COOLING LOAD PREDICTION MODEL DURING THE DESIGN OF MOSQUES IN MADINAH

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ABSTRACT

The building sector accounts for almost 40% of the total global energy consumption. Saudi Arabia, along with other developed countries have expressed their concern on the increasing energy demand and established several related policies focusing on the building sector. Mosques are one category of buildings that consume huge amounts of energy above other public sector buildings such as hospitals. An extensive review of literature has revealed that there is an increased demand to build new mosques. The majority of previous research works focused on operational and maintenance stages. In term of energy reduction, not much can be done to existing mosques as the solutions are both costly and time consuming. The importance of making right design at the design stage has been stressed which may save up to 70% of total energy consumption. The literature also revealed that there is a gap and absence of design stage integration for mosque projects, due to the complexity of the stage, the lack of information, and limited support tools. This research aims to develop a prediction model known as the Mosque Cooling Load Prediction Model (MCLPM) to assist designers and local authorities in reducing the energy consumption of mosques during the design stage. The process began by identifying significant structural and architectural design parameters that influence the energy consumption of mosques, using a three rounds of Delphi approach with 33 local experts. Thirteen significant parameters were identified, of which mosque orientation was found to be the most significant. Integration between Rhinoceros/Grasshopper parametric model, EnergyPlus™ simulation of selected medium-sized mosques, and optimization through Genetic Algorithm (GA) and Galapagos were made to generate the dataset required for developing mosque cooling load prediction model based on the Artificial Neural Network (ANN) approach. Two thousand five hundred simulations were performed to achieve the optimum (approximately 58%) of total energy reduction, and 23 non-repetitive design alternatives with the least demand for cooling load were generated. The Mean Square Error (MSE) and correlation coefficient (R) were obtained for the developed ANN prediction model. Based on the findings, the least MSE and R values were at $6.27 * 10^{-9}$ and 0.99888, respectively. Validation of the results revealed that the back-propagation strategy and Levenberg–Marquardt algorithm have the highest accuracies in predicting the exact total cooling load, in comparison to the actual values, and the absolute difference is less than 1%. The comparison with other methods and algorithms showed that the proposed prediction model has the highest accuracy, effectiveness, and least time required, to complete a given task. Hence, the developed prediction model act as a powerful tool to support the decision-making process that helps mosque designers provide a range of lowest cooling load design alternatives, thus facilitating the design process, and easy-quick estimation of total cooling load.

ABSTRAK

Sektor bangunan menyumbang hampir 40% daripada jumlah penggunaan tenaga global. Arab Saudi, bersama dengan negara maju lainnya telah menyatakan keprihatinan mereka terhadap peningkatan permintaan keatas tenaga dan menyediakan sebilangan polisi berkaitan yang memberi fokus terhadap sektor bangunan. Masjid adalah bangunan yang menggunakan jumlah tenaga yang besar mengatasi bangunan lain di sektor awam seperti hospital. Kajian menyeluruh literatur telah menunjukkan bahawa terdapatnya peningkatan permintaan untuk membangun masjid baru. Majoriti kerja penyelidikan terdahulu difokuskan pada peringkat operasi dan penyelenggaraan. Dari segi pengurangan tenaga, tidak banyak yang dapat dilakukan untuk masjid yang sedia ada kerana penyelesaiannya adalah mahal dan memakan masa. Kepentingan membuat keputusan tepat di peringkat rekabentuk telah ditekankan yang mungkin menjimatkan sehingga 70% daripada jumlah penggunaan tenaga. Kajian literatur juga menunjukkan bahawa terdapat jurang dan tiadanya integrasi peringkat rekabentuk untuk projek masjid, disebabkan kerumitan di peringkat ini, kekurangan informasi, dan alat sokongan yang terbatas. Tujuan penyelidikan ini adalah untuk membangunkan model ramalan yang dikenali sebagai Model Ramalan Beban Penyejukan Masjid (MCLPM) untuk membantu perekabentuk dan pihak berkuasa tempatan dalam mengurangkan penggunaan tenaga masjid semasa peringkat rekabentuk. Prosesnya bermula dengan mengenalpasti parameter rekabentuk dan senibina yang mempengaruhi penggunaan tenaga masjid, menggunakan tiga pusingan kaedah Delphi bersama dengan 33 pakar tempatan. Tiga belas parameter penting telah dikenalpasti, yang mana orientasi masjid didapati paling signifikan. Integrasi antara *Rhinoceros/Grasshoper* sebagai model parametrik, simulasi EnergyPlus™ bagi masjid saiz-sederhana terpilih, dan pengoptimuman melalui *Genetic Algorithm* (GA) dan *Galapagos* telah dibuat untuk menghasilkan set data yang diperlukan bagi membangunkan model ramalan berasaskan Rangkaian Neural Buatan (ANN). Dua seribu lima ratus simulasi dilakukan bagi mencapai pengurangan optimum (anggaran 58%) jumlah tenaga, dan 23 rekabentuk alternatif tidak-berulang dengan permintaan paling sedikit untuk beban penyejukan telah dihasilkan. Ralat Min Kuasa Dua (MSE) dan Pekali Korelasi (*R*) diperoleh untuk model ramalan ANN yang telah dibangunkan. Berdasarkan dapatan, nilai terkecil MSE dan R masing-masing adalah pada $6.27 * 10^{-9}$ dan 0.99888. Validasi keputusan menunjukkan bahawa strategi Penyebaran-belakang dan algoritma Levenberg–Marquardt menunjukkan ketepatan tertinggi untuk meramalkan jumlah beban penyejukan, berbanding dengan nilai sebenar, dan perbezaan mutlak kurang dari 1%. Perbandingan dengan kaedah dan algoritma lain menunjukkan bahawa model ramalan yang dicadangkan mempunyai ketepatan, keberkesanan, dan memerlukan masa yang paling sedikit untuk menyelesaikan tugas yang diberikan. Oleh itu, model ramalan yang dibangunkan bertindak sebagai alat yang berkuasa untuk menyokong proses membuat keputusan yang membantu perekabentuk masjid menyediakan pelbagai alternatif rekabentuk dengan beban penyejukan terendah, sekaligus memudahkan proses rekabentuk, dan anggaran mudah-cepat jumlah beban penyejukan.

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LIST OF ABBREVIATIONS

AI	-	Artificial Intelligence
ANN	-	Artificial Neural Networks
ASHRAE	-	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BIM	-	Building Information Modeling
BP	-	Back-Propagation
BPS	-	Building Performance Simulation
CFD	-	Computational Fluid Dynamic
CL	-	Cooling Load
CO2	-	Carbon Dioxide
DT	-	Decision Trees
EE	-	Energy Efficiency
EED	-	Energy Efficiency Design
EPW	-	Energy Plus Weather
FFNN	-	Feed-Forward of Neural Network
GA	-	Genetic Algorithms
GBI	-	Green Building Index
GH	-	Grasshopper
GHG	-	Greenhouse Gas
GUI	-	Graphical User Interface
HB	-	Honeybee
HL	-	Heating Load
HVAC	-	Heating, Ventilation, and Air-Conditioned
KACST	-	King Abdul-Aziz City for Science and Technology
KFUPM	-	King Fahad University of Petroleum and Minerals
KNN	-	K-Nearest Neighbors
LCA	-	Life Cycle Assessment
LB	-	Ladybug
MAE	-	Mean Absolute Error
MIADG	-	Ministry of Islamic Affairs Dawah and Guidance

ML	-	Machine Learning
MLR	-	Multiple Linear Regression
MRE	-	Mean Relative Error
MSE	-	Mean Squared Error
NEEP	-	National Energy Efficiency Program
NN	-	Neural Network
PMV	-	Prediction of Mean Vote
PPD	-	Predicted Percentage of Dissatisfied
RMSE	-	Root Mean Squared Error
RNN	-	Recurrent Neutral Network
SASO	-	Saudi Arabian Standards Organization
SCE	-	Saudi Council of Engineers
SCNC	-	Saudi Code National Committee
SBC	-	Saudi Building Code
SVM	-	Support Vector Machines
SVR	-	Support Vector Regression
WWR	-	Window to Wall Ratio

LIST OF SYMBOLS

Lvi	-	Likert mean for each parameter
Lv	-	The mean value of Lvi
Pvi	-	Likert scale points
Cvi	-	Corresponding weigh for each parameter
S	-	The statistical square sum of Lvi
$\overline{Y}$	-	Series numbers correspond to the computed and trained
$\overline{T}$	-	Mean value of total number of trains
T_i	-	Mean value of total number of trains prediction model prediction model
Y_i	-	Series numbers correspond to the computed and trained prediction model
R	-	Correlation Coefficient

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Recently, energy consumption in the building sector has become a global concern. It accounts for about 40% of all energy consumption, which has led to the establishment of several pieces of legislation worldwide that aim to reduce this form of energy consumption (Moayedi & Mosavi, 2021; Al-Homoud & Krarti, 2021; Tran et al., 2020). Saudi Arabia, along with other developed countries, has expressed its concern and established a number of related policies, as well as expressing the urgent need to achieve environmental sustainability and energy efficiency criteria, especially within the building sector (Almushaikah & Almasri, 2020). Currently, the building sector in Saudi Arabia, including mosque building, accounts for about 80% of the total energy used (Al-Tamimi et al., 2020). As a result, there is an urgent need to lower the energy consumption within the building sector, which requires immediate improvements in order to achieve energy efficiency and avoid future negative economic consequences (Felimban et al., 2019).

Recent studies show that buildings in Saudi Arabia consume large amounts of energy, and it has been discovered that mosques are some of the highest energy consumers, consuming more energy than many other building types, such as hospitals and educational buildings (Shohan & Gadi, 2020; Alabdullatief & Omer, 2017; Alabdullatief et al., 2016). In addition, very little research has been conducted with regard to mosque buildings when compared to research into other building types, such as residential buildings (Shohan & Gadi, 2020). According to the results of a literature review, the most common problem in mosque buildings is wasted energy, while reductions in energy consumption and improvements to thermal comfort are areas that have clearly been neglected by researchers (Al-Tamimi et al., 2020; Samiuddin & Budaiwi, 2018; Al-Tamimi & Qahtan, 2018).

Thermal systems and air-conditioning play a vital role in increasing the energy consumption of mosques (Samiuddin & Budaiwi et al., 2018; Al-Tamimi & Qahtan, 2018; Al-Shaalan et al. 2017). This happens for several reasons, such as poorly designed buildings, improperly operated A/C systems, frequent overcooling load demand and a major lack of research (Shohan & Gadi, 2020; Elshurafa et al., 2019; Al-Tamimi & Qahtan, 2018). Numerous studies, worldwide and in Saudi Arabia, stress the need for additional support to bridge the knowledge gap, as the potential for energy conservation in mosque buildings is significant (Harsritanto et al., 2021; Azmi et al., 2021; El Fouih et al., 2020). Some crucial issues need further investigation, such as energy efficiency, sustainable design, low energy criteria, indoor thermal performance, passive strategies and guidelines for design criteria (Azmi et al., 2021; Al-Tamimi et al., 2020; Azmi & Kandar, 2019).

Recently, there has been a global increase in the demand for new mosques to be established, including in many parts of Saudi Arabia, due to increased urbanization and the growing Muslim population (Azmi & Kandar, 2019; Alabdullatief & Omer 2017; Alabdullatief et al., 2016). The rate of mosque growth in general is estimated to be 1.3% per year and the number of mosques increased from 3.6 million in 2015 to about 3.85 million in 2019 (El Fouih et al., 2020; Al-Tamimi & Qahtan, 2018). In particular, Saudi Arabia is experiencing one of the largest expansions in the number of mosques around the country, and the number of mosques significantly increased, from about 55,266 in 2008 to about 102,580 in 2015 (Al-Tamimi & Qahtan, 2018; Alabdullatief & Omer, 2017). In addition, the study of Al-shamrani et al. (2016) indicated that Saudi Arabia is the largest Muslim country to witness such a huge demand to establish new mosque buildings.

Regarding existing mosque buildings, the study by Elshurafa et al. (2019) in Saudi Arabia found that there is a lack of policy support for such a model system and results indicate that nothing more can be done for existing mosques. In addition, Khan (2019) stated that one of the most time-consuming and costly stages is that of operation and maintenance. Similarly, the study of Alshibani & Alshamrani (2017) revealed that resolving the deficiencies of existing buildings or constructed facilities is costly and time-consuming, while the study of Azmi et al. (2021) concluded that for mosques already at the operation stage, changing the building structure appears to be impossible and economically infeasible.

As a result, the design stage integration is necessary due to increase demand for establishing new mosques and dificulty in retrofitting existing mosques. It is widely believed that the design stage is the most promising and critical stage at which to support the decision-making process in order to reduce energy consumption by up to 70% (Al-Saggaf et al., 2020; Li et al., 2019). Several researchers have concluded that the design stage decision appears to be the most important step in reducing the demand for energy consumption (Almushaikah & Almasri, 2020; Al-Saggaf et al., 2020; Ahmed et al., 2019). In recent years, energy-efficient design has become a major topic, receiving increased attention from governments, policymakers, developers and researchers (Li et al., 2019). During the design stage, an efficient design is critical, and it is estimated that proper design solutions can reduce a significant quantity of energy and save millions of dollars in annual costs and this is applicable for Saudi Arabia (Al-Saggaf et al., 2020).

The need to improve energy-efficient design and minimize energy consumption in buildings has become very clear to designers and engineers, and several studies in Saudi Arabia have highlighted the challenges due to the lack of information and adequate tools to assist designers, especially at the design stage (Almushaikah & Almasri, 2020; Ahmed et al., 2019). Although it is the responsibility of designers to design sustainable mosques with the lowest energy demands, they suffer from a lack of design information and the limited support tools available, so they consider only a few design solutions but ignore many others (Azmi et al., 2021; Azmi & Kandar, 2019). Consequently, limited design-decision supporting tools are available to allow designers to quickly estimate energy performance (Al-Saggaf et al., 2020). There is also a need for tools and techniques to help designers, along with other professionals and stakeholders in the building industry, by providing multiple design options so that wise decisions and informed choices can be made during the design stage (Al-Saggaf et al., 2020; Ngo, 2019; Batish et al., 2019).

1.2 Problem Statement

Mosque buildings are unique and they operate five times a day and 365 days a year, with a varying number of people each time (Al-Tamimi & Qahtan, 2018). However, compared with other types of buildings, very little research has been found in regard to mosque buildings. Only in the last 20 years has research highlighted the issue of energy consumption of mosques (Harsritanto et al., 2021; Azmi et al., 2021; El Fouih et al., 2020). The literature review identifies a gap in this regard, that is, the absence of design stage integration for mosque projects. This is due to several reasons, such as the complexity of the stage, lack of information, limited support tools and high level of designer subjectivity at this stage (Al-Saggaf et al., 2020; Batish et al., 2019). In Saudi Arabia, the software market lacks the appropriate tools that can assist designers to find the optimum design solutions to minimize energy consumption and cost (Al-Yami & Sanni-Anibire, 2019). The main limitations of the existing software are complex, inaccuracy, highly time-consuming, based on the scenario-by-scenario approach, and fail to meet the requirements of engineers and designers, especially at the design stage (Bui et al., 2020; Pereira, 2020; Al-Yami & Sanni-Anibire, 2019; Alshibani & Alshamrani, 2017).

In addition, the design parameters that allow mosques to be more sustainable are similar to those of any other buildings that contribute to energy consumption and need to be identified (Azmi & Kandar 2019). Similarly, the study of Aljofi (2018) in Saudi Arabia revealed that one of the ways for achieving the target of sustainable mosques is to explore the potential environmental architectural parameters of mosques. This notion is in line with several research findings in Saudi Arabia indicating that little consideration has been given to the architectural design parameters, the diversity of building forms and the significant parameters that have a great impact on energy consumption need to be addressed, especially at the design stage (Al-Saggaf et al., 2020; Almushaikah & Almasri, 2020; Ahmed et al., 2019;

Ghabra et al., 2017). Figure 1.1 illustrates a summary of the research gaps that support the identification of the research problem.

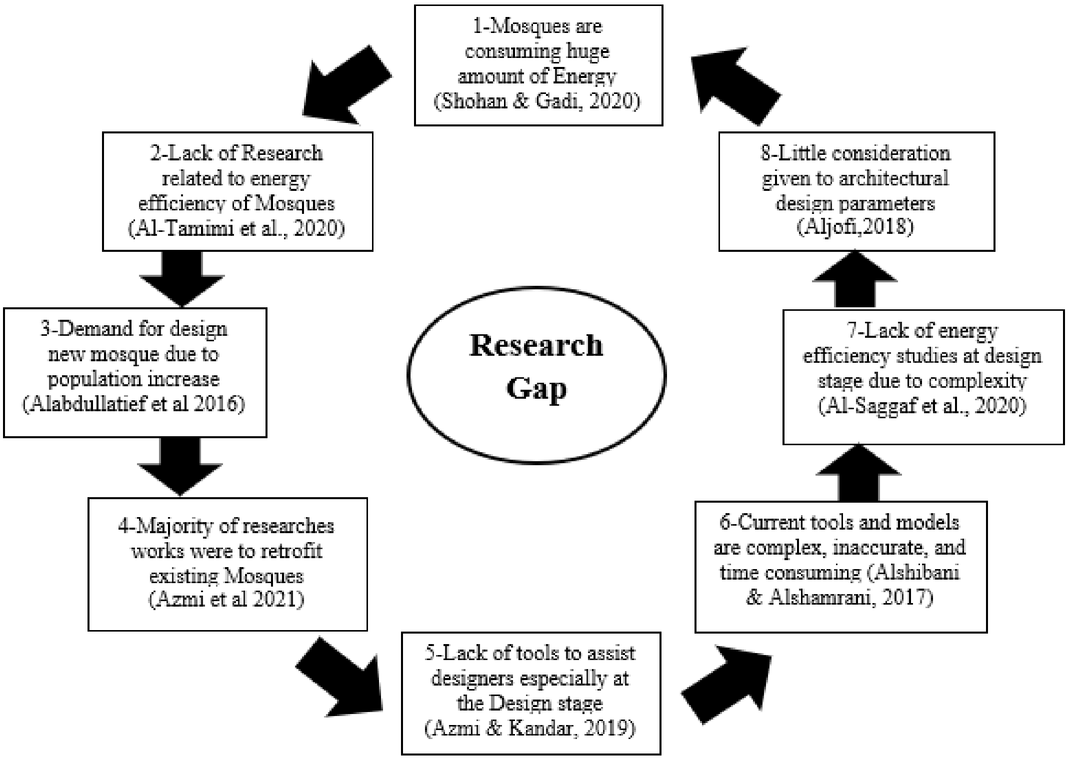

Figure 1.1 Summary of research gaps support the identification of the research problem

Based on Figure 1.1, several gaps and the lack of research are demonstrated. It is clear that the potential for energy saving in mosque buildings is substantial (Harsritanto et al.,2021). There is a major opportunity to improve the performance of mosque buildings and reduce their energy consumption by properly designing mosques at the design stage. This can be achieved by integrating different elements and software tools, such as parametric modelling and the optimization of buildings, along with the adoption of Artificial Intelligence (AI) methods such as Genetic Algorithms (GA) and Artificial Neural Networks (ANN) to predict the energy consumption of mosques during the design stage. This integration of different elements into one frame usually demonstrates the best approach to achieving both success and an accurate and fast calculation method for predicting the energy consumption of mosques (Ilbeigi et al., 2020; Li et al., 2019). To address the issues and problems that have been highlighted, a new cooling load prediction model needs to be developed to enable designers and local authorities to generate, explore and design sustainable mosques that demand far less cooling load energy.

1.3 Research Questions

The research question that arose from the problem statement is:

> "How is it possible to assist designers and local authorities in the decision-making process to promote energy efficiency and to design sustainable mosques with the lowest demand for cooling load during the design stage?"

In order to answer the main research question, six sub-questions were devised and are listed as follows:

1. How can new mosques be constructed to be sustainable and obtain the best energy efficiency levels to support future government policies?
2. Which significant parameters influence the energy consumption of mosques at the design stage?
3. How can the best design approach be developed that assist, facilitates and enables designers to predict the energy consumption of mosques at the design stage?
4. What is the best way to generate a dataset that is sufficient for use in a prediction model?
5. Can energy consumption be reduced significantly if a prediction model is proposed?
6. To what extent is the developed cooling load prediction model accurate, effective and efficient?

1.4 The Aim and Objectives of Research

This research basically aims to develop a mosque cooling load prediction model (MCLPM) to assist designers during the design stage and allow them to generate, explore, and design sustainable mosques with least demand for cooling loads energy.

To achieve the above aim the following objectives are identified:

1- To identify the significant parameters influencing the energy consumption of mosque buildings during the design stage.
2- To generate the dataset for the cooling load prediction model.
3- To develop the mosque cooling load prediction model (MCLPM) to assist designers during the design stage.
4- To evaluate level of accuracy, effectiveness, and usability of the prediction model prototype.

1.5 Scope of the Research

The scope of this research focuses on the development of cooling load prediction model during the design stage of mosque buildings. There are several estimation methods and simulation tools are existed to calculate the energy consumption. However, these methods and tools are not-friendly, time consuming, and required experience and knowledge to complete such a task, whereas prediction model based on artificial intelligence (AI) and machine learning (ML) techniques recently approved its applicability to provide accurate, quick estimation, and solve complicated problems (Das et al., 2020; Bourdeau et al., 2019; Wei et al., 2018).

Due to the fact that Saudi Arabia is along with other developed countries, consume huge quantity of energy in building sector with increase demand for energy, which expected to be double at 2025 (Al-Tamimi et al., 2020). However, the focus of this research is on mosque building because literature proves that mosque consume energy above many public building sectors in Saudi Arabia, with clear gab and lack of researches. Besides that, the data collection for this research is limited for mosques located in Al-Madinah, Saudi Arabia, with specific climate zone number one among other three climate zones. As per the literature review, semi-structure interviews, and mosque design regulations by MIADG, mosque designs are divided into three main types small, medium, and large. Therefore, the literature review indicated that there is an increased demand for establishing medium-sized mosques especially in urban areas with high demographic populations, and these medium-sized mosques are including both Jumah prayers and women prayers zone.

The central focus of this research is on the design stage to reduce the energy consumption for new mosque projects, and not for retrofitting an existing mosque during the operational and maintenance stages, which approved to be costly, time consuming, and structurally impossible. The estimation of energy consumption and life cycle of mosque project are limited to only architectural and structural design parameters of mosque envelope, where the electrical and mechanical parameters are out of this research scope.

In addition, criteria related to this research are gathered from all available references; however, for refining the significant parameters, purposive sampling and Delphi approach are applied to extract information from experienced and experts in the field. The experts are selected from the construction industry, academic field, and the Ministry of Islamic Affairs Dawah and Guidance (MIADG) in Al-Madinah.

1.6 Significance of Research

The building sector in Saudi Arabia, which includes mosques, currently accounts for about 80% of all the electrical energy used in the country (Al-Tamimi et al., 2020). In addition, due to its extremely hot climate, Saudi Arabia has expressed concern about the dramatic increase in energy consumption levels, which are expected to double by 2025, compared to levels in 2011 (AlHashmi et al., 2021). This situation has become an increasingly pressing challenge, causing the government to establish a number of policies and express the urgent need to achieve environmental sustainability and energy efficiency criteria, especially in the building sector (Almushaikah & Almasri, 2020).

The importance of this research effort is substantial, since designers, the government and local authorities, such as MIADG, need a way to focus and prioritize their efforts when establishing new mosques. These efforts can have a significant impact on reducing total energy consumption. There is a clear absence of the design stage integration and nothing more can be done for existing mosques. In the design stage, only basic information and fundamental decisions about the mosques tend to be made, and it is the responsibility of architects to design sustainable mosques with the lowest demand for cooling load. However, this lack of mitigation tools has been challenged, and a need has been recognized for an alternative technique, rather than traditional methods, to assist them with their future projects.

It is necessary to develop a design approach with fewer computational processes that can predict the energy consumption for a whole construction project. However, the impact of this research entails the integration of energy-efficient design solutions during the design stage through the combination of parametric modelling of (BIM), EnergyPlus™ simulation analysis, the optimization of buildings through Genetic Algorithm (GA) method and the development of a prediction model, using Artificial Intelligence (AI) to improve the sustainability and energy performance of mosques. Moreover, this research supports the aim of predicting accruable energy consumption at the design stage in order to improve the energy efficiency of future mosques. This research has the potential to bridge the gap between determining accurate levels of energy performance during the design stage and the actual energy performance during service life.

The findings from this research will contribute to the body of knowledge by providing a better energy-efficient design solution that contributes to the construction industry. The integration of the prediction model for initial estimations to minimize the total energy consumption will serve as a green assessment tool that fills the gap in the area of research coverage. A clear gap and a lack of work in this area are evident, especially concerning the design stage. The prediction model has several advantages over the traditional methods. It can create an estimation of energy consumption based on historical data, solve complicated problems, assist designers and local authorities to select the best design form with the lowest demand for cooling load and illustrate the impact of significant parameters. Its use can be extended to other countries with similar climate conditions.

The finding of the prediction model acts as a powerful tool to support the decision-making process and benefits several mosque stakeholders such as designers, the government, local authorities such as MIADG, society in general and mosque occupants. The proposed MCLPM prototype provides a range of design alternatives that offer the lowest demand for cooling load. The proposed prototype is an easy, user-friendly and quick decision-making method, which can be used by non-experts without much knowledge of simulation scenarios or complex calculations. This allows the respective mosque stakeholders to explore and understand the performance of their new mosque project after running the proposed prototype.

1.7 Chapter Organization

This research consists of seven chapters, which mainly considering energy consumption of mosque building and rational behind the research objectives as follow:

Chapter 1 entails introduction, background, and highlights the problem statement of the research. Then, the raised research question with six sub-questions, aim, and the objectives of the research. After that, scope, significance, and brief summary of research chapters.

Chapter 2 provides a literature review on related studies of building industry, energy consumption of mosque building, energy efficiency and key parameters, parametric modeling of (BIM) and simulation tools, optimization process through genetic algorithm (GA), machine learning technique through artificial neural network (ANN) to predict the total cooling load, and summary of the chapter.

Chapter 3 presents the research methodology and explain the steps required to fulfill the research aim, objectives, and justification behind the selection of research techniques such as sampling technique, data collection, modeling and simulation software, techniques for optimization process, strategy for developing the prediction model, validation of research instruments, and summary of the chapter.

Chapter 4 corresponds to first objective in this research and illustrates the process to identify the significant parameters influencing energy consumption of mosque building at the design stage. Experienced and experts in the field were qualified and selected to participate in sequence of three rounds of Delphi approach by adopting the criteria of flexible points. Significant parameters were identified at end of chapter and the results were moved to next chapter to use as a material to generate the required dataset for developing the prediction model.

Chapter 5 describes the process for generating the dataset for the cooling load prediction model, which begins by modeling, simulation, and validation for the simulation results. Followed by identifying the minimum and maximum range of parameters that used for optimizing the building geometry. Various design alternatives are generated and manually select for optimum results with least demand for cooling load.

Chapter 6 illustrates the process of developing the prediction model prototype through artificial neural network (ANN) strategies, Back-propagation technique, and Levenberg–Marquardt algorithm. In addition, estimate level of accuracy and performance of proposed model through trial-and-error technique, and through correlation coefficient (R) and mean square error (MSE). After that, the evaluating of the proposed production model prototype was presented by estimating level of accuracy, effectiveness, usability of the proposed prototype.

Chapter 7 describes the conclusion derived from the research, objectives achieved, contribution to body of knowledge, limitations, and recommendations for future researches.

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