University of Bahrain

College of Science

Environment and Sustainable Development Program

Sustainable Building:

An Exploratory Study

A Thesis submitted in partial fulfillment of the requirements for the Master's degree in Environment and Sustainable Development – Sustainable Urbanism

Prepared By:

Ghadah Abdullah Aldossary

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Supervised By:

Dr. Matthew Hardy

University of Bahrain

In collaboration with the Prince Foundation

Kingdom of Bahrain

May ٢٠٢٢

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University of Bahrain
Deanship of Graduate Studies
And scientific Research

جامعة البحرين
عمادة الدراسات العليا والبحث العلمي

Thesis Discussion Committee Decision

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3.04

The Discussion Committee met on 13-Jul-22 In Online. Upon discussing the student whose details are stated above in public, the discussion committee recommends the following:

The student is awarded a grade A- in the thesis subject.

☐ Without making any changes to the thesis.

☒ After making the modifications attached with this decision.

Discussion Committee Members Approval:

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Approved at the University Council 6th meeting, 2013
In accordance with Decision No. 736/2013 dated 14/3/2013
Modified by University Council Decision No. 2043/2013 dated 20/11/2013.

Abstract

Sustainable building is an important step for the building sector worldwide in terms of being more ecologically conscious and is a key instrument for accelerating action to combat global heating. Several other industries have as big an influence on sustainable development as the building industry, where sustainability issues have become an increasingly urgent consideration. As a result, the idea of sustainable building has emerged to include sustainable initiatives in construction projects. Sustainable industrial building, on the other hand, is the least recognized, and the notion is still relatively new in the Saudi Arabian construction business. Consequently, this dissertation outlines a recommended method for examining the building industry's sustainable construction capabilities. The research is based on interviews with key industry figures and a desktop survey of key research literature. The research concludes that sustainable buildings should Sustainable building approaches in building projects recommended include recycling and using recycled materials whenever possible, conservation of water, conservation of energy and increasing the use of renewable sources of energy. In the construction, repair, and retrofit of buildings, the condition of the interior airflow should be safeguarded. Sites that have been constructed should be cleaned up and reused, and clean diesel should be used throughout the building cycle and thereafter. Finally, sustainable buildings must include ecologically sustainable infrastructure and surroundings.

Dedication

To..

my father & mother

for being with me step by step and for their prayers

my beloved husband

for supporting me

my upcoming baby

for making me stronger

my sisters

for believing on me

Acknowledgments

In the name of Allah, the Most Gracious and the Most Merciful…

First praise is to Allah the Almighty, on whom ultimately, we depend for strength and guidance, by whose mercy I was able to reach this stage, Alhamdulillah.

Second, my sincere appreciation goes to my supervisor Dr. Matthew, for his constant support and invaluable help of constructive comments and suggestions throughout this research. Thank you for your trust and faith.

I am also deeply indebted to all my Family members for their kindness patience, care and moral support that helped me since my first day at this college to become who I am today.

And with a tear of pride, I am warmly thankful to my beloved family. To my Father who was with me in every step I had to make. Thank you for being at my side. Thank you for your support, your patience and faith... thank you for everything!

Finally, my acknowledge goes to all my wonderful colleagues whom I have met in UOB. I am thankful of every one of you.

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Acronyms

Abbreviation	Definition
EU	European Commission
GE	General Electric
LEED	Leadership in Energy and Environmental Design
LCA	Life Cycle Assessment
ISO	International Standards Organization

Chapter One

Introduction

1.1 Introduction

The building sector is influenced by international environmental challenges such as emission of Greenhouse gases, air pollution, and inefficient management of waste all through its life cycle. The building sector involves six lifecycle stages, including extraction of raw materials, manufacturing, construction, operation and maintenance, demolition, and disposal. Each of the stages involves the consumption of natural resources, water and energy and contributes to the emission of greenhouse gases and other pollutants. For example, the extraction of raw materials involves the extraction of nonrenewable raw materials, such as timber, limestone, bauxite, iron ore, petroleum, and copper, among others and when continued extraction of these raw materials takes place, it leads to their eventual depletion (Ngwepe and Aigbavboa, 2015). Therefore, alternative actions, such as recycling, are necessary to limit the extraction of these nonrenewable resources. Simultaneously, the extraction process also involves the consumption of resources like water, fuel or electricity and contributes to the emission of greenhouse gases and pollutants. The processing of raw materials also contributes to the creation of a large amount of waste that ends up in landfills, thereby contaminating the surrounding environment. The construction phase of a building also contributes to significant environmental pollution. According to one study, the building construction industry is responsible for the consumption of 40% of the materials entering the global economy and the creation of between 40%-50% of the greenhouse gas emissions and the consequent acid rain production (Khasreen, Banfill, & Menzies, 2009). The operation and use stage of the building also involves the consumption of water and energy for running power lighting systems, electricity, heat ventilation air

conditioning, and telecommunication networks, among others (Ngwepe and Aigbavboa, 2015). According to Webster (2004), the greenhouse gas emissions from buildings in the USA amounts to 22 million new automobiles running across the US roads every year. 75% of the energy consumption in the USA is attributed to buildings (DOE, 2007). Before a building is demolished, maintenance and refurbishment take place at least twice and contribute to the generation of a large amount of solid waste. After a building is demolished, it leads to the creation of large quantities of solid waste that can either end in incineration, which produces greenhouse gases or may end up in landfills, thereby contaminating the air and ground water quality.

According to Kumar, Tewari, Mathur, S., Mathur, J., (2017), the environmental impacts of the building industry on the environment has sparked a rising awareness of the need to choose a more ecologically effective route. Ecological effectiveness, according to the concept of environmental sustainability, is the competence of economic actors in an area to enhance non-resource production while reducing resource consumption such as capital and labor, (Kumar, Tewari, Mathur, S., Mathur, J., 2017). Sustainable buildings were developed as an ecologically friendly method since they employ sustainable concepts in their development systems and processes.

Sustainable building refers to the construction technique that applies sustainable design at every stage of the building's life cycle, starting from the planning of the building or the land where the building is constructed right to its demolition at the end of the life cycle (Gatley, 2021). Even though sustainable building design is interchangeably used with green design, the concept of sustainable building differs from the concept of green building which is primarily focused on the environment and involves individual

practice and processes that ensure environmental sustainability. On the other hand, sustainable buildings take into consideration three pillars of sustainability, including the planet, people, and profit (Gatley, 2021). A sustainable building design involves a sustainable structural system that not only focuses on the aesthetic appeal of a building but also takes into consideration the internal structural conditions of the building (Wang and Adeli, 2013). The sustainable building design takes into consideration the land use, the type of materials that will go into the construction of the building, the amount of energy consumption, the amount of greenhouse gas emissions, risk management, maintenance and repair of the building, and lifecycle cost. For example, while selecting the raw materials for the construction of a building, instead of using traditional woods, such as untreated cedar, yellow pine, and redwood, alternative lumber can be used for its better slip-resistance, aesthetics, and durability (Wang and Adeli, 2013). The construction of concrete buildings involves the use of aggregates and cement paste. The cement paste releases carbon dioxide gas as it gets older from chemical reactions. Approximately one pound of carbon dioxide per pound of cement is released throughout its lifetime (Kang and Kren, 2007) and therefore, the addition of fly ash and slag to the traditional cement paste can reduce the carbon emissions. A report published by the US Green Building Council highlights that sustainable buildings can contribute to the reduction of between 24%-50% in energy consumption, 30% in carbon emissions, 40% in water usage, and 70% in solid water generation (Wang and Adeli, 2013). Since peoples' welfare is affected by detrimental environmental consequences associated with the building sector, sustainable building design by minimizing the negative environmental impact can prevent the worsening of climate change condition and habitat degradation.

Worldwide actions on climate change seen as a possible hindrance to economic progress in Saudi Arabia and some of developing countries, as well as a danger to export of raw materials. One of the largest countries in the world with an arid climate is Saudi Arabia. Rainfall is extremely limited in Saudi Arabia and over the last 50 years, the kingdom has witnessed a 1.9°C increase in average temperature (Alotaibi, Abbas, Ullah, Nayak, Azeem, & Kassem,. 2021). As a result of climate change, the average temperature in Saudi Arabia may further increase by 2 to 4°C by the end of 2100 (Alotaibi, Abbas, Ullah, Nayak, Azeem, & Kassem,. 2021). It is predicted that 14 out of 33 countries that will be facing acute water shortage by 2040 are in the Middle East and Saudi Arabia comes 9th in ranking in terms of its potential to experience water stress (Alotaibi, Abbas, Ullah, Nayak, Azeem, & Kassem,. 2021). The arid climate combined with the negative impact of climate change may negatively impact the agriculture and other sectors of the Saudi economy. For example, the water stress may contribute to significant losses of yields because approximately 90% of agriculture in Saudi Arabia depends on irrigation (Alotaibi, Abbas, Ullah, Nayak, Azeem, & Kassem,. 2021). Saudi Arabia makes a substantial amount of money through the export of dates, but the climate change will reduce the climate suitability for date palm production in the country and therefore, the total annual income from date palm growers will reduce significantly in the Kingdom.

Sustainable model of development that focuses on the well-being of planet, people and profit contributes to economic growth and increased standard of living through more efficient allocation and increased efficiency in the use of resources such as labor, wealth, and natural resources and minimizes environmental degradation (Abubakar & Dano, 2019). Saudi

Arabia can reap the benefits of sustainable building design to minimize the impact of its industrial growth on climate deterioration.

Saudi Arabia has had remarkable resource-based industrial growth over the last two decades, based on increased resource outputs and exploitation of natural resources in major natural gas production sites (Aboneama, 2018). Even though Saudi Arabia's industrial growth suffered a slump due to coronavirus impact in 2021, at present, its industrial growth is at an all-time high. Saudi Arabia recorded 24.8% year on year growth in March 2022 (CEIC Data, 2022). The goal of Vision 2030's strategic objective is to achieve economic diversification so that the country does not remain solely dependent on oil for the sustenance of its economy (Blazquez, Gakeotti, Manzano, Pierru,& Pradhan, 2021). To fulfill the vision 2030 strategic objectives, Saudi Arabia has implemented a series of socioeconomic reforms, such as the addition of a value added tax, the launch of renewable energy and reforms to domestic energy prices, among others (Blazquez, Gakeotti, Manzano, Pierru,& Pradhan, 2021). As a result of the strategies implemented for economic diversification, the country has witnessed a rapid industrialization especially in the manufacturing and production sector. This has resulted in positive economic growth for the country. As a result of economic expansion witnessed in Saudi Arabia, the demand for warehousing and industrial buildings has increased, which has contributed to increased growth in the construction industry. The Saudi Arabian construction industry is expected to record a compound annual growth rate of 5.2% between 2021 and 2026 (Trade Arabia, 2022). The construction industry is witnessing a new trend of an increased focus on sustainability and resilience from both public and private sector project owners. Traditionally, Saudi Arabia constructed buildings by

using locally available raw materials, such as limestone, wood, stone, and coral, but with renewed focus on sustainability and resilience, Saudi Arabia has started carrying out various sustainable building projects (Alwetaishi, Balabel, Abdelhafiz, Issa, Sharaky, Shamseldin, & Gadi, 2020). For example, King Khalid international airport, Riyadh metro, and Pepsi-Cola mega plant are all examples of sustainable building projects.

Alardhi, Alaboodi & Almasri (2020) suggest that Saudi Arabia may meet its objective of reducing greenhouse gas emissions in the environment by 60% by 2030, provided the construction sector recognizes the necessity for sustainable modified construction projects. This is in doubt, because only approximately a third of new buildings may be built according to the energy reduction objective, which would not be enough to substantially reduce its greenhouse gas emissions by 2030. As a result, participating in sustainability-efficient buildings is essential and will significantly reduce greenhouse gas emissions by 2030.

Construction industry specialists, who have mastered the basics of environmental knowledge, have long been familiar with terms like "environmentally friendly" products, "waste-free technology" and some others (Kozien, 2021). However, it should be noted that at present the approaches and methods aimed at the further development of ideas for the environmental justification of the adopted design decisions are constantly being improved and developed. In this regard, new environmental terms and concepts appear, the meanings of which are not always clear and familiar (Kozien, 2021). Thus, over the past 20 years, publications have often used such new term as "green building". The topics of publications reflect the issues of improving the environmental soundness of construction projects,

which affect the interests of a broad variety of professionals: constructors, designers, architects, developers, environmentalists, as well as experts in construction and operations structure and landscaping. In this regard, there is a need to disclose the meaning and content of the term "green building".

Experts usually associate the term “green” with the term “environment”. However, the phrase "green building" can be interpreted ambiguously and rather broadly (Bucklet & Lazarevic, 2014). For example, since the beginning of the nineties of the last century, the term “green building” has been introduced and widely used, the literal translation to which will most likely correspond to the phrase “sustainable building”. It should be noted that recently there have been regulatory documents related to the issues of landscaping (Bucklet & Lazarevic, 2014). Saudi Arabia also includes the term "green building” but has a slightly different meaning.

In the modern interpretation of "green building", a wider range of issues is considered, since we are talking about the construction of facilities using special technologies in specially prepared areas. Such buildings should be built with the calculation of the minimum impact on their natural environment and the provision of the most favorable and comfortable living conditions. The main directions of "green technology" advancement involve technical innovations lowering the creation of pollutants in the manufacturing process, for example, the use of nanotechnology in the construction of sustainable buildings is a revolutionary concept. Nanotechnology advancement for the construction of sustainable building includes new types of raw materials, such as insulating nanocoatings and carbon nanotubes as well as novel processes that include nanoporous filtration and photocatalysis (Elvin, 2007). Nanomaterials can help in mitigating pollution because they are mostly

recyclable and efficient catalysts, which can speed up chemical reactions to transform harmful vapors arising from automobiles or industrial plants into harmless gases (Khullar, 2017). Nanomaterials can contribute to sustainable buildings by enhancing the durability, strength, and versatility of structural as well as nonstructural materials, enhancing insulation and minimizing toxicity (Elvin, 2007). The strength of standard structural materials can be improved significantly by using nano-reinforcement of existing raw materials, such as steel and concrete (Elvin, 2007). The use of reinforced concrete is especially increasing in the construction of buildings.

Most governments have created their techniques for evaluating the extent of sustainability in building initiatives, to investigate the ecological, financial, and social elements of this sustainability. The creation of metric schemes for assessing these features was primarily based on the findings of the EU-led super-building initiative (European Commission, n.d.), with the following key goals:

1) Creating the ability to analyze sustainability by using benchmarks to make advances in the area of sustainable building.

2) Improving indicator mechanisms for evaluating the environmental, social, and financial performance of the building under development.

3) Formulating suggestions for the use of metrics at multiple phases of the building and project management.

4) Disseminating the findings among national stakeholders.

1.2 Research Problem

Dammam, Saudi Arabia is dedicated to achieving sustainable construction targets and considers them a high priority as per its guiding principles. The overall vision of Saudi Arabia for 2030 is as per sustainable performance targets (Blazquez, Gakeotti, Manzano, Pierru,& Pradhan, 2021). This bold vision, as well as the varied improvement strategies that go with it, provides the foundation for achieving goals for sustainable development. Buildings account for more than 40% of the city's total energy usage and contribute to most of its total pollution in form of greenhouse gases (Ngwepe and Aigbavboa, 2015). As a result, the country has developed a range of approaches, programs, and angles aimed at achieving sustainable construction goals. Merging technology breakthroughs in reduced-carbon energy structures and actions to minimize construction-related energy usage for the existing and new buildings is required to minimize carbon footprints. This will generate profitability for all residents, as well as render the Kingdom a desirable travel and tourism place. People will not be able to sustain their quality of life or that of the ecosystems until they recognize and mitigate the damage they cause every day. Some of the consequences of failing to learn how to live sustainably will result in pollution, deforestation, and the extinction of more creatures.

1.3 Research Questions

1. What are the key principles of sustainable construction?

2. Are there any criteria for sustainable construction?

3. How might sustainable construction standards be embraced and used in the development of a building in the present day?

4. What are the advantages of implementing sustainable building construction?

5. What are the major considerations to be considered during sustainable buildingconstruction?

1.4 Research objectives

1) To determine the difficulties and success factors for sustainable construction.
2) To examine the extent to which sustainable practices are used in both green and non-green building projects.
3) To identify the most significant sustainable practices for building projects.
4) To identify, and analyze the standards for sustainable building construction so that the best guidelines are used.
5) To improve the building's productivity in a variety of ways, including cheaper production costs owing to increased performance and reduced energy consumption.

1.5 Research significance

The importance of this research is to determine ways in which sustainability can be achieved and used at an optimum level in building construction not only in Dammam but also across the globe. It is therefore helpful in making a foundation and pathway to which sustainable construction can follow.

1.6 Definition of terms

Biodiversity- It refers to the biological diversity or a variety of life existing in a specific habitat or ecosystem.

Carbon footprint- The amount of carbon dioxide and other carbon compounds released during the consumption of fossil fuels by a specific company, country, individual or group.

Climate change - Long-term shifts in weather and temperature patterns due to increased levels of greenhouse gases in the earth's atmosphere.

Energy-efficient- It is the objective of minimizing the quantity of energy necessary to provide services and products while still minimizing the repercussions of pollution to the surrounding.

Eco-friendly or environmentally-friendly- It means non-polluting to the environment. Sustainable living or sustainable manufacturing processes that reduce the number of resources consumed are promoted by this factor.

Global warming - a gradual rise in the overall temperature of the earth's atmosphere because of greenhouse gas effect caused by increased emissions of greenhouse gases.

Green technology- It describes the use of technology to mitigate the impact of human activity on the natural environment.

Greenhouse gas - gaseous compounds, including carbon dioxide, nitrous oxide, or methane, that absorb infrared radiation and trap heat in the earth's atmosphere, thereby contributing to global warming.

Industrial buildings – Buildings that are used for industrial purposes such as factories, plants or warehouses used for manufacturing or storage purposes.

Nanomaterials - Nanomaterials refer to the materials that are produced by using nanotechnology.

Recycling - It refers to the process of converting waste into renewed materials or objects that can be used as raw materials again in the production of new products.

Sustainable development- It is a concept that aims to achieve human needs and desires while simultaneously preserving environmental systems' ability to continue supplying resources and services.

Sustainability- a business strategy that integrates the environmental, social, and economic components of project-based activity to fulfill present stakeholder demands while still safeguarding the future generations' welfare and not overburdening them.

Sustainable building- it is a building that portrays high efficiency in using resources such as energy, water and materials, therefore, reducing the impacts on environment and health.

Low carbon building- it is a building with high-energy efficiency ratings and low carbon emissions by relying on low-carbon sources of energy.

Chapter Two

Literature Review

2.1 A review of Dammam in Saudi Arabia

Dammam, Saudi Arabia's third-largest urban center is a desirable location for achieving sustainability. The town is, however, set in the center of a desert, with extreme weather conditions and little supplies. These and more factors impact the rate of returns in Dammam industrial buildings. As a consequence, developing a sustainable structure in Dammam necessitates thorough structural and situational research (Kumar, Singh, Mathur, A., Mathur, S., & Mathur, J., 2018).

Dammam's natural physical characteristics include hazardous groundwater, which affects the foundations of buildings (Abubakar & Dano, 2019). Rare rains, leaks from water networks, and seawater contribute to rising groundwater levels (Abubakar & Dano, 2019). Groundwater is a problem for the development of the city, as it can create emergencies in the structure and foundation of buildings. Additionally, the topography of Dammam shows that it is positioned 32 feet above sea level (Abubakar & Dano, 2019). The city and its surrounding territories within 3.5 km contain small changes within 48 km (Abubakar & Dano, 2019).

The increasing growth of the housing sector in Dammam, as well as faster development, which does not take into account energy efficiency and focuses only on initial investments, has contributed to the unsustainable development of the construction industry (Mujan, Anđelković, Munćan, Kljajić, & Ružić, 2019). It has resulted in the widespread building of unsuitable houses with poor insulation or without it, leaking windows, inefficient cooling systems, and ineffective construction methods (Alrashed & Asif, 2014). However, the political motives spelled out in Vision 2030 can

inspire developers to invest in environmentally friendly technologies, such as solar and wind power (Mujan, Anđelković, Munćan, Kljajić, & Ružić, 2019).

Nevertheless, in 2020, an insufficient number of incentives leads to a problematic situation for the development of sustainable buildings and is currently an obstacle to sustainable development.

Conventional drainage systems based on pipeline networks in Dammam are designed to collect and drain rainwater in urban areas (Poleto & Tassi, 2012). Their widespread use can lead to several problems associated with the flooding of territories, as well as with diffuse pollution of natural water bodies by the flow of water, which contains high concentrations of harmful substances such as heavy metals, oils, and others (Tarawneh, 2018). Thus, designing an environmentally friendly building in Dammam requires the use of sustainable drainage systems. In Dammam, there is a significant company, the GE Manufacturing Technology Center, which is specialized in the generation of power, oil, and gas, and water not only in Dammam but the whole country (GE Power in Saudi Arabia, 2020). Despite the excess of oil and gas in the country, the significance of the construction field in the sustainable development program is quite high, since carbon dioxide emissions and electricity consumption per person and the number of buildings increased sharply due to economic growth, as well as population growth. Per capita CO2 emissions in Saudi Arabia is one of the highest in the world at 15.94 tons per person (Worldometers, n.d.). Moreover, according to Ahmed, Asif, & Alrashed,., (2019), Saudi Arabia's residential sector consumes about half of its electricity, as shown in Figure. These indicators confirm the need to develop a sustainable design for the construction of residential buildings.

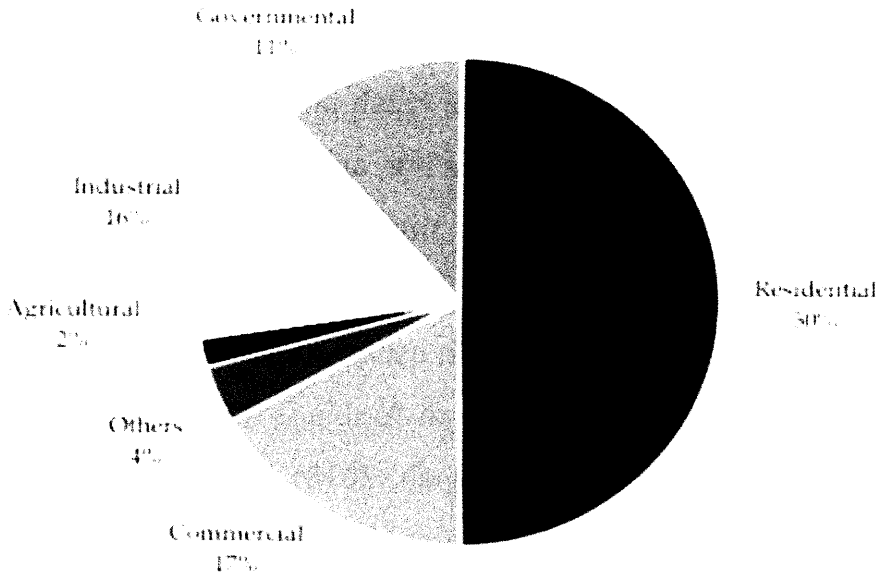


Figure 2. 1: Saudi Arabia's electricity consumption (Ahmed, Asif, & Alrashed, 2019, P.2)

Located in western Asia with a wide range of climates varying from the Mediterranean to the subtropical desert, Saudi Arabia has very severe climatic conditions, where all year long, it is hot and dry in most of the parts of the country, including Dammam. (Alardhi, Almasri & Alaboodi, 2020). This means that for long periods, structures are subjected to a wide range of solar radiation (Tarawneh, 2018). To account for the impacts of solar radiation and reduce the indoor temperatures for thermal comfort, buildings depend significantly on air conditioning, which uses around 80% of residential power in Saudi Arabia (Tarawneh, 2018). Thus, a sustainable home construction design should include the active use of passive ventilation to supply people with optimal thermal comfort while using the least amount of energy for air conditioning. The building sector in Dammam continues to depend on

inefficient methods, and houses are designed according to the conventional design process, which is linear and fragmented.

The city of Dammam city has a harsh hot desert climate. The period from March to October in Dammam is hot, and other months are just warm. Due to the proximity of the desert at night, temperatures can drop to zero degrees Celsius in the winter months. Also, there are often dust storms. Rain in Dammam is a rare occurrence, and it usually falls in small amounts during the winter months. The climate in Saudi Arabia is arid, and it has about 100 mm of precipitation annually (Tarawneh, 2018). The average annual wind direction in the city comes from the east. According to the Gaisma weather website, the sun in Dammam has the following path:

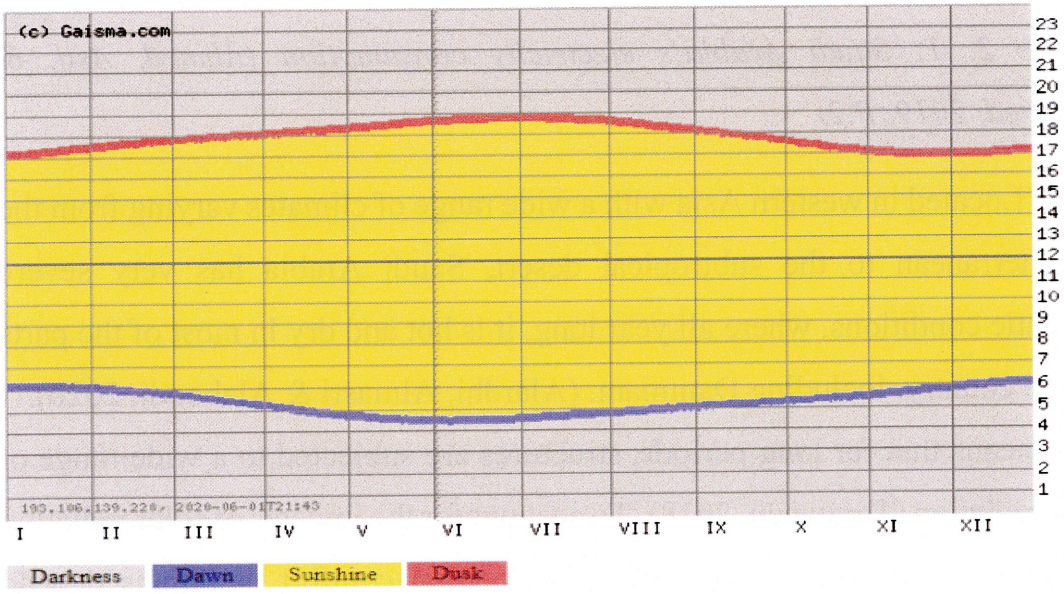


Table 2. 1:The sun path in Dammam (Gaisma website, n.d.).

Dammam has quality roads that connect it with other cities of the country. Traffic in the city is quite heavy, as the low price of cars provokes high demand among the population to buy their vehicles (Abubakar & Dano,

2019). As is shown in the table below, the majority of families in Dammam have one or two cars (Abubakar & Dano, 2019). As a result, Dammam has an ever-increasing number of traffic jams.

	Saudi families (%)	Non-Saudi families (%)
No car	4.97	28.72
One car	48.21	58.86
Two cars	25.28	7.78
Three cars and more	21.54	4.63
Total	100	100

*Table 2.2: Car ownership in Dammam (*Al-Surf, Balabel, Alwetaishi, Abdelhafiz, Issa, Sharaky,& … Al-Harthi, 2021*)*

It needs to be noted here that the total population of Saudi Arabia, as of March 2022, stood at 35.84 million (GMI, 2022). Over 30% of the Saudi population are non-Saudis (GMI, 2022). The neighboring territory includes the province of Ash Sharqiyah, as the city is located within the wealthiest oil region in Saudi Arabia (Mujan, Anđelković, Munćan, Kljajić, & Ružić, 2019). Dammam is a major industrial center, containing a rather motley conglomerate of nationalities. A large number of highly skilled Dammam workers are foreigners. The city has few tourist attractions, but it is known for its variety of restaurants and supermarkets. Moreover, Dammam is a strategic transportation hub. The railway line and the state highway connect the coast with the capital, Riyadh. Indeed, King Fahd International Airport, also called Dammam International Airport, is one of the three primary Airports in Saudi Arabia is near the city. The neighborhood context includes the quick development of Dammam infrastructure in the last two decades through land

reclamation and filling the Gulf Beach. In 2020, the area of the city covers about 800 square kilometers (Abubakar & Dano, 2019). Dammam is located near the state border, near Bahrain. For Saudi Arabia, Bahrain is an important trading partner. In 2020, the trade between Bahrain and Saudi Arabia reached a whopping $2.91 billion (Arab News, 2021). Dammam being near Bahrain provides an easy connection to carry out trades between the two destinations.

2.2 Sustainability of buildings in Dammam, Saudi Arabia

Faced with unexpected social and economic expansion, the Kingdom of Saudi Arabia has experienced fast urban development over the past years, particularly in its largest cities, resulting also in an increased number of towns, which totaled 285 in 2014 (Balabel & Alwetaishi, 2021). As a consequence, several contemporary urban difficulties have arisen. To respond to this challenge, the "Future Saudi Cities" initiative was designed and deployed to accomplish the region's sustainable development as a solution to the urban problems posed by its rapid expansion, as well as to promote the country's urban goal of attaining coordinated growth (Balabel & Alwetaishi, 2021). The "Future Saudi Cities" program is seen as a viable initiative that, through its specific aims and outcomes, is completely linked with the country's 2030 vision.

There are underlying concerns of ecological impacts in the context of sustainability of the cities in Saudi Arabia and other parts of the world. Energy, water, air pollution, and garbage are only a few examples of these concerns. According to Balabel and Alwetaishi,(2021), environmentally friendly cities in Saudi Arabia should strive to achieve optimal financial,

economic, societal, and ecological sustainability standards to operate more efficiently and productively.

Sustainable industrial buildings are those that are resource-efficient in their architecture, construction, and operation (Mujan, Anđelković, Munćan, Kljajić, & Ružić, 2019). The primary goal of sustainable construction techniques is to decrease the total influence on the environment and human health, as well as energy utilization (Shan, Wang, Hu, & Gao., 2019). The aspect of sustainable architecture continues to grab people's attention and generates heated discussion throughout the world. Because of their economical, societal, and environmental consequences, sustainable buildings have attracted more attention in the recent two decades, particularly in Saudi Arabia (Shan, Wang, Hu, & Gao., 2019). As a result, Saudi Arabia's investments in the sustainable building industry are presently the world's third largest, and the country is on track to becoming the sector's global leader (Balabel & Alwetaishi, 2021).

LEED ("Leadership in Energy and Environmental Design") certification system metrics are used widely across the globe to measure the level of sustainability in industrial buildings. The table shows the aggregate number of projects in Saudi Arabia and the United Arab Emirates that have been certified and accredited by LEED.

Country	No. of Registered Projects	Rating System	Rating Version	Certified Projects	
Saudi Arabia	159	LEED BD + C New Construction	LEED 2.2 LEED 2009 LEED v4	22	Platinum 4 Gold 9 Silver 7 Certified 2
United Arab Emirates	594	LEED BD + C New Construction	LEED 2.2 LEED 2009 LEED v4	139	Platinum 12 Gold 76 Silver 37 Certified 14

*Table 2.3: The aggregate number of projects in Saudi Arabia and the United Arab Emirates(*Al-Surf, Balabel, Alwetaishi, Abdelhafiz, Issa, Sharaky,& … Al-Harthi, 2021*)*.

However, certain LEED accreditation methods are not appropriate for usage in some nations, like Saudi Arabia (Alardhi, Almasri & Alaboodi, 2020). As a result, many sustainable construction evaluation methodologies have been devised and implemented that are especially suited to Saudi Arabia's architectural design. Saudi Arabia has therefore established a specific sustainable building grading system known as "Mostadam" to promote energy and water efficiency (Balabel & Alwetaishi, 2021). The grading system is a collection of three separate green building grading systems that depend on the kind of construction under consideration: residential structures, community, or commercial buildings (Balabel & Alwetaishi, 2021).

Mostadam is designed to meet the demands of the Saudi Arabian area, as well as the local environmental and climatic conditions. The advantages of Mostadam are numerous. This special green building scaling system is aimed at assisting Saudi Arabia to develop a more sustainable building sector and enhance the overall quality of building projects in the country. The grading

system's societal effect is also a positive since it is meant to boost Dammam and most of Saudi Arabia's economic growth and employment creation. Additionally, Mostadam is built under local regulations, with an emphasis on local architecture and tradition (Balabel & Alwetaishi, 2021). In general, such a grading system's activities will result in considerable energy savings in green construction. Some of the economic and social advantages that may also be realized include better living and working conditions, greater working efficiency, and improved ventilation. The graph below shows the suitability of Mostadam in comparison to LEED, in Saudi Arabia, which is mostly hot and dry, and therefore the main aim is to save water.

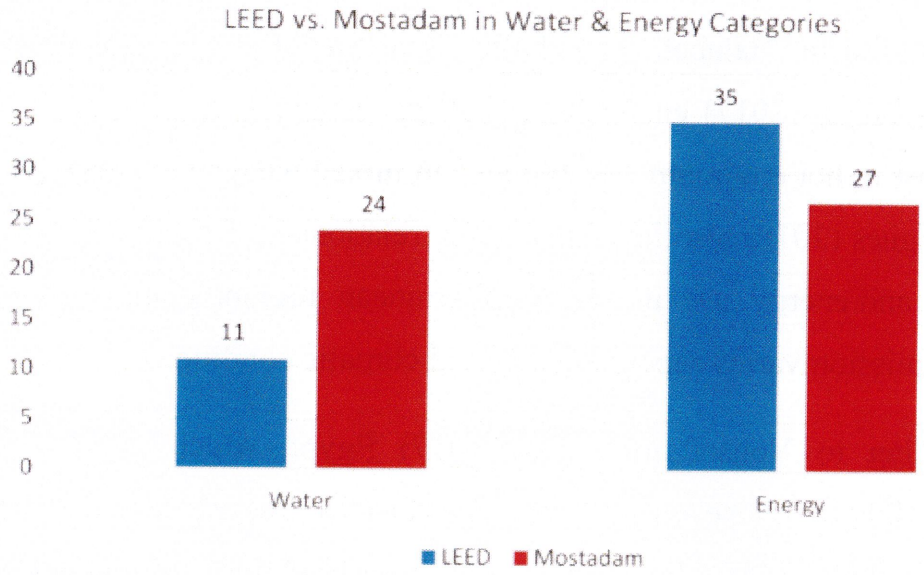


Figure 2. 2: The suitability of Mostadam in comparison to LEED, in Saudi Arabia. (Al-Surf, Balabel, Alwetaishi, Abdelhafiz, Issa, Sharaky,& ... Al-Harthi, 2021, p.19)

2.3 Indoor Environmental Condition

The indoor environmental condition may be influenced by some major aspects such as thermal comfort, airflow, and thermal mass, which is significantly related to thermal comfort (Alwetaishi, Balabel, Abdelhafiz, Issa, Sharaky, Shamseldin, & Gadi, 2020). Two categories of thermal mass include internal thermal mass, like equipment and partitions, and exterior thermal mass, like surfaces, walls, and ceilings. The usage of thermal mass has the potential to influence energy demand and the occupant's thermal comfort. Thermal mass is useful in sunny environments where outside temperature increases rapidly, as well as in cooler environments with hot summers (Alwetaishi, Balabel, Abdelhafiz, Issa, Sharaky, Shamseldin, & Gadi, 2020). Kumar (2017) emphasized that the usage of thermal mass is helpful not just in hot environments, but also in mixed weather patterns like India's. Rodrigues (2019) also investigated the relationship between thermal transmission and energy use in the Mediterranean region, claiming that thermal transmission varies depending on local climatic conditions.

According to Yousef and Lang (2017) Egypt, which has a hot environment, did a complete assessment using a historical structure made with stone and a modernized building constructed using bricks. According to the research, historic buildings have components that help to reduce interior air temperatures by 1.4 degrees Celsius (Yousef & Lang, 2017). Based on the research conducted by Kumar, (2017), thermal mass can relieve 40 percent of the 98 percent of inhabitants' discomfort. The modification of the appropriate evaluation areas in the grading systems should therefore be explored due to the relevance of indoor conditions in sustainable construction. As a result, a section entitled health and comfort has been established for

interior environmental assessment in the Mostadam grading system (Balabel & Alwetaishi, 2021).

Considering ventilation, Saudi Arabia has extreme weather conditions, which include hot and dry conditions all year across a large part of the nation, including Dammam. Buildings, therefore, have exposure to a considerable quantity of solar radiation for lengthy periods. To mitigate the impacts of solar radiation and reduce indoor temperatures, buildings rely significantly upon, air conditioners, which use around 80% of residential power in the country (Wolisz, Kull, Muller,& Kurnitski,. 2020). As a result, sustainability in house design must feature the effective utilization of passive ventilation to offer inhabitants optimal temperature satisfaction while consuming the least amount of energy by air conditioners (Alwetaishi, Balabel, Abdelhafiz, Issa, Sharaky, Shamseldin, & Gadi, 2020). However, in Dammam, despite these advances in techniques and rating systems, the building sector continues to rely on ineffective techniques, and dwellings continue to be constructed using outdated techniques.

A possible energy-efficient solution in Dammam could be as below:

Element	Description
Orientation	North–south
Finish Color	White
Window-to-Wall Ratio	7%
Shading	1 m horizontal overhang
Glazing	Double low-e (argon-filled) U-value: 1.5 $W/m^2 \cdot K$
Envelope	Added R-30 board insulation to walls and roof Wall U-value: 0.544 $W/m^2 \cdot K$ Roof U-value: 0.525 $W/m^2 \cdot K$
HVAC System	Split systems, COP = 3
Lighting System	LED (2.5 W/m^2)

Table 2. 4: Possible energy-efficient solution in Dammam (Ahmed, Asif, & Alrashed, 2019, p8).

2.4 Privacy and Building Design

Saudi Arabia's architectural layout is heavily influenced by the country's climate and topography (Alardhi, Almasri & Alaboodi, 2020). This is because it is located in western Asia with a wide range of climates varying from the Mediterranean to the subtropical desert (Alardhi, Almasri & Alaboodi, 2020).

Because of the various climatic changes in Saudi Arabia, various architectural designs and building techniques are used in Dammam. Residents in Dammam attempt to represent their firm loyalty to the Islamic faith and feeling of selfhood, through the way of living. Furthermore, consumers make an effort to arrange the internal areas of their homes according to their everyday requirements. As a result, Saudi Arabian building designs are usually impacted by the resident's social and privacy demands.

2.5 Saudi Arabian Residential Building Types

Residential structures are classified into three categories: contemporary building blocks with several apartments, mansions, and traditional dwellings (Alwetaishi, Balabel, Abdelhafiz, Issa, Sharaky, Shamseldin, & Gadi, 2020). In Dammam, advanced building blocks stand out. More than 55 percent of Saudi residents live in apartments, according to a poll done by Balabel, (2021) in his latest research on a total of roughly 1500 persons.

Furthermore, almost 40% claim that they reside in a different contemporary house or mansion, whereas fewer than 5% reside in traditional

residences (Balabel & Alwetaishi, 2021). These traditional dwellings are classified as historic structures since they were established around 1940 and were made of domestically sourced construction materials like stone and clay (Balabel & Alwetaishi, 2021). This kind of unique indigenous construction material offers the benefit of thermal mass, which helps a structure adjust to the hot environment in Saudi Arabia without the use of air conditioners.



Figure 2.3: Types of residential buildings found in Dammam (Alwetaishi, Balabel, Abdelhafiz, Issa, Sharaky, Shamseldin, & Gadi, 2020).

The three types of residential buildings found in Dammam are shown above: a mansion, a residential building block (apartments), and a traditional home designed with high-thermal performance respectively (Alwetaishi, Balabel, Abdelhafiz, Issa, Sharaky, Shamseldin, & Gadi, 2020).

2.6 Limitations to developing sustainable housing in Dammam, Saudi Arabia.

The most notable challenge to adopting sustainable home construction in Saudi Arabia, which employs smart technology, has been highlighted as a lack of public knowledge (Abubakar & Dano., 2019). To overcome the

challenges described in this research, increasing public knowledge of the necessity of having sustainable buildings and educating major project contributors in the development of sustainable buildings are both necessary. Furthermore, it is critical to use smart, sustainable building technologies, such as water conservation and sewage treatment facilities that are both durable and ecological. The community, government, and housing business must therefore all work together to make sustainable housing a reality. Popular support may be hampered by a lack of raised attention and comprehension of the terminology and concepts related to a sustainable building.

2.7 The "sustainable building" concept.

As we have seen in section 1.2, over 40% of emissions of greenhouse gases into the surrounding atmosphere are due to the functioning of buildings and structures (Balabel & Alwetaishi, 2021). That is why it is considered necessary to use innovative solutions when constructing sustainable buildings, which fulfills the objective of minimizing waste or even eliminating it, from the environment (Rothaermel, 2017). One of the initial stages of the implementation of the concept of sustainable and safe development of urban areas, undoubtedly, is the certification process, in which the developed building project is submitted to the certifying organization for the assessment (necessary and sufficient) of the submitted environmental solutions. Based on the results of the assessment, a conclusion can be made about the possibility of classifying the industrial buildings, following the proposed project, in the appropriate sustainable approach. It should be noted that abroad the term "green building" is used in the context of the "green building" standard, which most likely implies the normative document itself, within which certain

generally accepted and legalized norms and rules are regulated (Rothaermel, 2017).

However, this term also denotes a certain normalized indicator (norm), which is an established and legalized standard indicator, norm (or simply - a standard). Sometimes a "green building" standard is called a methodological document containing the characteristics of a set of specific regulatory indicators (standards) that an object classified as such construction must satisfy, and therefore, with this case, instead of the term "green building" standard, it is probably more logical to use the expression methodical document (methodology) (Kozien, 2021). It should be noted that the list of such normative indicators (standards) in the methodological document can be quite large. As a rule, within the framework of a specific methodological document, they are grouped in a certain way, defining the direction in which to act to achieve certain goals set during the design, construction, and operation of the facility (Kozien, 2021). For example, this approach can be used to assess the energy efficiency of the equipment of a constructed building, and the microclimate in its premises.

Of greatest interest are the currently existing mechanisms that allow one or another building to be classified as a structure erected following the principles of "green building". This interest is because of the technique can always be successfully used in solving a specific practical problem. It is known that several methodological approaches currently exist and are used abroad, detailed analysis and study of which allows (Kozien, 2021):

- Firstly, guided by the requirements set out in them, to determine to what extent the designed structure meets the requirements for "green building" objects (Kozien, 2021)
- Secondly, based on studying their general structure and requirements, the principles underlying their universality and applicability for various types of objects and natural conditions can be established (Kozien, 2021);
- Third, to establish how successful their adaptation in other countries is, considering the peculiarities of natural conditions and the specifics of the existing regulatory framework.

Such environmental standards have been developed and are successfully applied in several European countries: France, Germany, Finland, and Great Britain. They also exist and are used in Canada, Australia, India, and the United States (Kozien, 2021). Their diversity and number are associated with the variety of natural conditions in these countries, which to a certain extent affects the design features of the facilities, the technological and technical solutions used in the projects, and most importantly, on the scale and characteristics of the manifestation of the facility's impact on the environment.

2.8 Public associations, the so-called construction clusters.

The level of economic development of any country can be assessed by a large number of criteria, including the presence of industries that are competitive in the world market, which is also a derivative of many basic and specific factors and innovative ways of their development (Emas, 2015). The strategy for creating clusters is one of such development paths today. Interest in the theory of clusters increased in the 90s after the publication of several

works by the researcher, M. Porter. He defined a cluster as "a collection of physically contiguous linked enterprises and associated organizations functioning in a particular region, characterized by shared activities and complementary to one another," (Stead & Stead, 2010). Thus, it is imperative to consider the existing perhaps, 'the existing clusters of sustainable construction in Saudi Arabia:

2.8.1 Dom Architectura's Design.



Figure 2.4: Dom Architectural design (Jewell, 2014).

Islamic, or rather, Arab-Islamic architectural traditions have always had a fairly strong visual impact on architects and designers. The latest prime example is a project recently completed by Dom Architectura (2021) in Jeddah, Saudi Arabia, to build four completely modern homes. But in these residential buildings, traditional Islamic design features not only add aesthetic

appeal to the buildings but also ensure their functionality is fully in line with modern principles of sustainable construction (Dom Architectura, 2021). In the design of the buildings, Dom Architectura said they paid particular attention to bringing modern building designs in line with the challenging climatic conditions of Saudi Arabia. This is why they used several different Islamic architectural concepts, such as incorporating open spaces into enclosed spaces, limiting access to sunlight, and having many fountains and large plants (Dom Architectura, 2021).

As is customary in Islamic architecture, the ground floor is organized around a small central courtyard, built of concrete and wood, with a strict design style. The space is painted plain white to minimize solar radiation. Numerous gazebos located on the ground floor promote natural air circulation (Dom Architectura, 2021). Separate terraces throughout the house are used as transitional spaces to the interior. These outdoor areas are equipped with lush living plants and small fountains. The interior is striking with an abundance of natural light. A green garden, water, and light are often used to symbolize the Islamic understanding of the oasis of paradise, according to the Qur'an (Dom Architectura, 2021).

On the ground floor, there are three bedrooms and two bathrooms, surrounded by a long gallery-style terrace along the perimeter of the walls. Because this terrace is most exposed to the Saudi hot sun, it has large sliding shutters made of solid wood, perforated with Arabic patterns (Dom Architectura, 2021). The openings in the shutters provide the required level of privacy and shading.

2.8.2 The Hanifa Valley in Saudi Arabia

Another project was to rehabilitate a natural drainage system for the capital and the Hanifa Valley in Saudi Arabia, the largest and most prominent valley near Riyadh. This valley has been subjected to severe pressure during urbanization (Teller, 2012). Over time, the valley became filled with garbage and simply a dangerous place for human habitation. The local authority undertook to rehabilitate and recover the valley is on its journey to recover and has become a popular public space where residents of Riyadh can gather. Agricultural land is being rehabilitated and water treatment facilities are under construction to provide an additional source of water for the arid region (Teller, 2012).

The socio-political issues of everyday life are something that architecture can help solve. Buildings are not international treaties; they cannot solve all the problems of the world (Teller, 2012). However, buildings can be a powerful transformation tool in everyday life, both in being adapted to changes in the environment and the use of building materials and customs. Examples of these buildings are shown below.

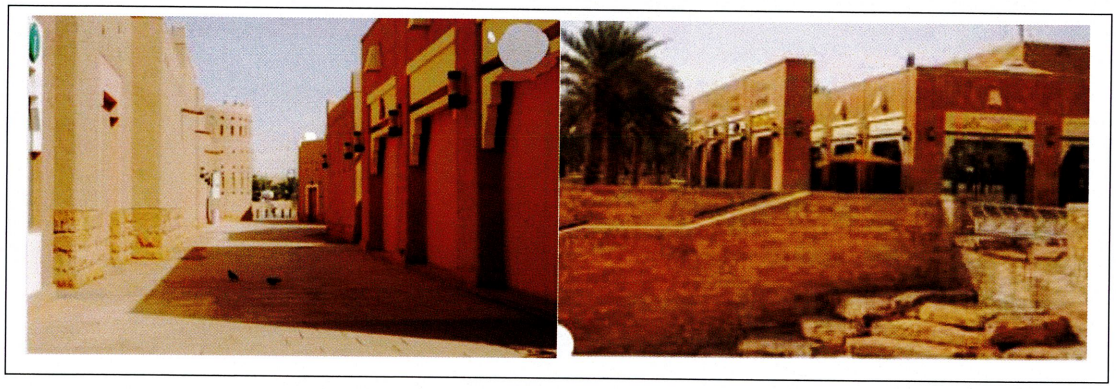


Figure 2. 5: Buildings in the Hanifa Valley, Saudi Arabia.

2.9 Executive summary

Sustainable building is the way forward for Dammam's building sector to address the challenge of global warming. This concept is a key instrument for accelerating sustainable construction. As a result, the idea of sustainable building was developed to include environmentally friendly practices into construction. The importance of sustainable building in environmental projects cannot be underestimated. Sustainable building has been identified in previous studies that buildings that minimize the environmental impact during the course of their life cycle. The path onward for this study has been chosen depending on an established strategy in research technique, to accomplish the objectives of this research and to answer the research questions posed earlier. The literature review will influence the research method and technique used in the methodology chapter and the following phases of this study.

Immense efforts are being paid out by Saudi Arabia and other nations to have sustainable buildings to reduce the negative effects caused to the environment such as pollution.

Chapter Three

Methodology

3.1 Introduction

The research methods have been chosen based on the study aims and objectives, considering the numerous research strategies and options offered by other researchers in the literature. The use of interviews for evaluating and monitoring data is considered an efficient qualitative research approach (Silverman,2010). Interviews are used as a data-gathering tool, and the method involves questioning, content analysis, and observations as an additional tactic. The interviews take a qualitative methodology, focusing on who, how much, what, where, and how many, as the major concerns. This strategy has been utilized to give a better answer to the shortcomings of previous research methodologies thus bringing information together. The literature review served as the foundation for determining the study orientation and next steps. A qualitative technique was used, after which, it was followed by a context analysis. As a result, interviews are a major contributor to this study.

3.2 Methodology and process for doing research.

This research was undertaken in several stages to meet the research goals and objectives and included the following forms: semi-structured interviews and unstructured interviews were used to engage experts in a conversation. Unstructured interviews are those in which just a few if any, questions are asked. They frequently go in the same manner as a typical discussion, but they are about the study issue under consideration.

3.3 Research process

There are four major stages that interviewees were involved in during the research interview (UMBC, n.d.).

Stage 1: The preliminary stage.

Introducing oneself and explaining why the interviewee has been selected for the interview.

Stage 2: The stage of assuming a character and establishing a relationship.

Preparation of questions also happens here so that the other party can assist in answering the research questions.

Stage 3: The stage of particular inquiries and actions.

By categorizing all queries and subjects into queries, one may put them in order. One may also check that they can quickly switch between queries and subjects.

Stage 4: The closing stage.

Short analysis and responses should be given concerning the interview. The interviewer must also make a composition of the data collected.

In case of a more detailed interview, the procedures below are followed.

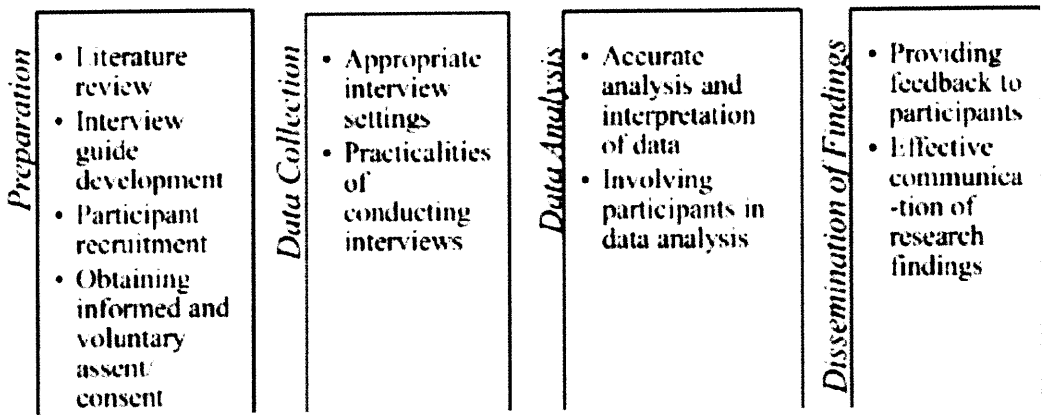


Figure 3. 1: Detailed procedures in a research interview (McGrath, Palmgren, & Liljedahl, 2018).

3.4 Data collection and procedures

While conducting the interview, the following questions were asked.

1. How can you describe sustainable building?
2. Most people believe that sustainable projects are more expensive; have you noted similar results, or would you suggest that this is a misleading argument? Why do you think sustainable buildings are more or less expensive than traditional frameworks?
3. What recommendations would you provide to somebody interested in getting into the expanding sustainable building industry?
4. Where do you think the future trends of the building sector in Dammam be?
5. Why do you think you should be concerned about sustainable building practices?

Table 3. 1: Interview responses.

	Interviewer1	Interviewer 2	Interviewer 3
1.	I would say that it is a comprehensive idea that relates to a building's total capacity to deliver a pleasant, hygienic, and productive environment throughout time while minimizing environmental effects.	Our lifestyle is causing us to perish. Our homes require approximately 40% of all the material and energy, and they account for 70% of our overall consumption. The ecological impact that has been created in the last century is a direct effect of how our houses are constructed. Sustainable building is a solution to all these problems. This means that sustainable building is an ecologically friendly lifestyle.	It is a way of considering buildings that conserves water, reduces energy usage, betters indoor air quality, and reduces human reliance on environmental assets. Although the underlying principles for sustainable buildings have been present for years, the building industry's environmental protection has just recently exploded, with biodiversity as the main factor.
2.	This is a deceptive remark frequently made by businesses and organizations in opposition to the current changing market. My justification for this is that; designing and building a sustainable structure entails seeking connections, achieving more with less, and searching for cost reductions in a cross-disciplinary, comprehensive manner.	This is a typical illusion spread by inexperienced clients and engineers who are frightened to construct in a new method. This is because skilled architect understands how to save costs for their customers. The cost is as well specified by the customer, and a development task should be completed within that budget. There is no explanation why you cannot develop a sustainable building at a similar cost or even less compared to	This is a misleading argument! The problem emerges when attempting to equate "apples and oranges." When evaluating a house with solar energy to a traditional house lacking solar panels, for example, the traditional house seems to be less expensive. This is exclusively concerned with the construction costs up ahead. This approach ignores the fact that a house with solar panels will start producing power right away, cutting your monthly power

		a traditional building if you have a precise budget in mind.	expenditure. The solar house's lifespan expenses will be substantially lower. This monthly advantage, known as a return on investment, soon covers any extra initial costs for solar panel installation.
3.	I would not hesitate to tell them to start the business. It is for sure profitable than ever, to the side of business owners, to the public, and to the environment at large.	I would advise them to first understand how to implement various sustainable buildings, management standards, and operational plans. They should also include sustainable aspects while starting constructions and making modifications to existing buildings, to raise the worth of their assets.	I would tell them to incorporate their sustainability skills into all of their offline and online promotional strategies. The good thing about sustainability is that once they have learned them and are prepared, they are the same in any place. Because of this, numerous produces in Europe and other areas of the globe have adjusted and are delivering and developing their businesses overseas.
4.	Through my research, the loosening of regulations, the gradual improvement in the global economic situation, and developments in the healthcare industry are expected to help the industry's production this year. The industry is however expected to rebound in 2022, rising by 3.2 percent, then expanding by 4.3 percent for the rest of the projected timeframe (2023-2025).	The government's emphasis on general building projects, as well as utility building projects and energy, is likely to enhance the industry's productivity during this period, as it seeks to diversify its economy.	Conserving the environment in Dammam can greatly increase its future chances of climatic changes. The hot region, as described, can form a new shape of Saudi Arabia.

5.	Sustainable buildings are well-planned, built, and managed to improve inhabitants' well-being while minimizing negative consequences on society and global ecosystems. Buildings absorb 40% of the total energy across the globe, 25% of the globe's wood supply, and 16% of the earth's water. A green constructed home relieves part of this burden on the ecosystem in comparison to traditional buildings.	Sustainable architecture is the healthier, common-sense solution for a good life because many of us live more than 90% of our lives indoors. Because of building materials, poor lighting, and several other factors, the condition of the interior environment is significantly worse than the condition of the outside environment in traditional buildings.	I can only state this out by listing the potentials of sustainable building. Enhance long-term economic success by providing a cleaner and more friendly atmosphere, Utilize energy and water-saving technology, Increased resale value by reducing waste materials, Improving the condition of the indoor environment and the comfort of the inhabitants, and are more durable and require easy maintenance.

Chapter Four

Results, Discussion, And Recommendations

4.1 Results

Following the methodology that was employed in this research, sustainable building is brought out as the best strategy towards eco-friendly living. Interviews conducted on the three experienced individuals above have shown several major areas of concern. These include advantages of sustainable building implementation, the future of the sustainable building industry, specific strategies that are important while getting into the sustainable building industry, and the general aspects of sustainable building.

It has been noted that there are numerous advantages of having sustainable buildings. First, as described by the first interviewee, these buildings are well-planned, built, and managed to improve inhabitants' wellbeing while minimizing negative consequences on society and global ecosystems. The second interviewee focuses and describes the advantage as the 'healthier, common sense for a good life.' Moreover, the last interviewee lists several advantages such as economic success, better indoor environment, durability, and the use of energy and water-saving approaches.

The future of sustainable building construction has also been advanced as efficient to enhance the industry's productivity as it seeks to diversify its economy. It is also anticipated that it will contribute to improving the climatic and environmental conditions of Saudi Arabia in due course. Additionally, the industry is expected to rise and expand over the next few years.

Specific strategies that pave the way to broadening the sustainable building construction industry have also been identified. As seen, they include; understanding how to implement various sustainable buildings, management standards, operational plans, and sustainable aspects. Moreover,

they should incorporate their sustainability skills into all of their offline and online promotional strategies.

Other general aspects of sustainable building have also been identified. Sustainability has been found to deliver a pleasant, hygienic, and productive environment throughout time while minimizing environmental effects. Furthermore, it minimizes energy usage, conserves water, betters indoor air condition, and minimizes human reliance. Finally, sustainable buildings - by reducing greenhouse gas emissions and impacts on climate change have a major part to play in preserving biodiversity.

4.2 Discussion

Industrial buildings have a massive environmental effect. The building industry accounts for 40% of overall energy use in developed nations (Wolisz, Kull, Muller,& Kurnitski,. 2020). In the worldwide economy, the construction industry utilizes a comparable share of all resources. Several other industries have as big an influence on sustainable development as the building industry, where environmental issues have developed for a while. This raises concerns for a safe environment, and sustainable building comes in as the solution.

The need for green construction materials that are produced from natural sources rather than nonrenewable alternatives is a key consideration to be made in a sustainable building. Sustainable resources are ecologically friendly since their effects are evaluated throughout the life cycle of a product. An examination of environmentally friendly materials must include one or several of the following conditions, based on the development's unique goals: energy efficiency, material efficiency, indoor air quality, water management, and cost (Mujan, Anđelković, Munćan, Kljajić, & Ružić, 2019). Energy and

material efficiency are two of the most important factors to consider. Following the creation of construction-specific sustainability goals, specification and product selection may proceed.

4.2.1 The building Life Cycle and Sustainability Considerations.

Several macro standards or "sustainable needs" in the layout of a building are part of the inventive concepts of a sustainable building. As a result, the structure must adhere to world-wide sustainable features that are established concerning goals and needs. These should be addressed throughout the life cycle of a building, including designing, development, operation, and incorporation.

Preventing risks and promoting safety. Safety refers to an accident-avoidance policy that safeguards the physical wellbeing of anybody in or around the structure, especially while building, renovating, and maintaining. The primary objective of this strategy is to avoid workplace accidents.

Environment. It is important to weigh the pros and cons of different building locations. Furthermore, the usage of ecological resources with a reduced environmental effect should be evaluated to minimize the amount of energy usage. It is also possible to investigate the utilization of recyclable materials. The last stages of a building's life cycle include controlled destruction and garbage treatment, which can help to reduce the total environmental effects.

Functionality. Functional blueprint indicates that specific tasks can be readily carried out without encountering any building-related issues. The amount of space allocated in the building for functional adjustments should be

evaluated in event of future economic development that would necessitate additional development. This would decrease the demand for new materials, thus cutting economic expenses, and eliminating any possible losses. To counteract potential difficulties, the indoor setting and atmospheric environment should be correctly configured.

Economy. The building's economic requirements should be carefully considered during construction, as well as management and protection operations during its lifetime. To achieve sustainability, it is critical to coordinate consumption habits all through the building's lifespan.

4.3 The system of a sustainable building.

The review of literature has shown a clear consensus on the elements of sustainable building. From this, we can infer the elements of sustainable building. It has been established that industrial building is one of the most striking examples of anthropogenic activity that has a serious negative impact not only on individual components of the environment but also on the sustainability of urban ecosystems. Therefore, at present, the concept of sustainable building is becoming more widespread, embodying the key principles of sustainable development in the building sector. The scope of the building sector shows that the building process is sustainable if the guidelines of sustainable development of an urban area are used within the framework of the integrated construction cycle. These are raw material extraction and processing, designing, construction, demolition, and waste disposal.

This process is focused on sustaining a balance between the natural and manmade surroundings, supporting economic benefit while honoring human dignity. The focus on sustainable building principles accompanies the use of

environmentally friendly resources with the desire for efficiency, usefulness, longevity, and comfort, and entails the most effective and least damaging utilization of energy, land, water, and other sorts of resources. Sustainable buildings, therefore, use renewable energy sources and ecologically friendly materials, encourage the use of natural materials, accumulate, and use atmospheric water. As a result, as mentioned earlier, sustainable buildings can save between 24%-50% in energy consumption, 30% in carbon emissions, 40% in water usage, and 70% in solid water generation (Wang and Adeli, 2013).

The execution of the following techniques is required for the development of a sustainable building system:

1. Site design for the building location:

1.1. Reducing the loss of precious land and green regions to a minimum.

1.2. Retaining the pace of urban growth, renovation, and new construction at a greater level.

1.3. Performing a complete examination of the building site to preserve the region's natural value.

1.4. An integration of design and implementation aimed at reducing devastation of regions where development is taking place, as well as habitat conservation and regeneration.

2. Water quality and reduction in its use:

2.1. Preservation of the existing water cycle, design, and construction with an approximation to natural hydrological systems.

2.2. Minimizing inefficient water use at the construction site, maximizing treatment and reusing of water, including stormwater, rainwater, and wastewater.

3. Energy and environment:

3.1. Minimizing adverse environmental impacts through site optimization, designing, selection of materials, and proactive energy conservancy actions.

3.2. Maximum utilization of renewable and other low-grade energy sources.

4. Indoor environmental standards:

4.1. Maintaining a pleasant and healthy indoor climate.

4.2. When designing buildings, take into account the parameters of indoor air quality, natural ventilation, thermal comfort, lighting, and efficient management over environmental parameters. However, shading, orientation, insulation among other factors play a major role in a building's sustainability. The table below represents the amount of energy and carbon emission reduced as a result of using the sustainable methods shown.

Table 4.1: Reduced amounts of energy and carbon emission (Ahmed, Asif, & Alrashed, 2019, p13).

Element	EUI (kWh/m²/year)	Energy Consumption Reduced (%)	Total CO_2 Emission of House (kg/year)
-	148.8	0.0	43,840
Orientation	146.1	1.9	43,024
W–W Ratio	146.0	1.9	42,991
Finish Color	144.5	2.9	42,564
Window Shading	143.9	3.3	42,387
Lighting	145.3	2.4	42,800
Glazing Type	141.3	5.1	41,619
Envelope Insulation	119.0	20.0	35,065
HVAC	97.1	34.7	28,613
All Solutions	**72.5**	**51.3**	**21,350**

5. Resources and materials:

5.1. Using non-renewable construction materials and resources as little as possible through effective design and waste management.

5.2. Optimum use of recyclable and innovative resource-saving products, as well as biologically based components.

The computerized Life Cycle Assessment (LCA) approach created by the International Standards Organization (ISO) is the primary instrument for analyzing environmental sustainability in the pursuit of sustainable building objectives. The application of green building techniques is centered on the utilization of "green technologies," which are new solutions developed based on ecological sustainability, resource conservation, and reusability.

4.4 Conclusion

The importance of sustainable building in green initiatives cannot be underestimated. Sustainable building has been identified in previous studies as a way to speed up the creation of environmentally friendly environments. A review of studies above has also shown that the "Mostadam" grading system

for the assessment of new and existing residential structures was successfully created, centered on Saudi Arabia's Vision 2030 for attaining sustainability success in all areas, particularly in housing developments. Despite this, Saudi Arabia still has a relatively small percentage of percentage of fully sustainable buildings in comparison to the rest of the Gulf regions.

This research has helped in identifying and outlining concepts related to sustainable building, the benefits encountered, the building life cycle and sustainability considerations, of buildings in Dammam, Saudi Arabia, and the world at large. At present, much has been done to systematize and develop a strategy for sustainable urban development to eliminate the contributions of the building industry to the climate crisis. Sustainable architecture and construction play a decisive role in this context. The expansion of the research method used was achieved through interviewing three professionals, who determined the assessment path, identifying criteria, metrics, and a specific direction of focus. This research can be used as a starting point for additional investigation on industrial building sustainability.

4.5 Recommendations

A collection of critical challenges is experienced in a non-sustainable building environment as shown within this study. It is advisable to implement sustainable building to avoid the negative repercussions faced. Sustainable building approaches in building projects recommended include:

- Recycling and utilizing recycled materials whenever possible.
- Conservation of water.
- Conservation of energy and increasing the use of renewable sources of energy.

- In the construction, repair, and retrofit of buildings, the condition of the interior airflow should be safeguarded.
- Sites that have been constructed should be cleaned up and reused.
- Clean diesel should be used throughout the building cycle and thereafter.
- Implementing ecologically sustainable infrastructure and surroundings.

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APPENDIX 1

Sustainability Questionnaire

Company Name: _____

Business Leader Name:

1. Please describe your experience in your industry and/or in your business sector in general. (Open Ended)
2. How many years of experience do you have? (Provide a number)
3. Please describe your role in the management team of a building in the industrial city. (Open-ended)
4. How many workers are employed in your building? (Provide a number)
5. Do you think the building can be improved to help working conditions? (open-ended)
6. Do you believe that better construction design for your building can help facilitate the workers? (Close Ended)

   Yes **No**

7. When constructing a new work facility, how do you design so that improvements in workflow and employee productivity are realized? (Open-Ended)
8. When constructing a new facility, how do you design for sustainability? (OPEN-ENDED)

9. In these pandemic times, we hope your employees are staying healthy. How are you ensuring the safety of your employees during COVID-19? (Two-part question. Part one open-ended)

   I. Furthermore, the current COVID-19 virus is believed to spread more rapidly in enclosed spaces. Therefore, in your opinion, do you think the presence of an open space can reduce the risk posed to your employees of contracting the virus? (Close ended)

   Yes **No**

10. Does your organization have a written policy, commitment or vision stating that it will operate in an environmentally sustainable manner? If yes, please provide documentation. (Close ended)

Yes **No**

11. How does your organization and you as a business leader, do your best to preserve and sustain the environment including your impact on waste, water, land air? (Open ended)

12. In your opinion, what are the most effective changes currently being implemented by the Saudi government that can result in progress on the sustainable development agenda? (Open Ended)
13. What are some of the latest trends in sustainable development? (List)
14. Can they be easily adapted for Saudi Arabia? **(Open ended)**

APPENDIX 2

استبيان الاستدامة

اسم الشركة: .....

اسم مدير وقائد الأعمال:

1. الرجاء وصف تجربتك في مجال عملك الخاص و / أو في قطاع عملك بشكل عام. (سؤال مفتوح)
2. كم عدد سنوات الخبرة لديك ؟ (أكتب رقمًا)
3. الرجاء وصف دورك في فريق إدارة مبنى في المدينة الصناعية. (سؤال مفتوح)
   (الجواب: يتمحور دوري حول البحث عن ممارسات إدارة العقارات المستدامة وتنفيذها والتي تؤدي بشكل مباشر إلى تحسين بيئة العمل وكذلك استدامة المبنى).
4. كم عدد العمال العاملين في المبنى الخاص بك ؟ (أذكر رقمًا)
5. هل تعتقد أنه يمكن تحسين المبنى للمساعدة في ظروف العمل ؟ (سؤال مفتوح)
   (الجواب: نعم، لا تعتمد استدامة المبنى كليًا على تصميم البناء، ولكن لها أيضًا علاقة عميقة بممارسة الإدارة. لذلك، أعتقد أنه إذا تم تنفيذ ممارسات الإدارة المستدامة، فيمكن تحسين استدامة المباني.)
6. هل تعتقد أن تصميم البناء الأفضل للمبنى الخاص بك يمكن أن يساعد في التسهيل على العمال ؟ (سؤال مغلق)

   نعم لا
7. عند بناء مرافق عمل جديدة، كيف تقوم بتصميمها بحيث تحقق التحسينات في سير العمل وإنتاجية الموظفين ؟ (سؤال مفتوح)
8. عند تأسيس منشأة جديدة، كيف تقوم بتصميمها للاستدامة ؟ (سؤال مفتوح)
   (الجواب: عندما نقوم بتأسيس منشأة جديدة، هناك عدد من العوامل التي تؤخذ في الاعتبار والتي لها علاقة مباشرة بالاستدامة، على سبيل المثال، نهدف إلى استخدام التقنيات والتصميمات وطرق البناء التي لا تؤدي فقط إلى انخفاض تكاليف الطاقة، ولكن تؤدي أيضًا إلى انخفاض استخدام الطاقة).
9. في ظل هذا الوباء، نأمل أن يكون موظفوك بصحة جيدة. كيف تضمن سلامة موظفيك خلال تفشي فيروس كورونا المستجد COVID-19 ؟ (سؤال من جزأين. الجزء الأول مفتوح)
   ا. علاوة على ذلك، يُعتقد أن فيروس كوفيد-19 COVID-19 الحالي ينتشر بسرعة أكبر في الأماكن المغلقة. لذلك، في رأيك، هل تعتقد أن وجود مساحة مفتوحة يمكن أن يقلل من المخاطر التي يتعرض لها موظفوك للإصابة بالفيروس ؟ (سؤال مغلق)

   نعم لا
10. هل لدى مؤسستكم سياسة أو التزام أو رؤية مكتوبة تنص على أنها ستعمل بطريقة مستدامة بيئياً ؟ إذا كانت الإجابة بنعم، يرجى تقديم الوثائق. (سؤال مغلق)

    نعم لا
11. كيف تبذل مؤسستك وأنت كقائد أعمال قصارى جهدكم للحفاظ على البيئة واستدامتها بما في ذلك تأثيركم على النفايات والمياه والهواء ؟ (سؤال مفتوح)
12. في رأيك، ما هي أكثر التغييرات فعالية التي تنفذها الحكومة السعودية حاليًا والتي يمكن أن تؤدي إلى إحراز تقدم في أجندة التنمية المستدامة ؟ (سؤال مفتوح)

13. ما هي بعض آخر الاتجاهات في مجال التنمية المستدامة ؟ (اذكر)

14. هل يمكن تكييفها بسهولة في المملكة العربية السعودية ؟ (سؤال مفتوح)

APPENDIX 3

meeting request

<ghadahaldossary@gmail.com> **Ghadah Aldossary**

Dear Family,
hope this email finds you well.

Just to confirm our discussion
This is Ghadah aldossary a student in the Master of Enviroment and Sustainable Development porogram at University of Bahrain. Currently. I'm writing my thesis on Industrial Building at Dammam, Saudi Arabia. I would be honered to have the chance of meeting tomorrow 14-08-2020 Monday afternoon at 1 30 pm to collaborate in my educational study

kindly find the attached questionnaire to know more about the questions.
thank you in advanc.

Sincerely,
Ghadah Aldossary
ESD Student

Questionnaire.docx

الملخص

يعد البناء المستدام خطوة مهمة لقطاع البناء في جميع أنحاء العالم من حيث كونه أكثر وعيًا من الناحية البيئية وأنه أداة رئيسية لتحسين الإجراءات لمكافحة الاحتباس الحراري. وهناك العديد من القطاعات الأخرى التي لها تأثير كبير على التنمية المستدامة مثل قطاع التشييد ، حيث أصبحت قضايا الاستدامة عاجلة بشكل متزايد. ونتيجة لذلك، ظهرت فكرة البناء المستدام لتشمل مبادرات الاستدامة في مشاريع التشييد. من ناحية أخرى، فإن البناء الصناعي المستدام هو الأقل شهرة ومعرفة، ولا يزال هذا المفهوم جديدًا نسبيًا في أعمال البناء في المملكة العربية السعودية. وبالتالي، تحدد هذه الأطروحة طريقة موصى بها لفحص قدرات البناء المستدام بقطاع التشييد. يستند البحث إلى مقابلات مع شخصيات رئيسية بقطاع الصناعة ومسح مكتبي لمؤلفات بحثية رئيسية. يتم تقديم النتائج والتوصيات للبناء الصناعي المستدام لاحقًا.

جامعة البحرين

كلية العلوم

برنامج البيئة و التنمية المستدامة

البناء الصناعي المستدام:

دراسة استقصائية

البحث المقدم لاستكمال متطلبات الحصول على درجة الماجستير في البيئة و التنمية المستدامة–

العمارة المستدامة

إعداد الطالبه:

غادة عبدالله الدوسري

20171231

تحت إشراف:

د. ماثيو هاردي

جامعة البحرين

بالتعاون مع مؤسسة الامير بالمملكة المتحده

مملكة البحرين

مايو 2022