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The role of engineering consultation offices to achieve sustainable environmental built environments in Saudi Arabian context

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Abstract. In Saudi Arabia, scientific solutions for achieving a sustainable built environment tend to be initiated in engineering consultation offices. These address a client's social requirements, as well as the regulations for project approval at both the urban and architectural level. This paper investigates how far the role of engineering consultation offices meets environmental requirements in relation to the regulations as well as fulfilling social needs. The study primarily employed an analysis of a survey of experts that included members of engineering consultation offices, and decision makers in the Ministry of Municipal, Rural Affairs and Housing, along with a number of academics working in the field of the built environment. The sample included sixty experts from various institutes, including engineering consultation offices, the Ministry of Municipal, Rural Affairs and Housing and universities. The analysis focused on the quality of these projects' outputs in relation to environmental requirements, as well as the clients' influence on the final output of the project in relation to social needs. The findings reveal that clients tend to play a significant role in the final design of projects prioritizing social considerations. This also indicates that some engineering consultation offices need to orient their designs to take into account environmental issues, including demonstrating them through the application of simulation tools. The panel of experts evaluated several solutions for improving the environmental design of the Saudi built environment and the study concludes by offering recommendations for both engineering consultation offices and their clients.

Keywords: Saudi built environment; environmental design; Environmental control; urban and architectural development.

1. Introduction

It is now widely recognized throughout the globe that sustainable design is essential at both the urban and architectural level, in order to establish a sustainable environment. Many developed countries now apply assessment methods to control and manage existing and future projects (i.e. BREEAM and LEED) [1, 2]. The integration of intermittent generation, which has a low capacity value, with potentially significant increases in peak demand due to electrification of transportation and heating could result in a significant decline in the utilization of producing infrastructure and energy network assets [3]. System integration expenses are therefore anticipated to rise significantly [3]. In a climate, such as that of Saudi Arabia, with a substantial variation in diurnal temperature, the courtyard has proved one of the most important sustainable and environmental solutions for domestic dwellings and other types of buildings [4, 5]. The importance of a sustainable and comfortable built environment is currently confirmed by widespread discussions concerning the issues of global warming and climate change, along with the depletion of fossil resources, and concerns related to energy security. This therefore indicates a need to reverse current trends in the use of energy, including the level of CO2 emissions found in the construction industry [4, 5].

The challenge of meeting these aims requires creative research to increase the utilization of renewable energy sources, alongside the application of new technologies and methods [6, 7]. Due to the importance of the sustainable built environment (including the development of an urban society), it is important to highlight the role of social cultural impact. Hence, environmental challenges such as climate change and urban population expansion remain at the core of community aims concerning the future [8-10]. Furthermore, social and cultural issues are important factors in the concept of sustainable development, as they shape the attitudes of citizens and communicate the need for sustainability and an environmentally friendly built environment [11]. Sustainable development is therefore an effective factor when it comes to a community and its local culture, so influencing projects undertaken in the local built environment [8, 10].

Between 2018 and 2020, the price of gas on international market plummeted precipitously, leading Saudi Arabia to develop its 2030 Vision [12], which aims to ensure the country becomes a model for a sustainable society and lifestyle, in particular by minimizing its reliance on oil and creating a more environmentally friendly built environment [12]. Saudi Arabia currently consumes

approximately three times the energy per capita in comparison to other countries [12]. The residential sector makes a significant contribution, representing approximately 50% of the nation's annual energy use [12]. The Saudi Vision 2030 initiative encourages improvements in the management of energy consumption, in line with the need to address both economic and environmental concerns [13]. This research is divided into the following five main sections: (1) Introduction; (2) Methodology; (3) Results and Analysis; (4) Discussion; and (5) Conclusion and Recommendations. This exploration identified the gaps on which engineering consultation offices can focus in order to establish a sustainable built environment in Saudi Arabia, in accordance with its climatic conditions and cultural challenges.

2. Methodology

This study interviewed experts working in engineering consultation offices focused on achieving a sustainable built environment. These experts were appointed under criteria practiced in the design of future homes and neighborhoods in Saudi Arabia. They included heads of engineering consultation offices and decision makers in the Ministry of Municipal, Rural Affairs and Housing responsible for design approvements, along with a number of academics focusing on the field of built environment.

3. Aim and Objectives

Due to the final design of projects being reliant on engineering consultation offices, such offices are responsible for designing future projects in accordance with environmental issues and the roles of the Ministry of Municipal, Rural Affairs and Housing. The main aim of engineering consultation offices can be met by answering the following research questions.

- **RQ1:** How many sustainable environmental principals will be employed in future projects?
- **RQ2:** How great is the impact of engineering consultation offices in future designs of projects?
- **RQ3:** What is the impact of clients on the final design of future projects?
- **RQ4:** How can the construction industry be encouraged to move towards environmental sustainability?

In order to answer these research questions, this study examined the design of future projects from the point of view of the requirements of the clients, as well as the role of engineering consultation and the responsibilities of decision makers at the Ministry of Municipal, Rural Affairs and Housing. Furthermore, in order to investigate approved projects in terms of their environmental design, this study employed a questionnaire to examine current designs for future homes, projects and neighborhoods. The questionnaire focused on client requirements in terms of environmental issues, along with their future needs. In addition, it aimed to examine the role of engineering consultation in the application of environmental solutions in both the design of homes and neighborhoods, as well as the use of renewable energy sources and other environmental principals. The effectiveness of the designs from the engineering consultation offices was evaluated by the experts from the Ministry of Municipal, Rural Affairs and Housing, along with a number of academics and engineering consultants.

4. Expert Sampling

In drawing up the sampling criteria, it was important to take into account the identify of those contributing directly to the built environment. The sampling was therefore selected to include the following.

- **Engineering consultants:** These represent the first design step in collaboration with the client. These experts revealed the challenges they faced when it came to the lack of environmental principles found among their clients. This consultation therefore helped identify the reasons behind the current design of the built environment. The study took into account their levels of skill and experience, with the consultation including a variety of expert panels.
- **Contractors:** These are responsible for constructing the project on the basis of the final approved design. They can transfer their experience from the site itself, and identify weaknesses related to the design. Furthermore, they can highlight any change required in the design during construction period.
- **Urban developers:** These design and construct their own projects, selling them through real estate agents. They were essential for this study, due to their role in the current built environment of Saudi Araba. Developers liaise both the engineering consultation office and contractors, indicating that their contribution supports the result of this study.

- **Municipality specialists:** These are members of the engineering consultation office responsible for approving final designs. These experts review and critic designs in relation to the regulations, and can identify any weaknesses. Hence, their contribution supports the result of this study, due to their roles being that of a third party, working with clients, engineering consultation offices and developers.
- **Academics working in the field of built environment:** These included those with a PhD in Architecture, Urban Planning, Landscape Architecture or Civil Engineering, due to their knowledge and scientific approach to achieving a sustainable built environment. As a result of their work in Saudi universities, these experts possessed considerable experience of the built environment of Saudi Arabia. Their consultation supports the results and contributes to the output of this study.
- **Regional development authorities and other related specialists:** These experts include those working in development regional authorities responsible for urban and architectural projects. They contributed their expertise and supported the study through their evaluation of current homes and neighborhoods. Due to their experience in large urban projects for urban development, they were familiar with local engineering consultation offices and were able to identify how sustainable built environment needed to become a priority for the country of Saudi Arabia.

5. Consultation Dimensions

The study employed four main dimensions to determine the quality of current projects in terms of promoting a sustainable environment.

Firstly, the method of selecting the design from the point of view of the client, including in relation to social needs, recommendations and an ability accept the application of environmental principles. This dimension analyzes the ability of clients to accept environmentally-friendly designs and their roles and responsibilities when it comes to environmental protection. In addition, it determines the influence of the client on the engineering consultation office when it comes to the drawing up of the final design.

Secondly, the need of sustainable design for neighborhoods, along with the responsibility of engineering consultation offices to enforce the use of sustainable design and therefore to plan sustainable environmental projects even if this is against the interest of the client. This dimension

focuses on the priorities of engineering consultation offices when it comes to the design of projects in accordance with environmental criteria and principals.

Thirdly, the application of new simulation software tools capable of supporting decision makers in the final design of the project, including determining how far this meets the criteria relating to sustainability and predictions of energy consumption. This aspect evaluates how engineering consultation offices engage with software simulation tools as a part of the design process and to draw up a report to enable a decision. In addition, it includes the development of skills for engineering consultants.

Fourthly, public awareness of the need for sustainability in the built environment, including determining their knowledge of the importance a conducive built environment in Saudi Arabia.

6. Results and Analysis

This study analyzed the views of experts concerning the factors required to achieve a sustainable built environment. This included sixty experts from various institutes related directly to the built environment of Saudi Arabia, i.e. (1) a number of engineering consultation offices working on design projects in Saudi Ariba; (2) engineers and decision makers dealing with the built environment whose role is to approve projects in the Ministry of Municipal, Rural Affairs and Housing, and developers and other institutes. These are detailed in Table 1, below:

Table (1). demographic information of selected experts

Expert description	**Percentage (%)**
Engineering consultation office	34.5
Contracture	3.7
Urban developer	5.4
Municipality specialists	12.7
Academia in built environment field	21.8
Specialist in development authority	5.5
Other relater specialist	16.4
Total	100
Subject field	**Percentage (%)**
Architecture	42
Urban planner	24
Civil engineer	29
Other subject related to the built environment	5
Total	100
Years of experience	**Percentage (%)**
Less than 5 years	9
From 5 to less than 10 years	20
From 10 to less than 15 years	22

From 15 to less than 20 years	18
Over 20 years	31
Total	100

7. Design Concept

The analysis presents how design is being currently performed in relation to both urban and architectural factors. A design concept can be provided (or suggested) by the client, including how it addresses cultural and social needs. Furthermore, engineering consultation offices can lead and manage the design concept by providing a number of development models, focusing on the input of experts. These existing models can consist of those drawn up by a previous client, designed to address social needs but lacking the necessary environmental principals. Figure 1 (below) presents the views of experts concerning the preparation of a design concept, revealing that over 20% of respondents confirmed that, while engineering consultation offices can initiate a new design for each client, these designs can still lack the inclusion of environmental principals.

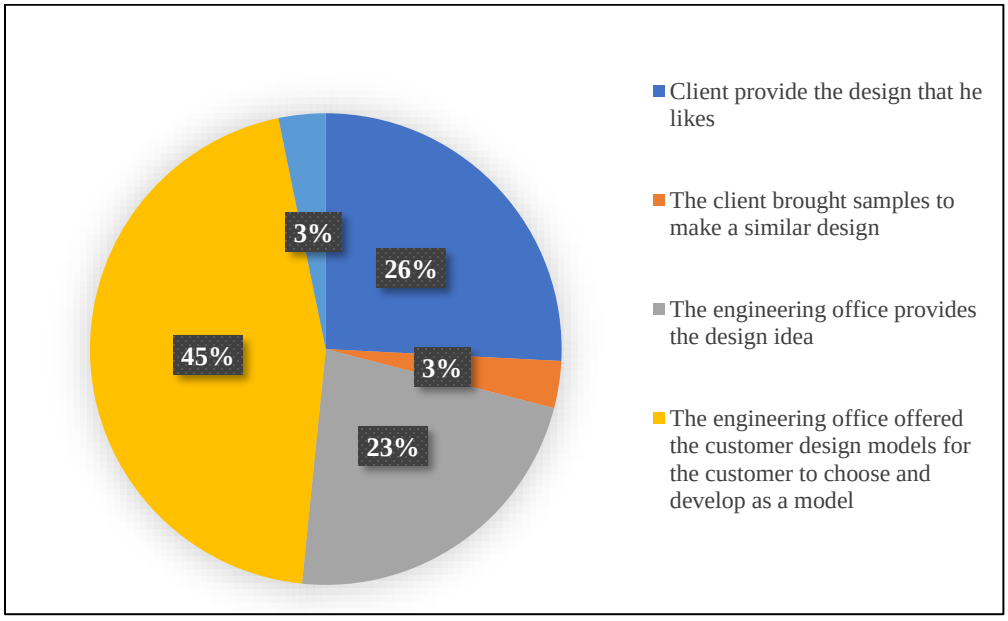

Fig. (1). The preparation of a design concept

8. Client Orientation

The expert panels analyzed the views of clients to identify whether they recognized environmental principals. Figure 2 illustrates the result of the analysis, demonstrating that the majority of experts confirmed that their clients tended to focus solely on social needs, including the inclusion of

luxury, which does not conform to environmental principals. This study found that the use of photovoltaic technology was rare, with only 3% of the experts confirming that their clients used renewable energy technology. This low percentage can be found in existing projects, which can include some environmental principles, or some large urban projects containing sustainable criteria and using efficient materials. Some of the clients were found to be aware of environmental principals and were seen to attempt to compromise between cultural issues, their needs and environmental principals. Approximately 19% of these experts confirmed that their clients reduced the area of a building while maintaining social requirements where practical.

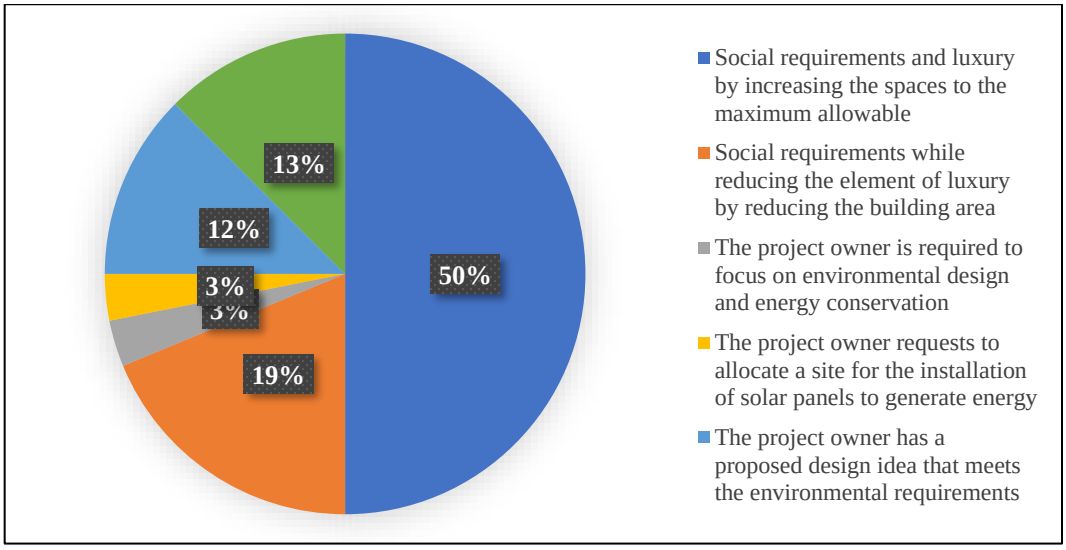

Fig. (2). Client orientation in relation to project design

In addition, the engineering consultation offices attempted to explain to their clients the importance of using environmental principals in the design process, due to its impact on the protection of the environment. Figure 3 outlines the engineering consultation offices figures for environmental principals, with approximately 47% of experts responses confirmed that clients were given an explanation of these principles, and where 43% evaluated this as ‘to some extent’.

On another hand, Figure 4 displays the clients’ acceptance of engineering consultation offices applying environmental principals. The majority of the expert panels found that over 80% of their clients do not accept the use of some environmental principals in their projects. The rejection of client for application sustainable environmental design is high due to which Is reflected as no and to some extent. This result shows haw the clients’ idea will influence in future environmental built

environment in Saudi Arabia. This result reflects the high probability of clients refusing to accept the use of sustainable design, which indicates that it is vital to raise awareness and address the need for new regulations for the construction of a sustainable built environment and to ensure environmental protections.

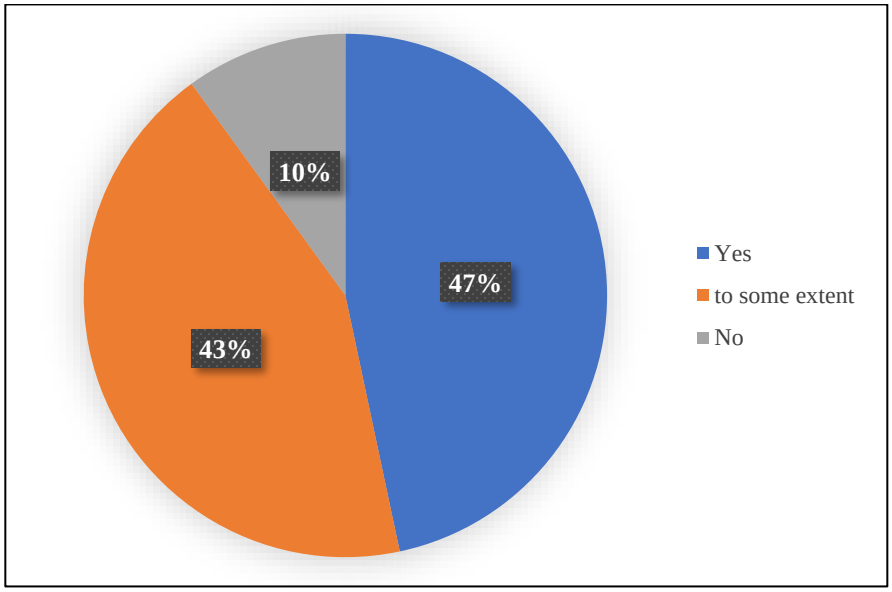

Fig. (3). Explanations of environmental principals made by engineering consultants

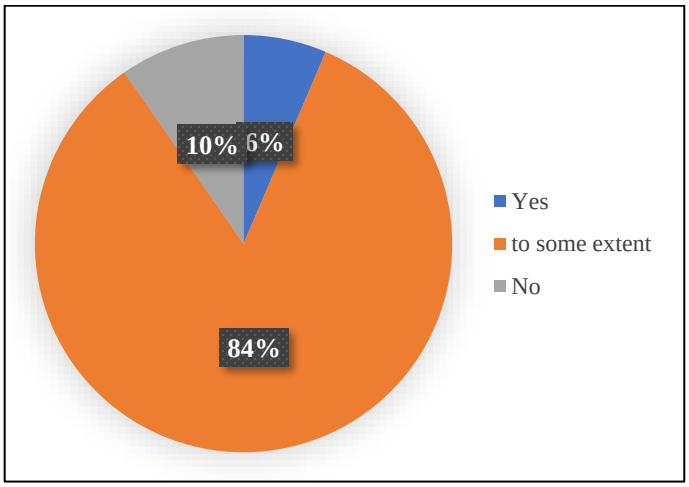

Fig. (4). Clients' agreement with consultation offices to apply environmental principals

Figure 5 (below) reveals the experts' analysis of the observations concerning the environmental aspects of a project designed by engineering offices and the client. It is notable for the lack of

environmental considerations, in particular by the client, with the focus being instead on current social requirements.

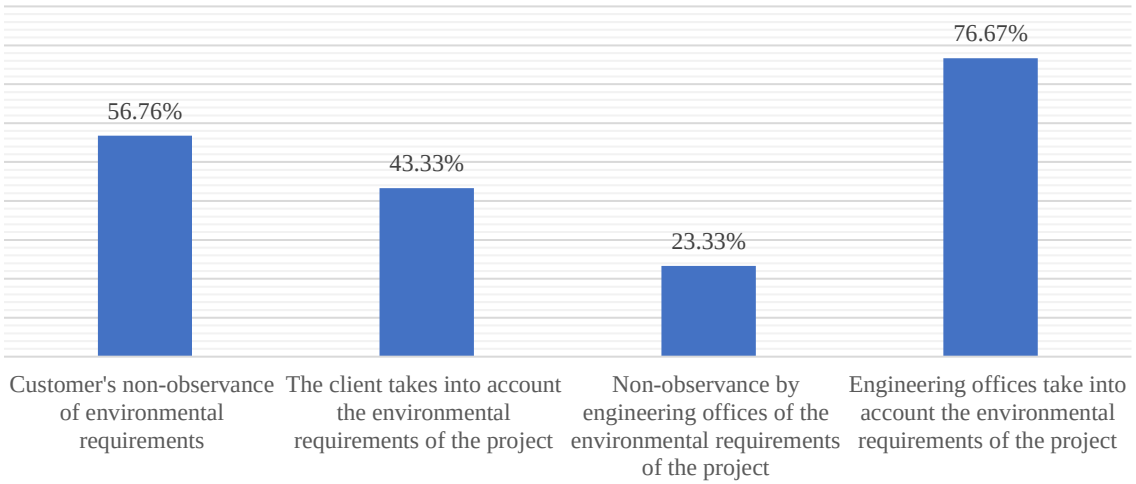

Fig. (5). Observations concerning the environmental design of a project drawn up by engineering offices and the client

9. Use of Environmental Principals

This study highlighted a variation in the level of acceptance of environmental principals in built environment projects, depending on firstly, the design and cost of construction and secondly, as the client's awareness of what constitutes a sustainable design. Clients can be prevented from using a sustainable design when there is an increase in environmental considerations, while commercial projects can modify a design during construction process in order to reduce the cost of construction. Figure 6 shows the results of the analysis of this issue, revealing the degree of a client's willingness to use sustainable design in the event of this resulting in increased cost in relation to the construction or the design. This demonstrates that the experts in this study considered that clients tend to have some degree of acceptance of increased costs when using sustainable approach, but only a limited degree of addition cost of when it comes to the construction. The analysis shows that the cost of both construction and design generally increases the overall cost of the project, and can therefore lead to a lack of sustainable principals. It is important to highlight that cost is not necessarily the primarily factor determining whether a client follows sustainable principals, particularly when motivated by an awareness of its importance and justification for such an increase over a short period of time.

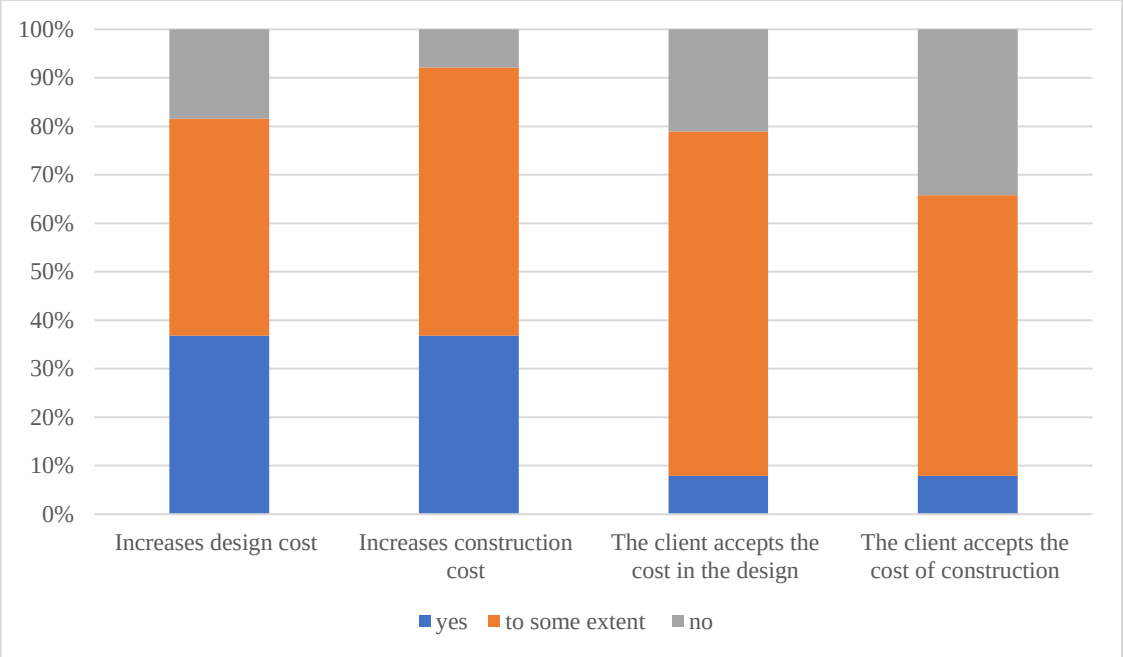

Fig. (6). The influence of the use of sustainable design in projects

10. Mainstream Design of the Built Environment

This study undertook an in-depth analysis of the current situation concerning the built environment, through means of the onsite examination and selected case studies. The evaluation made by the experts highlighted that the current built environment uses sustainable methods. Figure 7 below illustrates the analysis of current built environment when employing sustainable criteria for its design, as well as the use of renewable energy.

The analysis shows that residential neighborhoods need some environmental requirements, with Figure 7 revealing that the majority of the experts in the study evaluated this factor as strongly agree or agree. However, in reality, current buildings are increasing the areas of plots of land needed for residential neighborhoods and buildings spaces. The experts agreed that it is essential to apply renewable energy technologies, with most indicating that they strongly agreed that their clients tend to lack interest in this factor. Additionally, there remains a lack of focus on improving lifestyle, particularly when it comes to green areas.

1. Residential neighborhoods need some environmental facilities
2. Residential neighborhoods need renewable energy applications at both the neighborhood and residential levels

3. Exaggeration in increasing the areas of plots of land for residential neighborhoods
4. Exaggeration of buildings' spaces
5. Excessive increase in window areas
6. Lack of interest in applying renewable energy technologies
7. Searching for low-priced building materials, even if they result in a lack of efficiency
8. Lack of interest in external coordination and exploitation of green areas

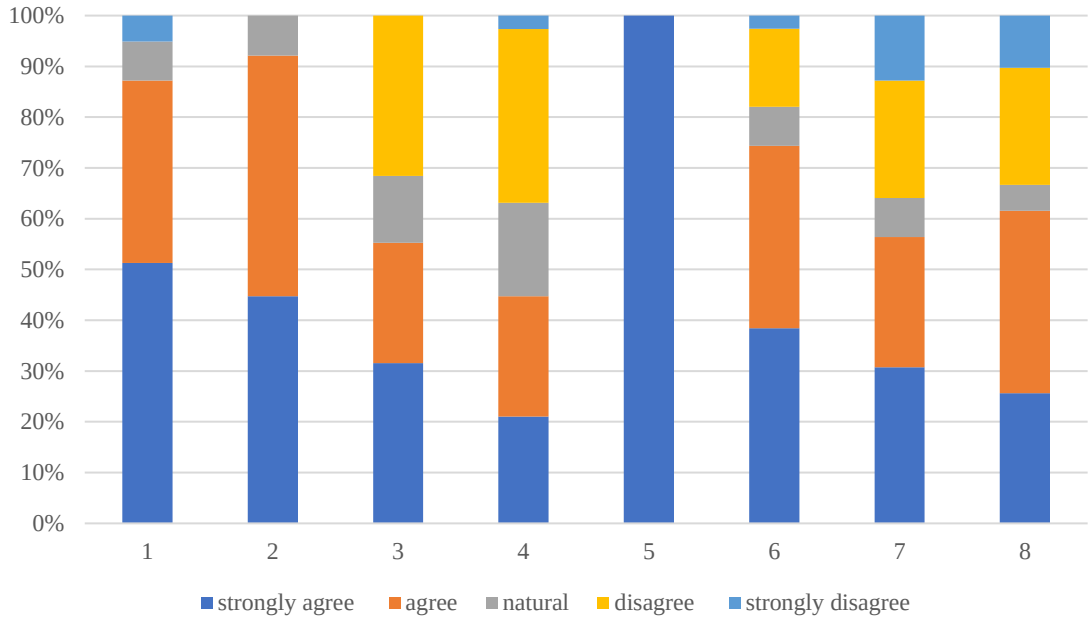

Fig. (7). Mainstream design of the built environment

11. Specialists Engineering Consultation Offices in Sustainable design

Due to recently established programs and design methods, engineering consultation offices currently continue to require further development, including in relation to new technologies related to design. Due to the changes currently being experienced in this industry, including the introduction of new technologies (i.e. BIM), it is vital engineering consultation offices adopt these technologies in their projects and develop the skills of their staff. Figure 8 demonstrates the need for engineering consultation offices to ensure ongoing development and the use of sustainable design in their projects, including employing an insufficient number of specialists in sustainable environmental design. The views of clients can influence the engineering office, with the analysis showing that the high costs of environmentally friendly design can lead compromises being made by the engineering offices in order to secure custom.

1. Lack of experience in engineering offices of sustainable design
2. Insufficient number of specialists in sustainable environmental design
3. Engineering offices influenced primarily by the client's wishes
4. The keenness of the engineering offices to attract the customer
5. The high costs of environmentally friendly designs tend to disincentivize the customer

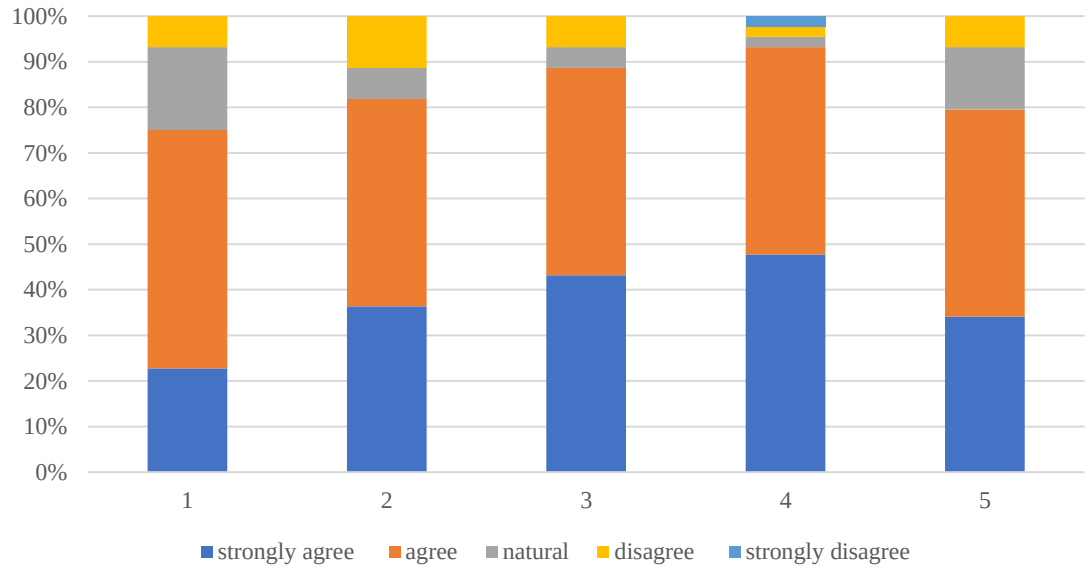

Fig. (8). The need of use sustainable design by engineering consultation offices

12. Development of Engineering Consultation

Figure 9 shows the results of the analysis related to the motivation and development of engineering consultation offices. It is important that these allocate appropriate workshops and training courses to enhance their role in environmental design. These courses can be made compulsory for licensed offices, requiring engineering offices to provide specializing in the use of environmental design. In addition, it is vital to be proactive, holding seminars and workshops related to environmental issues, particularly to enable engineering offices to raise awareness of the importance of adopting sustainable design. It should be noted that, due to the broad variety of services provided, the director of an engineering office may not necessarily be a specialist in sustainable design. However, it remains important to ensure awareness, in order to prioritize the use of sustainable design in projects.

1. Enhancing the importance of sustainable design in engineering offices

2. Allocating training courses for engineering offices related to environmental design
3. Requiring engineering offices to provide personnel specialized in environmental design
4. Holding seminars and workshops related to environmental design, particularly for engineering offices
5. The director of the engineering office should be specialized in environmental design

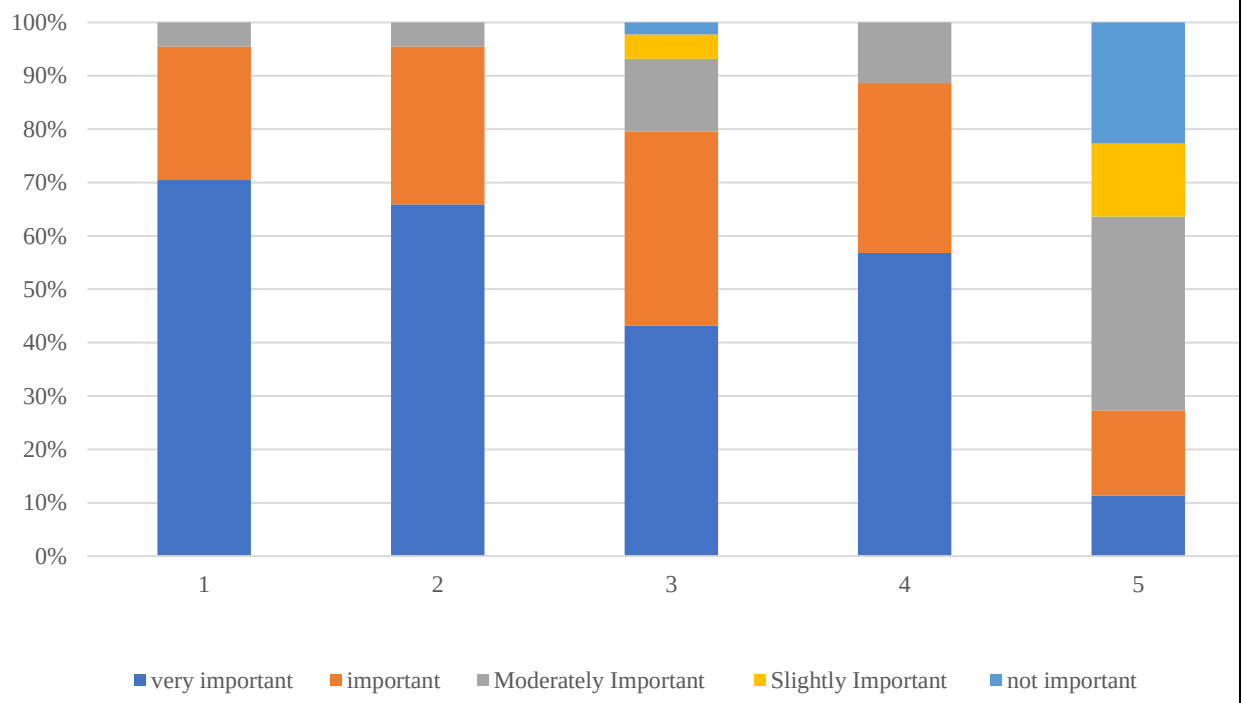

Fig. (9). The motivation and development of engineering consultations

13. Output Services Provided by Engineering Consultation Offices

The above discussion indicates that the output plans provided by engineering consultation offices generally reflect how far sustainable design can be applied in projects. The analysis therefore covers the reactions of these offices. The engineering office provides executive plans offering renewable applications or complete executive plans, including details of the building's outer shell and renewable energy applications, as presented in Figure 10 (below).

1. The engineering office provides executive plans that include renewable applications
2. At the building level, the engineering office provides complete executive plans, including details of the building's outer shell and renewable energy applications
3. The engineering office provides executive plans related to the project's interior finishes, including energy-saving electrical equipment
4. The consulting office clearly determines the cost of implementing the project

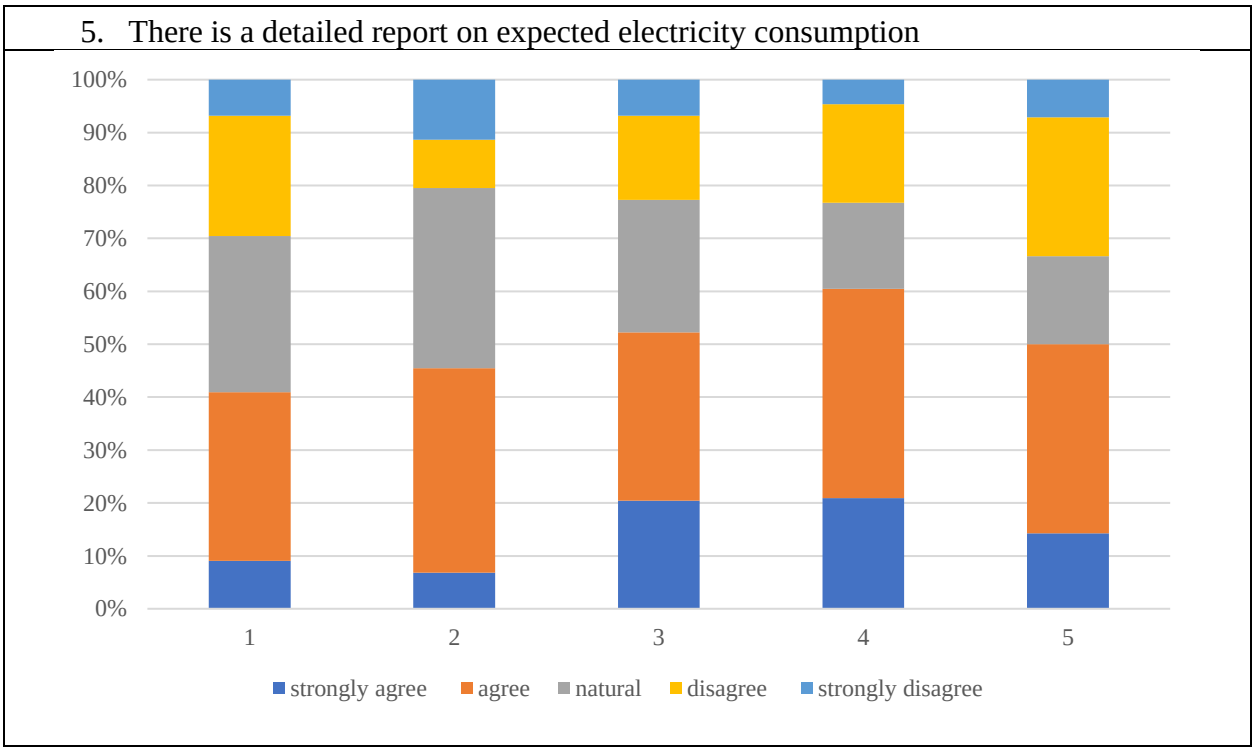

Fig. (10). The use of sustainable principles by consultation offices in both the design and final report

Half of the experts in this study (i.e. 50%) stated that the consulting office generally failed to offer a detailed report on the expected consumption of electricity, and made no recommendations for the contractor to focus on renewable energy, or indicated the cost of implementing the project. The plans also lacked details of the building's outer shell and renewable energy applications, or aspects related to the project's interior finishes, i.e. energy-saving electrical equipment.

14. Use of Simulation Tools

Simulation tools are generally employed to determine the energy consumption of a built environment and so assist the designer in making decisions. It is therefore essential to validate future projects through the use of existing simulation tools and train staff in their use as an essential stage of project design. Figure 11 displays how engineering consultation offices use simulation tools in their projects, in particular during the early stages of design. It is clear that the majority of experts on the panels confirmed that engineering consultation offices generally do not use simulation tools for their projects, due to the cost, time and additional effort, particularly as it is not required by Ministry of Municipal, Rural Affairs and Housing.

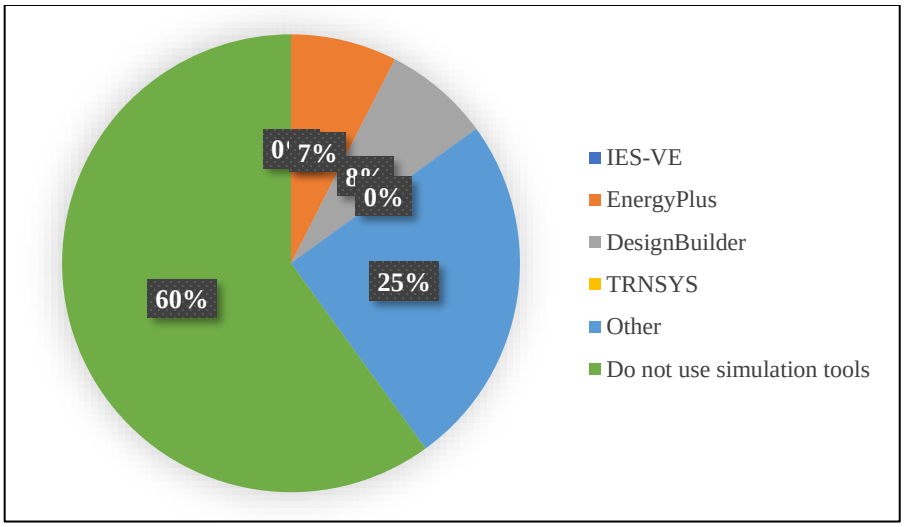

Fig. (11). Use of simulation tools by engineering consultation offices

Best practice in encouraging these offices to use simulation tools is to request an energy consumption report from the engineering consultant. This can increase the cost of the design, but at the same time enhance the environmental quality of the project. This report will validate the energy consumption prediction of the project in relation to the local environment, as these simulation tools recognize the climatic conditions in the majority of the world's cities and also have database of weather profiling, including annual solar radiation and temperature. The design can be modified by the report using the simulation tools until it achieves an ideal construction capable of meeting the environmental requirement, social needs, urban identity and the project's allocated budget. Support can be offered to engineering consultation offices by providing training courses to facilitate these practices and support the implementation of the final design.

15. Proposed Solutions for Developing Project Outputs from Engineering Offices

The experts in this study evaluated a considerable number of proposals aimed at enhancing the sustainability of the construction industry. Six of these solutions are displayed in Figure 12, some of which are related directly to engineering consultation offices, while others focus on clients and the raising of awareness. 70% of the experts agreed that energy simulation tools should be available for buildings as part of their creation and be essential when it comes to project approval. In addition, over 80% of the panels members agreed that it was essential of provide a report clarifying the strategies used to achieve project sustainability. The experts also indicated additional solutions,

including conducting workshops and seminars, as well as drawing up additional regulations to ensure future projects become more sustainable.

1. Employee energy simulation tools for buildings in projects and be part of the requirements for project approval
2. Implementation of the building evaluation system for the Saudi environment, such as LEED and BREEAM
3. Provide project reports clarifying the strategies contributing to achieving sustainability
4. The building evaluation system should accord with the local environment, taking into account the desert, coastal or mountainous regions of the Kingdom of Saudi Arabia
5. Conducting workshops and seminars for beneficiaries concerning the importance of applying environmental design standards for projects
6. Imposing regulations and roles obliging landlords and engineering consultation offices to adopt environmentally friendly designs

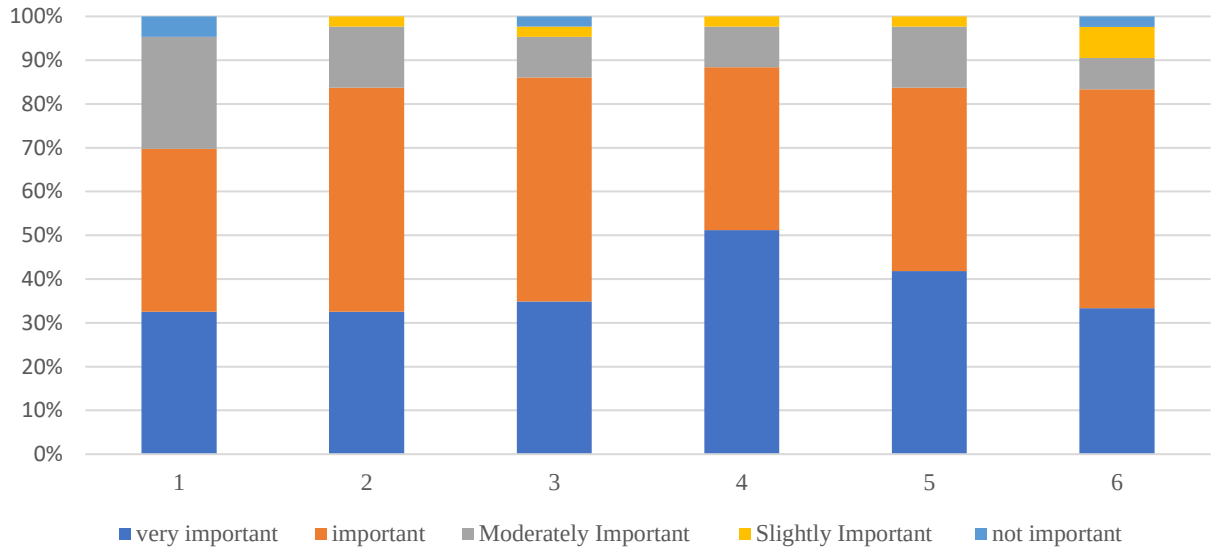

Fig. (12). Solutions for developing project outputs

16. Discussion

Due to the engineering consultation office being the first step in the design of future urban and architectural projects (following approval from the Ministry of Municipal, Rural Affairs and Housing), the discussion of the analysis undertaken in this study focuses on the four main categories shown in Figure 13 (below).

Fig. (13). Focused discussion categories

16.1. Impact of the client on the final design

Clients tend to emphasize the importance of social needs when planning a building, while the role of the engineering consultation office is to translate this into the final design. Many projects therefore consist of large buildings containing spacious rooms and a considerable number of facilities, in accordance with the needs of the individual client, as well as their culture. However, some clients show little interest in the application of environmental principals, including minimizing the area involved. This infers that, due to the requirement for environmental measures to be applied for housing, the engineering consultation office should explain the importance of these principles, both for the benefit of the environment and for the provision of a low energy design. This is important as a building's energy performance is significantly influenced by its external built environment [14]. Therefore, the design of sustainable friendly buildings takes into account alternative energy sources, including renewable energy. However, in order to achieve the most accurate assessment of a building’s performance, it is generally vital to run dynamic simulations and examine several scenarios [15, 16].

Western nations tend to have historical records outlining the performance of social housing, but there is less research into the evolution of social housing policy in developing countries, in particular among Middle Eastern states, due to the availability of natural resources. [17, 18]. In addition, migration from rural to urban areas has led to implications for economic, social and cultural development [19]. One of the resulting factors relates to the issue of the overheating of the indoor atmosphere of buildings [19], contributing to the expensive consumption of large amounts energy on cooling systems for houses [19].

The social culture of Saudi Arabia is reflected in its urban identity and architectural style, which in future should include environmentally friendly design and the application of renewable energy. It is therefore vital to acknowledge and respect the lifestyle and social cultural values of the local population, given the increased demands for low cost dwellings in the Saudi Arabia, as well as the

improved motivation for developers to invest in affordable projects, particularly the residential sector [20, 21]. Treating low cost housing in the same way as any other commodity leads to unattractive, and uninspiring environments that neither meet the needs of potential users not accord with their tastes [20]. Individual entitlement for this form of housing is determined by the Western concept of low cost dwellings [22, 23], based on levels of annual income, health conditions, and marital status [22]. Many researchers have highlighted the need to clarify the original concept, particularly as it has not been tailored to the way of life of individual regions, or local culture [22]. In addition, since the need for this type of dwelling has arisen in Saudi Arabia due to an increase in population, combined with uneven economic development, research into the flexible price of dwellings and the distribution of building materials to clients has adopted a stereotypical approach [22].

16.2. Responsibility of engineering consultation offices

This study has recognized the significant ability of engineering consultation offices to achieve a sustainable built environment. This is particularly important in Saudi Arabia, as these offices are familiar with the country's construction industry, including its regulations and roles. In addition, they are the first port of call for the client when initiating a project. Furthermore, these offices are fully authorized by Saudi Council of Engineers, which manages and regulates the country's engineering industry. Due to each client possessing an individual concept for a future project, including in relation to architecture and urban scale, along with the allocated a budget, it is the client who decides to apply a particular design. This study has shown that priorities can vary, while still focusing on the social aspect. Furthermore, when it comes to housing, clients tend to obey privacy regulations, but show little interest in environmental issues. Thus, in Jeddah, architecture in the western provinces has gradually undergone a significant shift in style and identify, as a result of the application of modern Western architecture following the expansion of the oil producing sector of the economy [24].

One of the most critical stages in the lifecycle of construction projects concerns the procurement of goods and services, particularly when allocating an expert contractor [25, 26]. In addition, the most effective value is obtained by awarding the contract to the best bidder [27]. Building information modelling is used for a geometric modelling of buildings, as well as facilitating the stages of managing and operating the construction [27, 28]. However, due to clients paying for

their services, engineering consultation offices prioritize their privacy and stated requirements, it is also their responsibility to address the issues of environmental principals. The adoption of new technologies within a design is essential for the management and operational stage. Building information modeling has become increasing popular worldwide, being used by architects, engineers and others related to construction industry [29, 30]. In addition, it can be implemented into existing buildings and retrofitting solutions [31]. This indicates that recognizing the new regulations for including environmental design can encourage engineering consultation offices to incorporate these in the design of future projects.

16.3 Motivation and orientation the future design in bases of environmental issues

This study has highlighted the importance of ensuring clients are motivated to consider sustainable and environmental issues, both in terms of architecture and the urban scale. The main challenge to the provision of urban developments that are more beneficial, reasonably priced, and ecologically responsible has been the lack of public awareness of the concept and benefits of a sustainable built environment.[32]. Furthermore, there is also a cultural challenge in the promotion of sustainability, in order to fulfil current national development ambitions [32]. In addition, it is crucial to obtain the support of government, as well as public and residential sectors, for the implementation of sustainable housing [33, 34]. Lack of public support may result from an absence of insufficient public awareness of the terminology and meaning of sustainable housing [33, 35]. Moreover, developers and landlords are continuing to ignore the distinctions between traditional and ‘green’ housing and the impact on the environment [36-38].

The current study has demonstrated that future sustainable projects in Saudi Arabia are essential for both the protection of the environment and the creation of a healthy atmosphere. Governments throughout the world are currently developing effective ways of reducing pollution and carbon emissions, particularly as residential households are responsible for the majority of both [39, 40]. Thus, one of most important factors in ensuring a sustainable built environment in Saudi Arabia is the engagement of clients in the related issues when it comes to the creation of new housing. This study has found that it is vital for cultural issues to be taken into account, but that these do not prevent the implementation of sustainable design.

One outcome of this study is the observation that buildings exceeding the provision of sufficient space for daily life will result in the need for additional energy for operation purposes, so leading to unsustainable rates of CO2 emissions. This indicates that the engineering consultation office needs to minimizing the area of each building, while simultaneously maintaining the relevant cultural requirements. The application of on-site renewable energy can be expensive in in the short-term, but such technology can, over the long-term, prove one of the most cost-efficient investments for landlords, as well as for environmental purposes.

Solar photovoltaic technology (which exploits solar radiation) has, over the previous decade, begun to offer a significantly efficient solution for alternative energy, proving highly effective due to its low cost and ability to provide sustainable rural energy [41, 42]. In addition, one of the most effective solutions that can be applied during the design stage is the photovoltaic (PV) system for micro energy generation. Although multiple systems and prototype designs are currently in use, there remains little information in the literature on how well they function in terms of system size, losses, and the efficiency of operation [41, 43]. Hence, this study considers that the priority for ensuring environmental and social solutions is to motivate clients to adopt sustainable solutions for projects, as well as employing natural resources.

16.4 Approved procedures for future projects

In Saudi Arabia, the Ministry of Municipal, Rural Affairs and Housing is responsible for regulations and processing approvement for projects, including managing the construction and issues concerning the required licenses. It is therefore essential to address the assessment methods capable of controlling and managing the sustainable built environment of the country, in order to protect the environment from CO2 emissions. Each individual in Saudi Arabia annually consumes approximately 9000 kWh of electricity, with about 52% of the nation's energy being used for housing sector. In addition, the demand for electricity in this sector is forecast to quadruple by 2025 [44]. This will lead to environmental and economic pressures resulting in demands for the adoption of energy efficiency measures to implement improvements in the management of energy provision and consumption [44]. However, specialized construction industry professionals (i.e. architects, investors, developers, and contractors) do not currently prioritize sustainable practices, including energy conservation [44]. Therefore, in order to create an environmentally friendly and sustainable built environment, the digital representation of physical and functional characteristics

(including building energy modelling) should be integrated into the environmental design process from the start [44]. In addition, effective application assessment methods that are followed by engineering consultation offices and managed by the Ministry of Municipal, Rural Affairs and Housing can contribute to a sustainable built environment. A number of assessment methods are currently in use in many international countries, including: firstly, LEED [45, 46] in the US; secondly, BREEAM in the UK [47, 48]; and thirdly, Green Star, as applied in Australia and New Zealand [49, 50].

A number of studies have confirmed that each assessment method can deal with the issues surrounding climatic change, social culture, and the needs of the population involved[51-53]. Furthermore, measures have been drawn up to minimize the negative consequences of construction and occupation, although the issue of CO2 levels due to greenhouse gas emissions still exert a negative short and long term impact on the environment [54, 55].

Over recent years, many commercial, industrial and institutional buildings, along with domestic housing, have been constructed worldwide that conform to the requirements of zero energy, and remain in use due to the efforts made to minimize their emissions, and in particular CO2 emission rates [54-56]. Many previous studies have confirmed that practitioners and decision makers currently face a significant challenge when it comes to household energy conservation to protect the environment [57, 58] . On the other hand, both landlords and home owners appear to be becoming more aware of the importance of environmental principals to protect to the environment, as well as the need to employ methods of sustainable energy, particular in light of public awareness of greenhouse gas emissions and climate change [57]. This indicates why, despite having sufficient awareness of the need to save energy, many clients or developers continue to fail to take significant measures, both when it comes to energy saving measures and the achievement of a sustainable built environment [57, 59].

17. Conclusion

The study has analyzed the impact of engineering consultation offices on the achievement of sustainable built environment in the context of Saudi Arabia, in light of the current challenges in relation to the global climate. The research employed expert evaluation of the projects under investigation, including the role of engineering consultation offices, the demands of their clients

and objections to the use of sustainable methods. These experts were selected from engineering consultation offices, construction companies, developers, and decision makers in the Ministry of Municipal, Rural Affairs and Housing of Municipalities responsible for approving projects, alongside academics from various universities in Saudi Arabia. In addition, all of the experts had worked in the field of the built environment, and possessed sufficient years of experience to be able to make a valuable contribution to the study.

The findings highlight that the output project design and details from engineering consultation offices require the implementation of additional stages, in order to include sustainable design and principals, along with the application of renewable energy technologies and the employment of simulation software tools. Furthermore, it should be recognized that clients have a significant influence on the creation of a project, with a tendency to focus on their social needs while ignoring sustainable principals and design. Furthermore, engineering consultation offices tend to combine following both their clients' requirements and current regulations, with attempting to motivate the use of sustainable principals. This indicates that some engineering consultation offices will require the provision of further courses to familiarize themselves with new technologies and tools related to sustainable design.

The analysis included a number of proposed solutions for developing project outputs from engineering offices and discussed the benefits arising from the application of sustainable design in environmentally friendly building projects in Saudi Arabia. This study therefore makes the following recommendations.

1. To raise awareness of clients and motivate them to include sustainable design in future projects.
2. To establish ongoing courses for engineering consultation offices to encourage them to employ new tools and simulation programs in the market
3. To put in place assessment method certificates for construction projects in Saudi Arabia based on climatic conditions and social needs.
4. To encourage engineering consultation offices to use simulation tools by for future projects in order to predict both energy consumption and CO2 emission rates.
5. To design neighborhoods by allocating the maximum Floor Area Ratio (FAR), so as to reduce the floor area of buildings and increase the green space and surrounding areas.

6. To include sustainable criteria skills in university curriculums for subjects focusing on the built environment.
7. To run ongoing public awareness campaigns regarding the issues of global warming and climate change.

18. References

[1] Rezaallah, A., C. Bolognesi, and R.A. Khoraskani. LEED and BREEAM; Comparison between policies, assessment criteria and calculation methods. in Proceedings of the 1st International Conference on Building Sustainability Assessment (BSA 2012), Porto, Portugal, 2012.

[2] Awadh, O., Sustainability and green building rating systems: LEED, BREEAM, GSAS and Estidama critical analysis. Journal of Building Engineering, 2017, 11, pp. 25-29.

[3] Strbac, G., et al., Strategic assessment of the role and value of energy storage systems in the UK low carbon energy future. Report for Carbon Trust, 2012.

[4] Zamani, Z., S. Heidari, and P. Hanachi, Reviewing the thermal and microclimatic function of courtyards. Renewable and Sustainable Energy Reviews, 2018. 93: pp. 580-595.

[5] Abuhussain, M.A., et al., Impact of Courtyard Concept on Energy Efficiency and Home Privacy in Saudi Arabia. Energies, 2022, 15 (15), pp. 5637.

[6] Soares, N., et al., A review on current advances in the energy and environmental performance of buildings towards a more sustainable built environment. Renewable and Sustainable Energy Reviews, 2017, 77, pp. 845-860.

[7] Qazi, A., et al., Towards sustainable energy: a systematic review of renewable energy sources, technologies, and public opinions. IEEE access, 2019. 7: pp. 63837-63851.

[8] Opoku, A., The role of culture in a sustainable built environment. Sustainable operations management: Advances in strategy and methodology, 2015, pp. 37-52.

[9] Lazar, N. and K. Chithra, Role of culture in sustainable development and sustainable built environment: a review. Environment, Development and Sustainability, 2022, 24 (5), pp. 5991-6031.

[10] Opoku, A., V. Ahmed, and H. Cruickshank, Leadership, culture and sustainable built environment. Built Environment Project and Asset Management, 2015, 5 (2).

[11] Hakiminejad, A., C. Fu, and H. Mohammadzadeh Titkanlou. Acritical review of sustainable built environment development in Iran. in Proceedings of the Institution of Civil Engineers-Engineering Sustainability, 2015, Thomas Telford Ltd.

[12] Hasanain, F.A. and N.O. Nawari, BIM-based model for sustainable built environment in Saudi Arabia. Frontiers in Built Environment, 2022, 8, pp. 950484.

[13] Ahmed, W., M. Asif, and F. Alrashed, Application of building performance simulation to design energy-efficient homes: Case study from Saudi Arabia. Sustainability, 2019. 11 (21): pp. 6048.

[14] Niu, S., W. Pan, and Y. Zhao, A BIM-GIS integrated web-based visualization system for low energy building design. Procedia engineering, 2015, 121, pp. 2184-2192.

[15] Longo, S., F. Montana, and E.R. Sanseverino, A review on optimization and cost-optimal methodologies in low-energy buildings design and environmental considerations. Sustainable cities and society, 2019, 45, pp. 87-104.

[16] Ahmed, A., et al., Assessment of the renewable energy generation towards net-zero energy buildings: A review. Energy and Buildings, 2022, 256, pp. 111755.
[17] Al Mulhim, K.A.M., M.S.H. Swapan, and S. Khan, Critical junctures in sustainable social housing policy development in Saudi Arabia: a review. Sustainability, 2022, 14 (5): pp. 2979.
[18] Kılınç, K. and M. Gharipour, Social Housing in the Middle East: Architecture, Urban Development, and Transnational Modernity, 2019: Indiana University Press.
[19] Mohd Sahabuddin, M.F. and C. Gonzalez-Longo, Traditional values and their adaptation in social housing design: towards a new typology and establishment of'Air House'standard in Malaysia. ArchNet-IJAR: International Journal of Architectural Research, 2015, 9 (2), pp. 31-44.
[20] Salama, A.M., A lifestyle theories approach for affordable housing research in Saudi Arabia. Emirates Journal for Engineering Research, 2006. 11(1): pp. 67-76.
[21] Alqahtany, A., Affordable housing in Saudi Arabia's vision 2030: new developments and new challenges. International Journal of Housing Markets and Analysis, 2021, 14 (1), pp. 243-256.
[22] Sidawi, B., Incorporating lifestyle in the design of affordable housing in Saudi Arabia kingdom. Emirates Journal for Engineering Research, 2008. 13(2): pp. 67-72.
[23] Andráško, I., " East meets West"-on Studying" Eastern" Housing Estates through" Western" Concepts and Approaches. Problemy Rozwoju Miast, 2017, 55, pp. 3-18.
[24] Shatwan, A.M., Domestic window design and interior daylight in Jeddah: designing for Saudi women, 2018.
[25] Olaniran, O.J., The effects of cost-based contractor selection on construction project performance. Journal of Financial Management of Property and Construction, 2015. 20 (3), pp. 235-251.
[26] Kshaf, D.A., M.A. Mohamed, and K.M. El-Dash, The major problems between main contractors and subcontractors in construction projects in Egypt. Ain Shams Engineering Journal, 2022. 13 (6), pp. 101813.
[27] Majzoub, M. and A. Eweda, Probability of Winning the Tender When Proposing Using BIM Strategy: A Case Study in Saudi Arabia. Buildings, 2021. 11(7): pp. 306.
[28] Hamidavi, T., S. Abrishami, and M.R. Hosseini, Towards intelligent structural design of buildings: A BIM-based solution. Journal of Building Engineering, 2020. 32, pp. 101685.
[29] Almuntaser, T., M.O. Sanni-Anibire, and M.A. Hassanain, Adoption and implementation of BIM–case study of a Saudi Arabian AEC firm. International Journal of Managing Projects in Business, 2018, 11 (3), pp. 608-624.
[30] Lu, Y., et al., Building Information Modeling (BIM) for green buildings: A critical review and future directions. Automation in Construction, 2017, 83, pp. 134-148.
[31] Khaddaj, M. and I. Srour, Using BIM to retrofit existing buildings. Procedia Engineering, 2016, 145, pp. 1526-1533.
[32] Al Surf, M.S. and L.A. Mostafa, Will the Saudi's 2030 vision raise the public awareness of sustainable practices? Procedia Environmental Sciences, 2017, 37, pp. 514-527.
[33] Susilawati, C. and M. Al Surf. Challenges facing sustainable housing in Saudi Arabia: a current study showing the level of public awareness. in Proceedings of the 17th Annual Pacific Rim Real Estate Society Conference. 2011. Pacific Rim Real Estate Society.

[34] Chan, A.P. and M.A. Adabre, Bridging the gap between sustainable housing and affordable housing: The required critical success criteria (CSC). Building and environment, 2019. 151: pp. 112-125.
[35] Barma, M., et al., A review on boilers energy use, energy savings, and emissions reductions. Renewable and Sustainable Energy Reviews, 2017. 79: pp. 970-983.
[36] Lim, C.K., K.L. Tan, and N. Hambira. An investigation on level of public awareness of green homes in Malaysia through web-based illustrations. in AIP Conference Proceedings. 2018. AIP Publishing.
[37] Lindberg, J., et al., Assessment of home care aides' respiratory exposure to total volatile organic compounds and chlorine during simulated bathroom cleaning: An experimental design with conventional and "green" products. Journal of occupational and environmental hygiene, 2021. 18(6): pp. 276-287.
[38] Kanika, S.K., K. Rana, and M. Dahiya, A comparative study on green and conventional buildings. International Journal of Home Science, 2016. 2(2): pp. 338-343.
[39] Al-Marri, W., A. Al-Habaibeh, and M. Watkins, An investigation into domestic energy consumption behaviour and public awareness of renewable energy in Qatar. Sustainable cities and society, 2018. 41: pp. 639-646.
[40] Yousefi, H., A. Abbaspour, and H. Seraj, Worldwide development of wind energy and co2 emission reduction. Environmental Energy and Economic Research, 2019. 3(1): pp. 1-9.
[41] Nasir, M., et al., Sustainable rural electrification through solar PV DC microgrids—An architecture-based assessment. Processes, 2020. 8(11): pp. 1417.
[42] Li, C., et al., Feasibility assessment of a hybrid PV/diesel/battery power system for a housing estate in the severe cold zone—A case study of Harbin, China. Energy, 2019. 185: pp. 671-681.
[43] Behroozpour, B., et al., Lidar system architectures and circuits. IEEE Communications Magazine, 2017. 55(10): pp. 135-142.
[44] Ahmed, W., H. Fardan, and M. Asif. Integration of building energy modeling in the design process to improve sustainability standards in the residential sector—Case study of the Eastern Province of Saudi Arabia. in 2017 IEEE International Conference on Smart Energy Grid Engineering (SEGE). 2017. IEEE.
[45] Amiri, A., J. Ottelin, and J. Sorvari, Are LEED-certified buildings energy-efficient in practice? Sustainability, 2019. 11(6): pp. 1672.
[46] Retzlaff, R.C., The use of LEED in planning and development regulation: an exploratory analysis. Journal of planning education and research, 2009. 29(1): pp. 67-77.
[47] Schweber, L., The effect of BREEAM on clients and construction professionals. Building Research & Information, 2013. 41(2): pp. 129-145.
[48] Polli, G.H.B., A comparison about european environmental sustainability rating systems: Breeam UK, DGNB, LiderA, ITACA and HQE. U. Porto Journal of Engineering, 2020. 6(2): pp. 46-58.
[49] GhaffarianHoseini, A., et al., Amplifying the practicality of contemporary building information modelling (BIM) implementations for New Zealand green building certification (Green Star). Engineering, Construction and Architectural Management, 2017. 24(4): pp. 696-714.
[50] Xia, B., et al., Green star points obtained by Australian building projects. Journal of Architectural Engineering, 2013. 19(4): pp. 302-308.

[51] Roderick, Y., et al., Comparison of energy performance assessment between LEED, BREEAM and Green Star. 2009.
[52] Doan, D.T., et al., A critical comparison of green building rating systems. Building and Environment, 2017. 123: pp. 243-260.
[53] Suzer, O., Analyzing the compliance and correlation of LEED and BREEAM by conducting a criteria-based comparative analysis and evaluating dual-certified projects. Building and Environment, 2019. 147: pp. 158-170.
[54] Makvandia, G. and M. Safiuddin, Obstacles to developing net-zero energy (NZE) homes in Greater Toronto Area. Buildings, 2021. 11(3): pp. 95.
[55] Jeffry, L., et al., Greenhouse gases utilization: A review. Fuel, 2021. 301: pp. 121017.
[56] Ritchie, H., M. Roser, and P. Rosado, CO_2 and greenhouse gas emissions. Our world in data, 2020.
[57] Frederiks, E.R., K. Stenner, and E.V. Hobman, Household energy use: Applying behavioural economics to understand consumer decision-making and behaviour. Renewable and Sustainable Energy Reviews, 2015. 41: pp. 1385-1394.
[58] Liu, X., et al., Scenario simulation of urban energy-related CO2 emissions by coupling the socioeconomic factors and spatial structures. Applied Energy, 2019. 238: pp. 1163-1178.
[59] Johansson, M.T. and P. Thollander, A review of barriers to and driving forces for improved energy efficiency in Swedish industry–Recommendations for successful in-house energy management. Renewable and Sustainable Energy Reviews, 2018. 82: pp. 618-628.

دور المكاتب الاستشارية الهندسية في تحقيق بيئة مبنية مستدامة في المملكة العربية السعودية

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ملخص البحث. تكون الحلول الهندسية العلمية لتحقيق بيئة عمرانية مستدامة صديقة للبيئة في المملكة العربية السعودية، ابتداءً بتصميم المشروع من خلال المكاتب الاستشارية الهندسية المتخصصة في العمران مروراً الى مراحل اعتمادها في الإدارات المعنية في الامانات او البلديات والدفاع المدني وغيرها من الجهات ذات العلاقة وفق أنظمة ولوائح منظمة لها. تتناول المكاتب الاستشارية الهندسية متطلبات العميل والتي تكون غالباً متطلبات اجتماعية من احتياج الاسرة للعناصر داخل المشروع بما لا يتعارض مع الأنظمة واللوائح لاعتماد المشروع من مساحة مسطحات البناء والارتفاعات والارتدادات على المستوى المعماري أو التخطيطي حسب أنظمة البناء المعمول بها في المخصص السكني. من هذا المنطق تم البحث في هذه الورقة العلمية عن مدى تحقيق المكاتب الاستشارية الهندسية للمتطلبات البيئية بالتوازي مع تلبية الاحتياجات الاجتماعية للمشاريع العمرانية. اعتمدت الدراسة في المقام الأول على تحليل استشاري من الخبراء شمل مهندسين من المكاتب الاستشارية الهندسية المرخصة، وبعض المهندسين المختصين من قطاعات مختلفة ذات العلاقة إلى جانب عدد من الأكاديميين العاملين في مجال البيئة العمرانية من جامعات مختلفة. شملت العينة على ستين خبيراً من مختلف المؤسسات العامة والقطاع الخاص في المكاتب الاستشارية الهندسية ووزارة الشؤون البلدية والقروية والإسكان وهيئات التطوير والجامعات. ركزت الدراسة على تحليل توافق مخرجات المشاريع العمرانية فيما يتعلق بالمتطلبات البيئية والاستدامة، وكذلك مدى تأثير العملاء على المخرجات النهائية للمشروع فيما يتعلق بالاحتياجات الاجتماعية على حساب المتطلبات البيئية. توضح النتائج أن العملاء لهم دور كبير في تحديد التصميم النهائي للمشاريع التي تعطيهم الأولوية للاعتبارات الاجتماعية مثل زيادة المساحات او عناصر للمشروع. كما تشير النتائج إلى أن المكاتب الاستشارية الهندسية تحتاج إلى فرض تصميماتها لتأخذ في الاعتبار المتطلبات البيئية قبل العوامل الاجتماعية، بما في ذلك تحليل التصميم النهائي من خلال برامج محاكاة الطاقة. كما أن الدراسة شملت تقييم العديد من الحلول الهندسية التي تساهم في تحسين التصميم البيئي لقطاع العمران في المملكة العربية السعودية من خلال الخبراء بالأخذ بعين الاعتبار المتطلبات الاجتماعية، وتختتم الدراسة بتقديم توصيات العلمية لكل من مكاتب الاستشارات الهندسية وعملائها.