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Opportunities and Challenges of Embracing Green City Principles in Saudi Arabia Future Cities

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ABSTRACT In the modern era, population and economic growth have accelerated urban sprawl in Saudi Arabia. This has placed tremendous pressure on the country's natural resources, including water, energy, and raw materials. Hence, the conventional means of expanding the built environment is no longer appropriate, as it has been found to be one of major causes of climate change and global warming. In the early 1970s, the principles of sustainable development emerged in developed countries, in order to remedy this global issue. During this period, Saudi Arabia experienced dramatic development in all of its industries, but the principles of sustainable development were, to a large degree, overlooked. However, there is now an ambitious Vision 2030 for Saudi Arabia, one of the purposes of which is to promote greater sustainability in the country. This study seeks to assist decision makers to identify the challenges and opportunities of the current Saudi practices of city design, and their related operational aspects, and to enable the adoption of effective measures for implementing sustainable development principles. Employing an ethnographic research methodology, the fieldwork concerned includes a public perception survey, followed by a site inspection, in order to develop an insider's view of the current level of sustainable practice in the city of Najran. A public survey is distributed to well-informed citizens, with the goal of obtaining their insights, and to assess their willingness to embrace green city practices. This is followed by a site inspection visit that seeks to obtain in-depth information regarding site design and operational practices. A checklist of sustainable criteria is adapted from well-known systems. The major outcomes of the study reveal that many challenges are encountered the application of green city principles. The paper offers effective approaches and strategic actions for overcoming these challenges.

INDEX TERMS Green city, sustainable development, built environment.

I. INTRODUCTION

Developed counties are currently striving to transform their cities into green and sustainable metropolises [1], [2]. Recently, the Kingdom of Saudi Arabia launched an ambitious vision, known as the Saudi Vision 2030, which seeks to transform the country from its traditional state into a sustainable and environmentally responsible country [3]. Various projects related to digital, smart, and sustainable development have been proposed to facilitate this new era of development and prosperity. Specifically, decision makers are greatly concerned with promoting the creation and adoption of a sustainable and green city model for the country's metropolises. However, the unique characteristics of Saudi Arabia's socio-cultural and environmental features are major obstacles to duplicating the extant international models, and there is a lack of effective and relevant studies in this field [4].

This paper seeks to illuminate the current practices in Saudi Arabia, and to explore the opportunities and challenges involved in creating a suitable green city strategic plan for the Saudi Arabian context. Since there is currently a lack of sufficient research in this area, the present study seeks to provide developers and decision makers with a critical view of the Saudi Arabian context, and to offer a strategic plan for its future city development. In other words, this research

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constitutes an action plan encompassing the criteria that promote success when embracing sustainable development in Saudi cities.

The main objectives of this research can be summarized as follows: (a) To provide a general view of the Saudi Arabian construction industry, and its progress in adopting green and sustainable development. (b) To identify the areas of challenge and opportunity encountered when seeking to implement the principles of sustainable development in the Saudi built environment. (c) To evaluate public willingness to embrace the sustainable development movement. (d) To provide decision makers with a strategic action plan for achieving sustainable development, including the essential green city practices that are suitable for the Saudi Arabian context.

II. LITERETURE REVIEW

Globally, climate change and global warming are controversial topics much debated among scientists [5], [6], and there are currently two primary stances regarding the matter. The first believes that climate change is occurring due to human activity, while the second opposes this view, claiming instead that climate change is a natural phenomenon resulting from the cyclical changes that occur as a result of the natural processes that impact the world's ecosystem. Seeking to address this differing of opinion, the Intergovernmental Panel on Climate Change (IPCC) published several reports regarding the causes of climate change, and how to deal with it, reaching a consensus that the main cause of climate change is human activity [7], [8]. Moreover, the IPCC proposed that one of the major strategies that should be implemented to mitigate the effects of climate change is to embrace the principles of sustainable development. The term 'sustainable development' was defined by the United Nations' (UN) World Commission on Environment and Development (WCED) [9], and was published in the outcome document titled, 'Our Common Future', which is sometimes referred to as the Brundtland Report. It reads as follows: ''Sustainable development is development which meets the needs of current generations without compromising the ability of future generations to meet their own needs'' [10], [11].

The Brundtland Report argued that intensive use of natural resources, due to the demands of population growth, industrialized activities, and socio-economic development, has had a significant impact on the world's ecosystem, and that the exacerbation of the problem is likely to affect the implementation of sustainable development. In 2006, the Renewed European Union Sustainable Strategy stated that a number of key challenges can hinder the effectiveness of sustainable development, including the availability of clean energy and sustainable transport, and the management of natural resources, public health and wellbeing, and sustainable production and consumption [12]. Since the Industrial Revolution, human lives have changed dramatically, and in the modern age, cities constitute the primary form of human settlement. However, cities are evolving into increasingly dynamic and complex systems, due to the expansion of communication, transport, sanitation, utilities and land use, and housing. According to [12], the traditional development of city and urban sprawl is no longer viable, as it is becoming increasingly vulnerable to the effects of climate change. Therefore, there is an urgent need to develop and adopt a strategic plan that incorporates sustainable development principles for building more sustainable and resilient cities and societies.

The World Health Organization (WHO) reported that air pollution causes 400,000 deaths every year in Europe, and that people living in cities are more likely to be exposed to this threat than those living elsewhere [13]. A study conducted in Spain by [14] sought to determine the level of concentration of pollutants in urban areas. Two fieldwork studies were conducted during different seasons of the year in a compound hotspot in Madrid, close to a large urban park, El Retiro. The findings revealed the positive effect of vegetation that reduced the air pollution present, which was recorded in concentrations of PM10, PM2.5, and BC. In contrast, in the exposed areas, and those close to traffic, the levels recorded were higher than those measured inside the park, and those at a distance of a 200 metres from the street.

Meanwhile, a study conducted by [15] in the city of Tabouk in Saudi Arabia sought to evaluate the degree of air pollution in terms of the presence of six heavy metals: copper, zinc, nickel, manganese, iron, and cadmium. Street dust and tree bark samples were collected from different locations, including a residential area, a city centre, and a rural area, in order to determine the difference in the results. The findings demonstrated that the city centre and the urban area were more polluted than the other locations, although the concentration of the heavy metals present was below the average of that found in major polluted cities. When listed in descending order, highest levels were recorded for iron, followed by manganese, then zinc, copper, nickel, and finally cadmium. The study concluded that traffic activities and the associated emissions were the main source of these pollutants.

These studies supported the assumption that green spaces in urban area are essential for minimizing the harmful effects of traffic, and also for meeting the goals of building healthier and sustainable cities. According to an extensive review conducted by [13], green spaces, trees, parks, and recreational programmes are crucial for human health and wellbeing, and for creating healthier green and sustainable cities. For instance, levels of obesity and mental illness can be reduced by providing access to parks and recreational programmes [16]. Moreover, Woo et al. (2009) reported that individuals who visit green space regularly have less stressful lives. Visits to parks can also rejuvenate city residents, providing a sense of peace and tranquility, and enhancing contemplation [17]. In addition, engaging in physical activities in green areas is highly effective for supporting mental health, and a meta-analysis of UK studies revealed that mood and self-esteem are significantly affected by exercise in green spaces [18]. In addition, green areas and parks provide a space for social

interaction, which plays an important role in raising perceptions of safety, and a sense of community and belonging [19].

In terms of practical applications for dealing with air pollution, London was one of the first cities to implement a green city programme as part of its long-standing strategic development plan. This urban greening plan sought to reduce air pollution by maximizing the number of green areas, and creating forests and parks. In recent years, a significant reduction in air pollution has been recorded, in terms of the CO2 level in these areas, which also serve as a temperature buffer, providing shade in the summer and a windbreak in the winter [12]. Another example of the practical implementation of measures to tackle air pollution is air quality monitoring systems, a smart city solution for tackling air pollution that has been introduced in the city of New York in the United States (US). The Hudson Yard Project in west Manhattan was designed to incorporate digital platforms, one task of which is to monitor air quality, in order to identify and control the sources of environmental pollution.

Buildings consume a tremendous amount of natural resources. They are estimated by the International Energy Agency (IEA) to consume 36% of global energy, and are responsible for almost 40% of CO_2 emissions [20]. This supports the importance of the need to locate effective solutions for reducing this environmental impact, and modern sustainable building researchers, and building designers and engineers have turned to ancient civilizations for solutions, learning from their reliance on natural and renewable resources for operating buildings. For instance, researchers found that the houses of Ancient China in 2800 BCE, effectively used the sun's orientation to gain heat, daylight, and natural ventilation [20]. In addition, in the 4th century BCE, the so-called 'Socratic House' of the Greek philosopher of that name employed the concept of building mass and orientation [21]. This in order to ensure that the shape of building benefitted from both the sun and the wind direction, as it was designed and constructed with a trapezoidal layout, and south-facing aspect, with its roof sloping to the north, in order to divert wind gusts [22]. In contrast, modern buildings require complex and technical systems to heat and cool the building, and to satisfy the needs of different modes of occupation. At the beginning of the 19th century, the concept of the passive building began to evolve in Europe and the US [21], and the oil crisis of 1973 dramatically accelerated the need for passive designs worldwide. Table 1 presents the current buildings codes, schemes and standards, and rating tools that adhere to sustainable and passive building design.

III. TRENDS IN SAUDI ARABIA

According to Saudi Ministry of Municipal and Rural Affairs [29], various initiatives will be launched as part of the transformation plans derived from the National Transformation Program 2020 and the Saudi 2030 Vision [3]. These initiatives aim to improve the urban development in Saudi Arabia via the application of sustainable, green, and smart city initiatives, also raising the level of citizen satisfaction, and increasing the competitiveness of cities and urban development. Furthermore, the plans seek to improve the efficiency of city management, in order to minimize the negative environmental impact, to attract local and foreign investments, and to create jobs and opportunities [30]. The initiatives are to be conducted via gradual phases that are proposed to be executed in partnership with the private sector, targeting five Saudi cities by 2020.

A recent study conducted by the Ministry of Municipal and Rural Affairs of the 17 major cities that constitute nearly 72% of the Kingdom's total population, revealed an inconsistency in the preparedness of the Kingdom's cities to become smart cities. Makkah city was deemed to be the most prepared to embrace smart city principles, followed by Riyadh, Jeddah, Madinah, and Ahsa [31]. Nevertheless, there is optimism regarding the launch of the Kingdom's 2030 Vision, which will produce unprecedented global projects, such as NEOM project that includes building a capital city that applies all the principles of sustainable development. According to articles published by the SPA, the country will focus on the future of nine specialized investment sectors: (1) mobility, (2) biotechnology, (3) food production, (4) technical and digital sciences, (5) advanced industrialization, (6) media production, (7) entertainment, (8) living, and (9) water and energy use [32].

Table 2 presents select examples of successful sustainable and green projects in Saudi Arabia, with the project types ranging from large-scale projects to a single family house, in order to provide insight into the extent to which sustainable construction projects can be achieved in one of the harshest environments in the world.

IV. RESEARCH METHODS

The complexity of cities and the nature of their operational aspects engendered the decision to apply Mixed Research Methods (MRM) to this study, with goal of obtaining an in-depth understanding of the current practices involved in Saudi Arabian city design and operational methods. MRM is employed in different fields of research to understand complex issues [37]. It is recognized as an effective qualitative empirical approach for observing various aspects of people, cultures, and their associated social and work practices [38]. This kind of studies are commonly performed in the social sciences [39], and research in the engineering and construction industry has also been conducted using this approach [40]. A specifically designed qualitative approach was employed for the present study, which concerned an assessment of the public perception of sustainability development and then, followed by a site inspection visit that sought to observe current practices employed, and to identify the related challenges and opportunities, and then to propose a strategic action plan for future development.

Sustainable development in the construction industry is a relatively new concept for Saudi Arabian citizens. For this reason, the primary goal of the survey aspect of this study was to comprehend public perception of certain key elements

TABLE 1. Well-known schemes for sustainable building.

System	Region	Type	Descriptions	References
Passivhaus	German	Standard	Professor Wolfgang Feist of the Institute developed the Passivhaus standard through a series of projects concerning the housing and environment of the Darmstadt University in Germany. According to this standard for central Europe, buildings should be designed in order that their annual energy demand for heating and cooling does not exceed 15 kWh/m2/year, nor does their energy consumption exceed a peak heat load of 10 W/m2. Additionally, buildings' total annual primary energy consumption should not surpass 120 kWh/m2. In order for a building to achieve the Passivhaus standard, it is expected to include high levels of insulation and minimal thermal bridging, as well as increased utilization of solar and internal gains for heating purposes. Ventilation is another important feature of Passivhaus buildings. A whole building mechanical ventilation system, equipped with highly efficient heat recovery systems, is expected to provide the building's users with excellent levels of air tightness and indoor air quality. Thus, the design for the heating load is restricted to the load that can be transported by the minimum ventilation air required, in order that traditional heating systems and active cooling for achieving comfort become unnecessary.	Passivhaus, 2019
DGNB	Deutsche Gesellschaft für Nachhaltiges Bauen e.V. (DGNB)	Rating tools	The DGNB system assesses the sustained overall performance of a building on the basis of approximately 50 different criteria, including thermal comfort, access for all, noise, and protection from six quality sections, including environmental, economic, socio-cultural and functional aspects, technology, processes, and site.	DGNB, 2019
BBC	French Bâtiment Basse Consommation	The French 'Low Energy Consumption Building'	In France, the BBC-Effinergie incorporates the regulatory requirements for the energy performance of buildings. The BBC-Effinergie label can be acquired by buildings whose primary energy requirements for heating, cooling, ventilation, hot water, and lighting do not exceed 50 kWh/m2/year.	CSTB, 2019
The British Code for Sustainable Homes	United Kingdom (UK)	Building code	The British Code for Sustainable Homes employs a sustainability rating star system to assess the overall sustainability performance of a building. A building can achieve one to six stars, depending on the extent to which it achieves the Code's minimum standards, which encompass nine areas, including the use of energy, CO2 emissions, and water. According to this rating system, six stars can be acquired by buildings that have zero carbon emissions.	energycalculations, 2019
Building Research Establishment Environmental Assessment Method (BREEAM)	UK	Rating tools	BREEAM employs accepted measures of performance that are set against established benchmarks for the evaluation of a building's specification, design, construction, and use. The measures employed represent a broad range of categories and criteria, and include aspects related to energy and water use, the internal environment (health and well-being), pollution, transport, materials, waste, ecology and land-use, and management processes.	BREEAM, 2019
Leadership in Energy and Environmental Design (LEED)	US	Rating tools	The LEED rating system assesses buildings on wide-range of categories, and has 100 possible base points distributed across six credit categories, including sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, and innovation in design. In addition, it awards four additional points for regional priority, and six additional points for innovation in design, or innovation in operation.	United States Green Building Council (USGBC), 2019b

TABLE 2. Examples of successful green projects in Saudi Arabia.

Project type	Description	References
University: King Abdullah University of Science and Technology (KAUST) green campus	KAUST is located in Thuwal, Jeddah. It is a 496, 000 acre green campus project. In 2010, KAUST was considered to be the largest LEED Platinum project in the world, with an estimated 100 year sustainable lifecycle. This figure was based on the efficiency of the systems installed, such as adopting photovoltaic cells for generating power, and installing solar towers and solar water heaters. KAUST is also designed to minimize waste and to use local, recyclable materials. The University was evaluated against set of sustainability criteria, including five areas of green practices: sustainable site development, water savings, energy efficiency, material selection, and indoor environmental quality (IEQ). The key features of the campus are: (a) The university buildings were specifically constructed to utilize natural light and ventilation. Also, the buildings support a roof capable of carrying 12,000 square metres of solar thermal and photovoltaic arrays. These arrays use the sun to produce 3,300-megawatt hours of clean energy annually. In the long term, it is proposed that 900,000 square metres of solar energy panels will eventually provide 100% of all campus energy needs, and make the university carbon neutral; (b) A full 100% of KAUST's wastewater is treated by the campus wastewater treatment plant (WWTP). The irrigation systems installed use recycled water to reduce irrigation water consumption by 53.8% of the estimated need; (c) A total of 100 shared electric vehicles and charging stations are distributed across the campus, and additional vehicles will be added as the university grows in size.	KAUST, 2019
Headquarters: King Abdullah Petroleum Studies and Research Center (KAPSARC)	KAPSARC, located in Riyadh, was awarded LEED Platinum certification by the USGBC. It is built on area of 70,000 metres square (m2), and has a total site area of 530,000 m2. The centre complied with certain applications of passive building design, and achieved a 45% reduction in its energy consumption, according to ASHRAE standards that take account of various aspect of passive building design, such as facade optimization, massing, and orientation. Furthermore, a south-facing roof was exploited to install solar panels with a capacity of 5,000MWh/year. Water conservation is also a crucial element of this centre's operational process, and the system introduced effectively utilizes potable water that is reused and recycled. Meanwhile, 100% of the water directed to irrigation is non-potable water. In terms of the construction materials used, 30% were from recycled content, with the Forest Stewardship Council (FSC) certifying 98% of the wood, while the waste management measures separate 4,000 tones and divert it from landfill.	Zaha-Hadid, 2019
Tower: Al-Midra	Saudi Aramco's Al-Midra tower, located in Dhahran, was awarded LEED Platinum certification by the USGBC. It was built on an area of 65,999 m2, as Saudi Aramco sought to comply with the highest level of sustainable environmental standards. The tower took efficient Building Management Systems (BMS) into consideration, and employs an automated HVAC system to ensure the high energy efficiency of the tower's operation. A 10.5 (MW) of solar energy was utilized to meet the total power demands of the tower, with 120,000 PVs installed over the parking area to play a dual role of providing shade, and producing clean energy. Furthermore, the IEQ was designed to ensure a comfortable and healthy indoor environment by utilizing CO_2 sensors connected to fresh air louvers to inject fresh air into the tower when the CO_2 reaches a designated level.	Aramco, 2019

TABLE 2. *(Continued)* **Examples of successful green projects in Saudi Arabia.**

Demonstration house	An 800m^2 demonstration house in Riyadh was built in a commercial business park by Saudi Basic Industries Corporation (SABIC), as part of a programme supporting home innovation. In 2015, this demonstration house became the first single family home in the Middle East to earn Platinum certification under LEED for Homes. This building achieves a 38% reduction in energy consumption, compared with similar villas, and applies passive design concepts, such as being airtight (< 1.0 ACH), possessing a thermal shell of highly insulated concrete, high performance fenestration, and proper orientation and massing. The installation of systems such as a mini-split unit, and a fresh air ventilation and filtration system maintains a healthy and comfortable indoor environment. The house was designed as a Zero Energy Building (ZEB), and included the installation of an array of solar panels with a capacity of 28 KW. Furthermore, the house achieves a 40% water reduction using low-flow plumbing fixtures, and utilizes efficient grey water and rain harvesting equipment for the purpose of irrigating a landscape that features native plants.	USGBC, 2019a

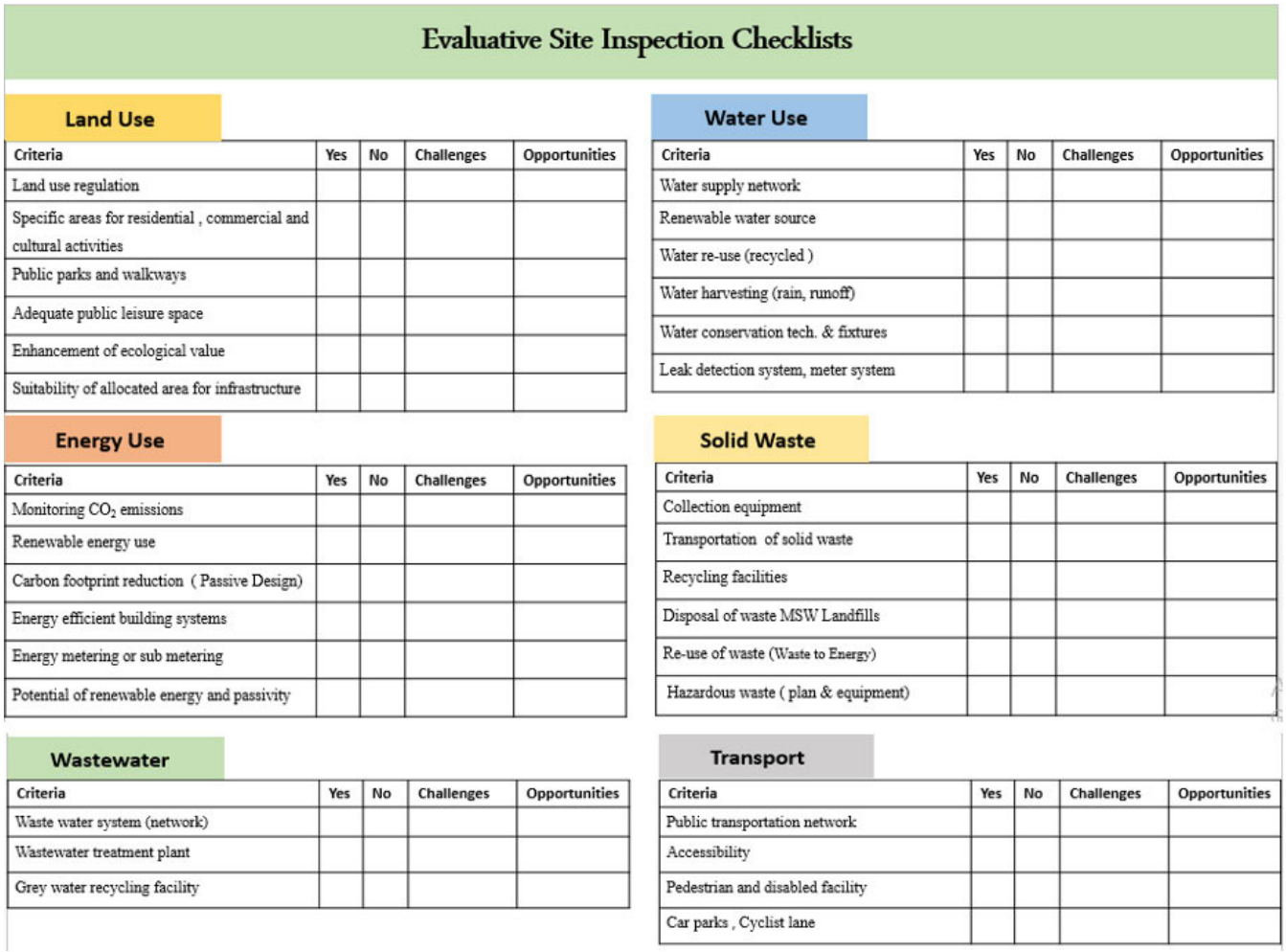
of the application of the sustainable and green city concept in Saudi Arabian cities. The survey therefore sought to gather societal views of the future of building and operating cities in Saudi Arabia.

The country's government is currently seeking to implement a new approach to the establishment of future cities that achieves the objectives of sustainable development that are commensurate with the economic, environmental, and social situation in the Kingdom. Various stages were involved in conducting this survey, in order to ensure the robustness and coverage of the relevant and associated topics. Moreover, the participants were well-informed individuals from different backgrounds, including academia, industry, and government. The survey was piloted to ensure the clarity and applicability of the questions. The feedback obtained from the subjects was considered, and the revised survey then distributed to the participants using a nomination and snowball sampling method.

The survey stage was followed by a site inspection, a method that is frequently employed in the construction industry, and seeks to ensure that the work underway proceeds according to the established plan. The process involved different phases and different aspects of work environment deskwork and fieldwork. It commenced by defining the purpose of the inspection visit, then by allocating a time and location for the inspection, and most importantly designing an applicable checklist that informed the final reporting. The public survey was employed as a preliminary method to know the public insight and attitude toward sustainability development in their own land. Afterward, their resulting perceptions was further explored using a different approach, which is site inspection.

A specific, customized site inspection visit was conducted in the central area of the city of Najran, Saudi Arabia, with the purpose of evaluating the design and operational aspects of such elements as the existing infrastructure and networks, buildings, and city management process. The exercise was an effective means of determining whether or not the area selected was supporting sustainable development principles. Since sustainable development and its evaluative criteria are extensive and multidisciplinary [41], it was imperative to establish a well-defined objective for the inspection, in order to design a clear and relevant checklist. Hence, the checklist used was created according to clear objectives developed after reviewing certain well-known systems for evaluating sustainable development. The team have taken five rounds to do the site inspections. First, a plan of the inspection method was set, which divided the area into four different zones. This helped the team to cover the site and collect all wanted data. Then each zone was inspected separately.

Meanwhile Saudi Arabia start to take serious steps to promote sustainable and green projects that can improve the performance of its built environment. BREEAM (Building Research Establishment Environmental Assessment Method-The UK) and LEED (Leadership in Energy and Environmental Design – The USA) have penetrating the KSA construction industry and attracted many organizations and individuals to certify their construction projects. The rational of using its categories in this research is based on two reasons: first BREEAM was the first assessment method that influenced the development of many assessment methods across the world. Second LEED has the highest number of certified projects in Saudi Arabia. According to Green Building Information Gateway (GBIG) LEED has more than 53 certification activities in Saudi Arabia. Therefore, the resulting list of criteria were adapted from those employed by BREEAM and LEED, as shown in Figure 1. The fieldwork element of this study, in the form of the site inspection visit, sought to



Evaluative Site Inspection Checklists

Land Use

Criteria	Yes	No	Challenges	Opportunities
Land use regulation				
Specific areas for residential , commercial and cultural activities				
Public parks and walkways				
Adequate public leisure space				
Enhancement of ecological value				
Suitability of allocated area for infrastructure				

Water Use

Criteria	Yes	No	Challenges	Opportunities
Water supply network				
Renewable water source				
Water re-use (recycled)				
Water harvesting (rain, runoff)				
Water conservation tech. & fixtures				
Leak detection system, meter system				

Energy Use

Criteria	Yes	No	Challenges	Opportunities
Monitoring CO_2 emissions				
Renewable energy use				
Carbon footprint reduction (Passive Design)				
Energy efficient building systems				
Energy metering or sub metering				
Potential of renewable energy and passivity				

Solid Waste

Criteria	Yes	No	Challenges	Opportunities
Collection equipment				
Transportation of solid waste				
Recycling facilities				
Disposal of waste MSW Landfills				
Re-use of waste (Waste to Energy)				
Hazardous waste (plan & equipment)				

Wastewater

Criteria	Yes	No	Challenges	Opportunities
Waste water system (network)				
Wastewater treatment plant				
Grey water recycling facility				

Transport

Criteria	Yes	No	Challenges	Opportunities
Public transportation network				
Accessibility				
Pedestrian and disabled facility				
Car parks , Cyclist lane				

FIGURE 1. Site inspection evaluation checklists.

determine the challenges and opportunities encountered by the site selected, and the key purpose of the checklist was to assist in establishing a clear and well-defined plan to conduct the inspection visit.

Data collection of both stages were designed and planned to obtain a real and justifiable data. In other words, the public survey was built and distributed using a web-based method to collect and analyses data automatically. Survey questions were asked to know exactly what concerns people the most. For instance, there were several open closed questions based on the level of importance, following the five Likert scales. The key questions of the survey were intended to identify the public attitude toward green development. Also to priorities sectors that should embrace sustainable development. Then the outcomes presented in statistical data, the SPSS software was used to analyze the collected data and rate public perceptions. In addition, the site was evaluated based on well-defined and allocated criteria in the form of checklists to eliminate subjective views.

Since the research methodology was designed to synthesize the findings from both the public perceptions identified by the survey, and the site inspection visit, it engendered the identification of the major challenges and opportunities in the field. It was then possible to draw generalizations and a holistic view to evaluate the current progress and level of sustainable development in the field of investigation. The main contribution of this study was the resulting robust strategic plan, which was intended to play central role in transforming conventional and traditional cities into a more sustainable and adaptable cities, into which smart city techniques and practices can be incorporated easily.

V. RESULTS AND ANALYSIS

The outcomes of both the site inspections and the public survey were synthesized, in order to create a critical analysis of the current practices employed in Najran city. This enabled a generalized evaluation of the current level of sustainable development in Saudi Arabian cities, with a particular focus on the design and operation of downtown areas. In total, 165 well-informed participants were involved in the first stage of the study. As illustrated in Figure 2, the majority of the participants were both well informed and highly educated

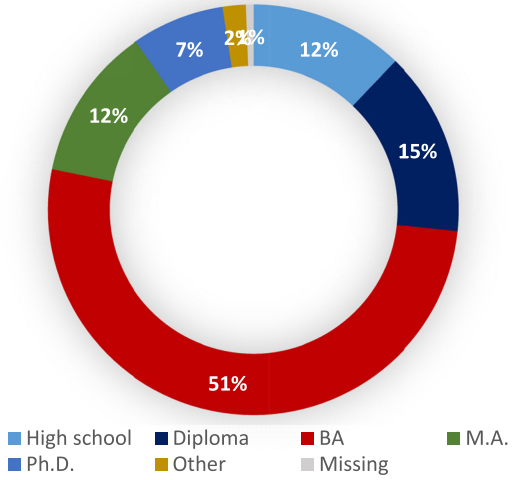


FIGURE 2. Qualifications of the survey participants.

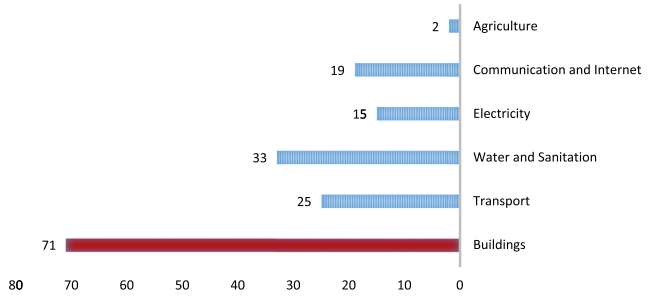


FIGURE 3. Sectors that should embrace sustainable development, in order of priority.

individuals, over half (51%) of whom held a bachelor's degree, while 12% held a master's degree, 15% held a PhD, and less than 10% were not educated to undergraduate level.

The different sectors and/or industries of Najran city were ranked according to their level of its importance, in order to prioritize the sectors in terms of their incorporation of sustainable development practices. As Figure 3 illustrates, the building sector was deemed to be the main sector that should embrace sustainable and green practices, since 71% of survey participants ranked it first in terms of the importance of it implementing sustainable green building concepts. Meanwhile, water and sanitation was ranked second (30%), transport third (25%), and only 2% of the participants believed that the agricultural sector should be considered in a sustainability transformation plan.

It was of key importance that the survey identified both public concerns regarding the sectors in Najran city that should embrace sustainable development, and the participants' level of satisfaction with the current city services and operations. As Figures 4 shows, a number of concerns were identified, and foremost among them was the management of solid waste, as well as that of the water and sanitation system. Furthermore, there was also a low level of satisfaction with transportation and roads, due to the fact that the city had expanded due to the dramatic rise in the population,

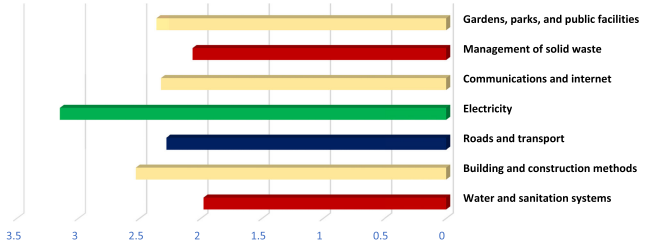


FIGURE 4. Level of satisfaction with city services and operations.

and in construction projects. It was also apparent from the comments of the participants that there is no alternative to cars as a mode of transportation in the city. The absence of public transport, such as trains and buses, is an issue in many cities around Saudi Arabia. The participants also reported that the existing public facilities, such as open spaces and parks, do not satisfy their needs, believing that the current approaches to building and construction are not efficient, and that cities should offer more gardens, and plant more trees to provide shade and reduce the effects of the harsh climate. Meanwhile, the majority of the participants were satisfied with the services provided by the electricity sector, which possesses an efficient system and team of technicians who respond rapidly to any fault or failure.

Public attitude is crucial for the successful implementation of sustainable and green building practices, therefore the willingness of the public, and their views regarding this matter were addressed by the survey. In Figure 5, a set of green building practices were provided for the participants to rank in order of their importance. These included: (a) Installing smart meters that periodically display the amount of energy consumed, (b) Installing sensors to control the flow of water, (c) Installing control screens to display the consumption quantities and IEQ, (d) Installing motion sensors to control the lighting system, (e) Eliminating air conditioning and instead employing an air-friendly environment with a high level of efficiency, (f) Installing solar panel to generate electricity, (g) Paying more than the usual cost of building a house in order to install high quality insulating material, (h) Employing an automated programme with a range of tools to guarantee the security and safety of a building. Overall, the participants displayed an interest in incorporating these practices in their buildings. However, those that involved a high cost and automated systems were of less interest, which may be due to the fact that the long-term benefits of these practices were unclear.

In order to obtain in-depth information regarding the current practices employed by the construction industry, and their related challenges and opportunities, a site in downtown Najran city was inspected. In total, seven civil engineers participated in completing the requirements of this inspection visit. As explained earlier, the site was inspected according to a list of criteria adapted from existing green building rating systems, such as LEED and BREEAM. The inspection included the following categories of sustainable development: land use, water use, waste water, energy use,

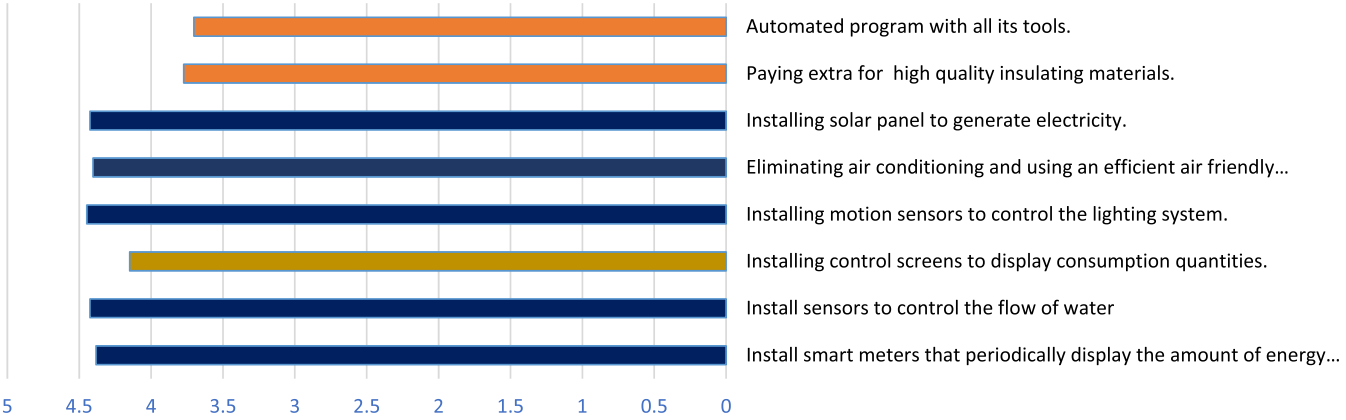


FIGURE 5. Public attitudes to green building practices.

FIGURE 6. Challenges and opportunities.

management of solid waste, and transportation system. Following the data collection stage, the results of the inspection was presented according to the challenges and opportunities encountered during the sustainable development of the site concerned. Figure 6 illustrates each criterion, divided into two parts: the potential challenge, and the potential opportunities. Despite the challenges the emerged from the analysis, it was apparent that there were also many opportunities that might assist engineers to achieve a high level of prosperity in similar downtown areas. The following are the main sustainable development practices that can be implemented, all of which are highly compatible with the objectives of the Saudi 2030 Vision.

A. POTENTIAL DEVELOPMENT

One of the main strategies of the Saudi 2030 Vision is affecting a smooth transition from the use of fossil fuels to the use of renewable energy [42]. According to various studies, such as those conducted by [43], [44], there is considerable potential renewable energy use across Saudi Arabia. It is estimated that sources of thermal solar energy can produce up to 2,200 kilowatt hours (kwh) per m2, and that this figure will greatly encourage the use of solar energy in future, which will reduce the reliance on oil and gas [45]. The application of solar energy can be highly efficient, whether in the form of installing photovoltaic (PV) panels on different types of building, such as homes, schools, and commercial buildings, or using a solar power station, such as Concentrated Solar Power (CSP), operated on a large scale, and integrated with the national electricity grid. While the downtown areas of cities in Saudi Arabia can be powered efficiently using solar energy, it is also necessary to consider the principles of passive building design. Passive design is essential for maximizing carbon footprint reduction, and for creating a more energy-efficient building sector. Economically, it is estimated that existing buildings can be developed to reduce the use of fossil fuels by up to 40%, while new buildings can achieve a 100% reduction of fossil fuel usage. This will reduce the consumption of the subsidized oil that is used locally, and instead raise the country's oil revenue by increasing the amount of oil production exported to the rest of the world.

Another important consideration in terms of future sustainable development is rain harvesting and grey water use. The current intense pressure on water resources is an extremely serious issue in Saudi Arabia, as the consumption of water is increasing dramatically, and the country remains reliant upon unsustainable resources [46]. However, a number of sustainable approaches exist that can minimize this intensive consumption. For instance, rain-harvesting is an effective method for storing large amounts of water, and controlling rain overflow. Moreover, in Saudi Arabia a large amount of water is used in the country's agricultural activities, therefore it is argued that grey water, which can easily be treated, should form a viable source of water for use in irrigation, and for other agricultural purposes, which will conserve the reserves of underground water for future generations, and allow aquifers to be replenished.

In addition, downtown areas of cities are known for their high population, which is the main source of municipal waste production. Therefore, the concept of waste-to-energy can play a dual role in diversifying energy production, and reducing the amount of waste directed to landfill sites. Meanwhile, in terms of public transportation, community connectivity and density development is one of the main concepts involved in building a sustainable site [41]. This concept can

TABLE 3. Strategic actions to promote sustainable development.

Strategic Actions	Responsible	Priority	Success Criteria
Goal # 1: Maximize the use of renewable energy			
Availability of renewable energy equipment	Electricity	High	Invest locally in renewable energy (RE) industry
Encourage building occupants to employ RE	Government	Medium	Programme of awareness and reward
Compulsory standards for buildings	Municipality	Low	Use green building rating system (e.g. LEED, BREEAM)
Launch specialized sustainable development companies and consultation agents	Government	High	Accredited engineers to design sustainable construction
Goal # 2: Effective management of water resources			
Rain harvesting system	MEWA	Medium	Enforce rain harvesting design in rainy areas
Conservation fixture	MEWA	High	Local market
Reduce consumption of non-renewable resources	MEWA	High	Enforce regulations of water supply
Reduce leakage and water losses	MEWA	High	Use automated systems
Goal # 3: Effective management of wastewater			
Wastewater (WW) treatment plant and network	MEWA	High	Link all buildings in the city to WW network
Equipment for grey water use	MEWA	Medium	Raise importance of on-site treatment
Goal # 4: Improving transportation sector			
Public transportation (PT)	Transport	High	Sustainable design and operation of PT
Density development and community connectivity	Municipality	High	Embrace the concept of the compact city
Availability of alternative transport	Transport	Medium	Feasible location and route of alternative transportation
Goal # 5: Reducing the impact of waste			
Recycling strategy	Municipality	High	Availability of equipment and facilities
Waste to energy from organic waste	Municipality	Medium	Construct plants for converting waste to energy
Reuse of non-organic solid waste	Municipality	Medium	Motivate public contribution
Encourage public to separate waste	Government	Low	Programme of awareness and reward
Landfill design	Municipality	High	Comply with design requirements of green landfill
Goal # 6: Using land sustainably			
Walkable city	Municipality	Medium	Incorporate shading strategies
Maximize vegetation	Municipality	Medium	Use grey and treated water
Public parks	Municipality	High	Design requirements
Regulations of land use	Government	High	Enforced by governmental body

be effectively applied in downtown areas of Saudi Arabia, because of their density of population, and their compact buildings. These existing features have the potential to make transportation more economical, merely by shortening journey routes by connecting terminuses to the transportation network. It is also argued that many downtown areas in Saudi Arabia possess a great history and heritage, and their traditional buildings, whether mud- or stone-based, along with their old markets, are valuable heritage locations that should be considered key features for the developing tourism industry, which will constitute a good source of revenue for the economy, especially if the country integrates modernity with tradition.

B. STRATEGIC PLAN

There are a number of essential actions that must be implemented in the Saudi built environment. These actions emerged from the synthesis of both the public consultation and the site inspection elements of this study. It seeks to improve the current performance of Saudi cities, in order that they comply with sustainable development principles and criteria. Table 3 presents the six major goals for leveraging sustainable development, which are: (a) Maximize the use of renewable energy, (b) Manage water resources effectively, (c) Manage wastewater effectively, (d) Improve the transportation sector, (e) Reduce the impact of waste, (f) Use land sustainably. In order to achieve these goals, collaboration between the government and the private sector, together with the engagement of the public, is essential. Table 3 also provides a success criterion for each of the actions that will assist in implementing the sustainable practices. Overall, the criteria of a green city are wide-ranging, and require a considerable degree of economic and social engagement. The intention of this strategic plan is to detect the major weakness

of the current Saudi city performance, and to provide suggestions of effective practices that will contribute to increasing the level of sustainable development in the existing Saudi built environment.

VI. CONCLUSION

Implementing sustainable development principles can introduce considerable positive changes, not only those that benefit the environment, but also those that improve the economy and the sociocultural aspects of a country. However, downtown areas across Saudi Arabia are currently highly dependent on unsustainable practices. Hence, this study sought to identify the current challenges and the potential opportunities for implementing sustainable development principles in future, in order to support the achievement of the Saudi 2030 Vision. This paper, and its strategic action plan, has the potential to assist decision makers in designing a sustainable future development plan for Saudi Arabia's downtown areas. Since the scope of the site inspection visit conducted as part of the study encompassed the following six important environmental aspects: land use, energy use, water use, transportation, and the management of solid waste and wastewater. Despite the current challenges, there are also a great number of opportunities that will enable the conversion of Saudi's downtown areas into more sustainable neighbourhoods. For instance, the use of renewable energy sources, such as solar energy, represent a great opportunity for the country, and densely populated areas of cities are considered a positive feature when building public transportation systems. Meanwhile, the heritage features of these downtown areas, including their traditional mud-based buildings and old markets, represent an excellent opportunity for developing the districts into destinations for both local and international tourists. These examples of potential opportunities alone represent areas of enormous potential that will go a considerable way to supporting the success of the Saudi 2030 Vision, and enhancing the diversification of the country's energy production plan. This in turn will improve the economy and living standards across the Kingdom.

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