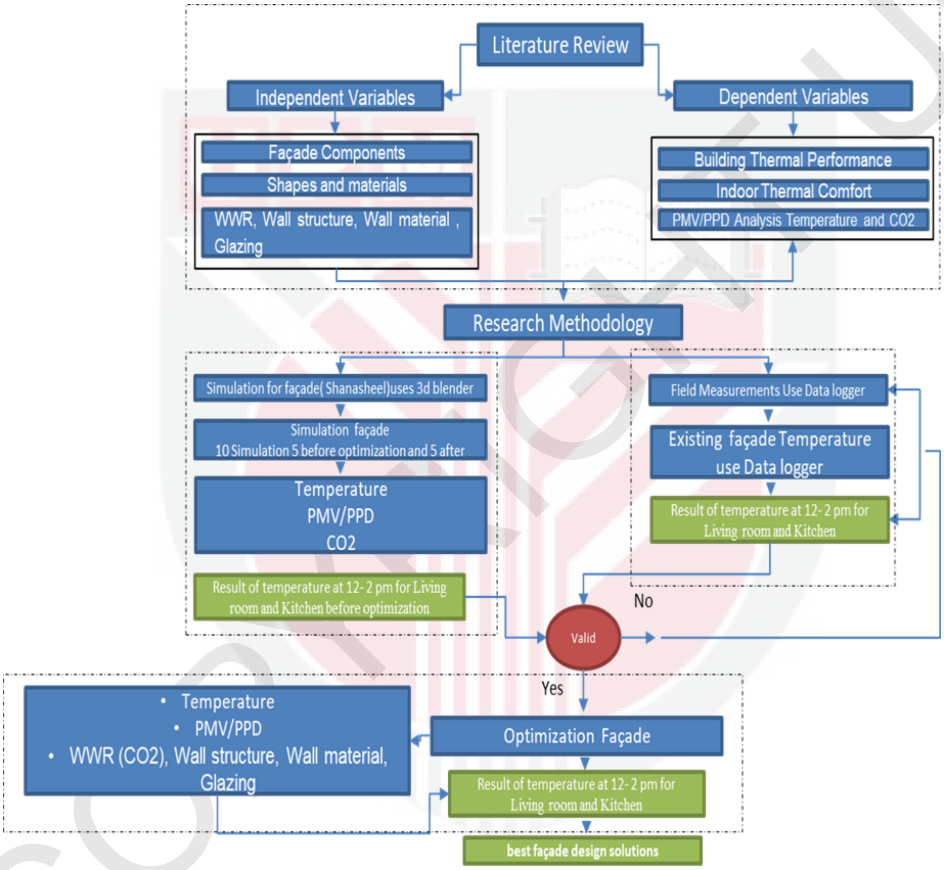

Figure 1.3: Research Framework Flow Process

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1.6 Limitation of Study

This research presented various traditional architecture in Iraq. In particular, this research described the evolution of façade features and the factors influencing residents' thermal comfort in Basra, Iraq. In addition, the characteristics of residential façade as a common factor for various designs to improve air quality and thermal comfort were discussed. The study was limited to the façade characteristics, air quality, and thermal comfort of residences in Basra.

1.7 Thesis Outlines

This thesis is divided into five chapters as follows:

Chapter One: Introduction

In this chapter, an overview of the background of the study from past studies is presented. This is followed by the problem statement, research hypothesis, research questions, and research objectives. Additionally, provided are the study's limitations and research framework. Finally, the organisation of the thesis outline is introduced.

Chapter Two: Literature Review

This chapter provides an overview of a recent research-related literature review. It highlights the concept of façade in Iraq's residences and the idea towards thermal comfort for Iraq's residences. This chapter also presents the façade techniques, factors influencing thermal comfort, and the challenges and barriers to achieving thermal comfort for Iraq's residences. In this chapter, the independent and dependent variables that affect the performance of the building's thermal comfort are discussed. In summary, this chapter provides the factors affecting thermal comfort through a comprehensive literature review.

Chapter Three: Research Methodology

The methodology used to achieve the objectives required is demonstrated in this chapter. The building's thermal performance is assessed using both quantitative and experimental methods. A thermal-based simulation model is performed using free and open source VI-suit. The façade is built using 3D software named Blender 3D, and the analysis is conducted in terms of indoor thermal performance for the old and new façade structure and materials. With the use of an Excel decision-making tool, the findings are compared to determine the best façade performance in terms of thermal comfort. The case study was performed on the historical *Shanasheel* house located in the south of Basra.

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Chapter Four: Results and Discussion

This chapter illustrates the findings from data analysis and model simulations. All the results obtained are displayed in the form of tables and figures. Additionally, the effect of façade techniques and materials on the thermal comfort of selected residential buildings in Basra is also presented. The results provide distinguished outlines for house façade design in the city of Basra and how it reduces the thermal effects to achieve the research objectives and lead to conclusions and recommendations.

Chapter Five: Conclusion and Recommendations

In this chapter, the conclusion and recommendations derived from the research findings are presented. The contribution and recommendations are identified based on the study's results. In the end, the study proposes several approaches for further research.

The following chapter will present a review of recent literature related to the study. It highlights the concept of façade in Iraq's residences and the idea towards thermal comfort for Iraq's residences.

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