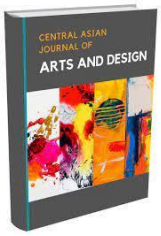

CENTRAL ASIAN JOURNAL OF ARTS AND DESIGN
https://cajad.centralasianstudies.org/index.php/CAJAD
Volume: 06 Issue: 01 | January 2025 ISSN: 2660-684

Article

The Role of Artificial Intelligence in Sustainable Urban Design

Nada Abdul-Ameer Mubarak[1]

1. Department of Architecture, College of Engineering, University of Babylon, Hillah, Iraq
* Correspondence: eng.nada.abdameer@uobabylon.edu.iq

Abstract: Sustainable urban design is fundamental effect on improving the urban environment, as it seeks to achieve a balance between population growth and community needs, while preserving natural resources and the environment. Artificial intelligence also has impacted urban design. It provides the ability to collect, analyze, and use data to make decisions and improve urban services. The current study aims to clarify the role of artificial intelligence and how to benefit from it and employ its applications in the field of sustainable urban design. This study followed an analytical approach, analyzing the available information and evaluating some selected samples to show the importance and role of artificial intelligence in sustainable urban design.

Keywords: artificial intelligence, smart cities, sustainability, urban design

1. Introduction

Sustainable urban design is a relatively modern concept that aims to achieve a balance between urban development requirements and environmental conservation needs. It meets the needs of society in the present and ensures their sustainability for future generations. Therefore, design must be based on advanced methods that enhance interaction between individuals and the surrounding environment [1].

Right from the first steps of any project, the architect is responsible for making exceptional efforts to achieve the important goals of sustainable urban design. It is well known that artificial intelligence has entered the global and regional arena as a result of the establishment of smart cities to accommodate the increasing world's population density [2]. Therefore, it is important to study the role of artificial intelligence in urban design, as it saves time and effort in studying and processing a huge amount of data very quickly and reducing errors from the beginning of the design process. Smart technologies can help in arriving at design decisions for space distribution, use of materials, and enhancing innovation and creativity. This enables the urban designer to simultaneously choose ideas and create designs that apply different concepts, including sustainability [3].

The research problem stems from a set of glitches (deficiency) that have arisen due to haphazard urban growth that lacks a long-term vision, resulting in increased overcrowding, significant environmental ruin, and intensified problems such as the lack of green spaces (desertification), the spread of pollution, and others. The research problem can be summarized in the following questions:

a. How can artificial intelligence be leveraged in all stages of urban design to achieve sustainability?

b. Have all the indicators mentioned in the IMD Index been achieved in each of the smart cities in the study sample?

Citation: Mubarak, N. A. A. The Role of Artificial Intelligence in Sustainable Urban Design. Central Asian Journal of Arts and Design (2025), 6(1), 36-51.

Received: 15th Jan 2025
Revised: 20th Jan 2025
Accepted: 24th Jan 2025
Published: 31th Jan 2025

1.1. Objectives of the Study

The current study tries to achieve the following aims:

a. Investigating the different ways through which AI can be utilized in all the stages of urban design to achieve sustainability.
b. Finding out whether all the all the indicators mentioned in the IMD index are achieved in each of the smart cities in the study sample.

1.2. Significance of the Study

The research is of interest to architects in general and urban designers in particular, as it highlights the importance of artificial intelligence and demonstrates its benefits across all design phases.

It could also be of interest to both researchers, given the information it provides on the role of artificial intelligence in the design process, and to architects, given its potential benefits in accelerating work completion and reducing costs, while simultaneously achieving the highest levels of quality and accuracy.

The importance of the research can be detailed in the following points:

a. Understanding the importance of keeping pace with technological developments, including artificial intelligence, and benefiting from its applications in the field of sustainable urban design.
b. Showing the importance of maximizing the use of artificial intelligence technologies in data analysis and achieving urban designs with the most accurate specifications and lowest costs.
c. Investing in artificial intelligence technologies to achieve a balance between aesthetics, functionality, and economy, and providing innovative solutions that enhance design quality.

2. Materials and Method

Theoretical Framework

2.1. Sustainable Design

Sustainable design is the pursuit of healthy environmental management based on respect for principles that lead to harmony with the environment. It is a construction method that seeks to integrate quality with economic, social, and environmental performance. Projects designed in a sustainably designed manner aim to reduce negative environmental impacts through efficient use of energy and resources. Sustainable construction incorporates the following principles:

a. Reducing the consumption of non-renewable resources.
b. Improving the natural environment.
c. Reducing or eliminating harmful toxic substances [4].

2.2. Artificial Intelligence

Artificial intelligence (AI) is the ability of machines and digital computers to perform certain tasks that mimic and resemble those performed by intelligent beings and the human mind, such as the ability to think, learn from past experiences, or other mental processes. AI also aims to create intelligent systems that behave in a manner similar to humans in terms of learning and understanding. These systems provide their users with various services, including education, guidance, interaction, and more. AI technologies can also be used to analyze data related to government projects [5].

Artificial intelligence technologies can contribute to providing accurate recommendations to improve planning and design processes, analyze data, and provide recommendations related to architectural design, such as using environmentally friendly materials, providing optimal ventilation, increasing energy efficiency, providing optimal

natural lighting, improving traffic flow, and providing sustainable public transportation [6].

Artificial intelligence emerged from two scientific fields: behavioral science/neuroscience, and computer science, or what is known as informatics. It is the science of devising systems capable of solving problems and performing functions by simulating mental processes. Hence, it is considered as one of the most important manifestations of AI at the present time, as it has replaced medical staff, factory workers and many other fields [6].

AI can be classified into three different types based on its capabilities:

a. Narrow ANI.
b. General AGI.
c. Strong superhuman ASI.

Some of the most important ways AI can help develop urban areas are the following [4], [6]:

a. Intelligent Transportation Management: AI analyzes traffic data and provides accurate guidance to improve traffic flow and reduce traffic jamming, developing an intelligent transportation system to improve public transportation services.
b. Smart government: AI analyzes citizen data, identifies their needs, and improves local government services to deliver city services more efficiently, such as waste management, water, and electricity.
c. Smart security: AI can analyze security and crime data and identifies areas requiring enhanced security. It can be used for early detection and mitigation of security threats.
d. Smart health: AI can also analyze medical data, identifies diseases and epidemics, and directs relevant authorities to take the necessary actions. It can be used to develop smart health solutions, such as surgical robots and self-diagnosis.

AI has entered the global and regional fields as a result of the establishment of smart cities to accommodate the world's population density. It is necessary to establish and organize smart, population-oriented, developmental cities that provide services to individuals through precise electronic methods based on the principle of digital transformation. Furthermore, the overcrowding of traditional cities, especially slum areas, require increasing development requirements that necessitate resorting to the establishment of smart cities. This is because smart cities are considered as the ideal solution for adopting urban policies, systems, and technical plans that are capable of including large human elements within the setting of environmentally friendly smart cities [7].

The European Union has defined smart cities as cities that bring together people and industry to improve life in urban areas through more sustainable, integrated applicable and well planned solutions, ; and a more participatory and efficient approach [8]. The smart city environment is manifested through the providing electricity, water, transportation management, security, garages, and alternative energy, which reduces public expenditures and increases the desire for shared cultural coexistence. The most important positive aspects of smart cities are the use of alternative energy, including solar energy, and all environmentally friendly services, in addition to providing a security system within the smart city. This is considered the common denominator between artificial intelligence and the establishment of smart cities [9].

2.3. Artificial Intelligence and Designing

AI applications can be utilized in various fields, including designing processes. AI technology helps designers create multiple variables and extract and produce designs and models using algorithms and inputs specified by the designer. Thus, AI becomes a partner and a design tool used by designers to meet the requirements of ever-evolving

work. This type of design focuses on enabling machines to think and plan independently, similar to human thinking [5].

It took decades to integrate AI technology and develop algorithms that can help in achieving scientific ideas and aspirations. Currently, there are at least four areas where AI can be employed in the construction sector:

a. Applications in the process of designing and constructing management, which are linked to modeling software and platforms.
b. Systems and applications used to deliver information from work sites and models (BIM-to-Field), (i.e. Building Information Modeling-to-field), such as laser scanning and others.
c. Robotic applications for executing construction operations on-site.
d. Software and hardware systems for collecting information from the site and delivering it to help in controlling operations and functions, this is referred as (field-to-BIM). These systems provide realistic design solutions based on site conditions and the project's surrounding circumstances.

Building Information Modeling (BIM) is defined as a computer system that oversees all departments operating on-site, from planning up to delivery, through implementation, to operation and maintenance. It is a mechanism that links responsibilities/specialties and schedules. It helps eliminate the negative effects of emergency modifications to make the orders of changing during the implementation phase approaches zero. In addition to that, it helps control and lead different departments to achieve collaborative work that achieves customer satisfaction [10].

2.4. The Concept of Sustainable Urban Design

Sustainable urban design is the application of sustainability principles to the development of cities and urban communities to preserve the environment, improve quality of life, and ensure the sustainability of natural resources for future generations. It is a process aimed at developing cities and urban areas in a way that takes into account the environmental, social, and economic needs of society. It relies on a balance between urban expansion, achieving sustainable natural resources, and preserving the environment. Sustainable urban design relies on the wise and efficient use of resources, while preserving the environment, reducing pollution, and improving public health. This requires concerting efforts among various stakeholders in cities. Of course, architects play a pivotal role in implementing these principles and achieving the vision of sustainability in the urban environment [11].

In addition, urban design requires integration and flexibility to keep pace with future changes. It relies on the use of modern technologies such as artificial intelligence and data analysis to support decision-making that takes into account the interconnectedness of various activities such as housing, work, entertainment, and others [8].

Sustainable urban planning and design have also witnessed numerous theories of development and preservation of the urban environment, each adopting its own perspective and approach. These theories may not be compatible with the urban design and planning of historic areas and cities, making them unsuitable for heritage preservation [8]. By the beginning of the twentieth century, sustainable design became a common goal for many long-term redevelopment policies, taking into account environmental and social factors and achieving a balance between preservation and urban development [12]. From this, the concept of sustainable urban planning and design can be summarized as the art of achieving interact between people and place, and attaining harmony between the environment and urban construction through the preservation of the natural environment and the urban fabric, the harmony of which leads to the sustainability of cities [13].

The philosophy of sustainable architecture is embodied in many activities that aim to reduce the negative impact of the different projects on the environment [14].

2.5. The Goals of Sustainable Urban Cities

The following goals of sustainable urban cities are proposed by [14-16]:

a. Reducing the negative impact on the environment: This aims to reduce the negative environmental impact of buildings, as they occupy a large amount of land and consume energy, water, and air, leading to climate change.
b. Reducing waste: Well-designed projects help reduce the amount of waste generated by their occupants by providing practical solutions, such as compost bins to reduce waste to landfills, and reducing the impact on wells or water treatment projects, among others.
c. Water efficiency: One of the primary goals of sustainable projects is to reduce water consumption and protect water quality. Therefore, the use of water collection, purification, and reuse sites in urban areas should be maximized.
d. Maximizing Operation and Maintenance Benefits: Every aspect of environmentally friendly building is integrated into the operation and maintenance phase of the building's lifecycle. This is achieved by adding new, environmentally friendly technologies (such as AI) that fall under the responsibility of operations and maintenance personnel.
e. Material Efficiency: The Environmental Protection Agency suggests that industrial goods be recycled and reused, and that building materials should be extracted and manufactured locally for construction sites in order to reduce energy loss.
f. Cost: Although newer technologies tend to cost more, the return is 10 times of what is spend over the entire life of the building. Studies over 20 years have shown that some eco-friendly projects have yielded a return on investment of $53 to $71 per square foot.
g. Energy Efficiency: environmentally friendly projects include processes to reduce energy use. Designers position the building effectively, which can provide more natural light while reducing the need for electric lighting, and generate renewable energy on-site through solar, wind, and hydropower. This is particularly helpful in achieving energy efficiency because energy generation is usually the most costly factor in projects.

Based on the above, the following sustainability indicators in sustainable urban cities can be arrived at, see Table 1.

2.6. Artificial Intelligence and Sustainable Urban Design

Artificial intelligence can be used to find solutions to the challenges cities have long faced due to increasing population growth rates. This has necessitated innovative solutions to make cities more sustainable and efficient, leading to the emergence of smart cities. AI is also used to control lighting using through using certain systems such as machine learning algorithms to improve the lighting of public areas. These systems can also analyze factors such as traffic jamming, air pollution, temperature control, and natural light levels, and transmit this information to smart city authorities in real time [9, 10].

Table 1. Sustainability indicators in sustainable urban cities.

	Sustainability indicators	The source from which the indicator is derived
1	Reducing the consumption of non-renewable resources	[1]
2	Taking into account the environmental, social and economic needs of society while developing cities in urban areas.	[11]
3	Making a wise and efficient use of all resources	[11]

4	Relying on the use of modern technologies such as AI and data analysis to support informed decision-making.	[11]
5	Achieving a balance between conservation and urban development	[12]
6	Reducing the negative impact of projects on the environment	[14]
7	Providing practical solutions such as compost bins to reduce the need for landfills.	[14]
8	Reducing water consumption and protecting water quality	[14]
9	Recycling and reusing industrial goods	[15]
10	Extracting and manufacturing building materials locally for construction sites in order to reduce energy loss.	[15]
11	Using modern technologies in environmentally friendly projects to increase the return on investment regardless of the cost.	[15]

AI can assist design teams by improving and reducing project timelines, expanding their discovery, and developing their creative potential through data recall and analysis.

2.7. IMD Index for Smart Cities

Cities are evaluated based on a large-scale survey that gathers citizens' perceptions of modern technologies implemented in their cities, as well as economic and social data. The 2023 edition of the index ranked 141 smart cities globally. It is a tool used to assess cities' performance in their transformation toward smart cities and modern technology [17]. These indicators focus on a set of factors that reflect the level of technological intelligence and innovation in cities, including:

a. Technological infrastructure: Availability of wireless networks, high-speed internet, and digital technology.
b. Sustainability: The extent of renewable energy use and resource efficiency.
c. Transportation: The quality and speed of public transportation and smart mobility options.
d. Healthcare: The use of technology to improve health services.
e. Education: The availability of digital learning and interactive educational resources.
f. Digital economy: The level of innovation and support for startups.

Indicators such as the IMD can help cities measure their progress, identify areas for improvement, and attract investment. According to the IMD 2023 Index, we present in Table 2 four models of the most prominent cities classified as smart cities globally [18].

Indicators of the use of artificial intelligence in sustainable urban cities in the post-construction phase can be summarized in Table 3.

Table 2. Four models of the most prominent smart cities in the world according to the IMD index for the year 2023 [18].

Project name	Place	Indicators of the use of artificial intelligence
Zurich, Switzerland	First	Using a power-to-heat system that uses renewable energy to generate heat for city buildings. Using digital technologies and data to improve the effectiveness of public services and increase citizen engagement. Allocating automated toll systems for zero-emission vehicles.
Oslo, Norway	Second	Future Built project that aims to reduce carbon emissions by 50% by raising awareness of architectural methods that help make cities environmentally friendly and lower carbon emissions. The Smart Street Lighting Project, which improves the efficiency of street lighting systems, has contributed to reducing the city's lighting costs by approximately $13 million annually in electricity costs.
Canberra,	Third	Canberra's Digital Strategy, which aims to use technology to enhance community well-

Australia		being, focuses on community services, data, planning, and industry partnerships, reshaping government operations and prioritizing citizen-centric services. The development of a citywide "digital twin" platform that enables real-time monitoring and management of various city functions. This platform enables data collection on traffic, energy use, water management, and other aspects of city life. This information is used to make data-driven decisions to improve city services.
Copenhagen, Denmark	Fourth	Citizens have free access to public data sources: The Copenhagen government provides free databases aimed at fostering innovation in the city. The city's smart streetlights have saved 76% of its public lighting bills, thanks to their ability to adjust light intensity based on traffic flow.

Table 3. Indicators of the use of artificial intelligence in sustainable urban cities (Researcher).

No.	Factors that reflect technological intelligence	How to apply it	How to apply it
1	Technological infrastructure	Availability of wireless networks, high-speed internet, and digital technology.	Using digital technologies and data to improve the effectiveness of public services and increase citizen engagement
2	Sustainability	The extent of renewable energy use and resource efficiency	Using a power-to-heat system that uses renewable energy to generate heat for city buildings Smart street lighting to improve lighting system efficiency and adjust light intensity according to traffic flow. Reducing waste by using smart containers Implementing modern technology to monitor and control energy consumption
3	Transportation	Quality and speed of public transportation and smart mobility options	Developing a digital twin platform enables the collection of data on traffic and other Provides an integrated network of various public transportation means with applications that provide information on smartphones.
4	Health Care	Using technology to improve health services	Medical data analysis and identification of diseases and epidemics Developing smart healthcare solutions such as surgical robots and self-diagnosis
5	Education	Provides digital education and interactive educational resources.	Underground parking, green spaces Digital education relies on computer and internet technologies that enable the creation of an interactive environment rich in applications.
6	Digital Economy	Level of innovation and support for startups.	Providing free databases that help innovation in the city

3. Results and Discussion

The Practical Part of the Study

In this section, we review an analytical study of a number of sustainable urban cities that have used artificial intelligence and evaluated them according to sustainable urban design.

3.1. Description of the Samples

3.1.1. Singapore

Singapore, located at the crossroads of international sea and air routes, has become a major commercial center in a short period of time. After its independence in 1965, the mainstay of its economy was contracting trade, in addition to business intelligence, which was limited to a small community of traders with a rapidly growing population. Over the course of 20-25 years, it joined the wave of development, maintaining its economic leadership. It is considered one of the first developing countries to realize the advantages of information technology. The Swiss business school IMD revealed that Singapore ranked first in the Smart City Index in 2020, achieving a goal it had been striving for forty years [19]. Figure 1 presentes two pictures of Singapore:

One of the most important reasons that made Singapore the smartest in the world:

a. Housing for All: The Housing Development Council provides free housing for all citizens. Housing represents community areas that encourage self-sufficiency, communication, integration, and sustainability. Eighty percent of the population lives in government housing.
b. Healthcare: Singapore has a comprehensive, integrated healthcare plan that emphasizes innovation and continuous learning. We also have adequate infrastructure, such as underground parking, green spaces, and pedestrian walkways, to enhance citizens' health, with the goal of creating a healthier city.
c. Transportation System: The transportation system relies on modern technologies such as self-driving vehicles, reliance on clean energy sources, and the integration of active means with public transportation services such as walking and cycling [19].

Figure 1. Pictures of the city of Singapore (Internet).

3.1.2. Dubai

Dubai has adopted a progressive approach to becoming a smart city, based on several pillars, most notably integration, interaction, and communication. The Swiss business school IMD World University Rankings ranked Dubai 29th in the Smart Cities Index in 2021, up from 43rd in 2000. The "Dubai Smart City" strategy includes more than 100 initiatives to transform government services into smart services. It is based on collaboration between the private and public sectors to achieve several smart goals in several areas, including smart living, smart society, smart environment, smart economy, smart governance, and smart transportation. See Figure 2 which presentes two pictures of Singapore. This is achieved through the fundamental principles of integration, cooperation, and communication.

This strategy includes six axes:

a. Government: A pioneering, innovative, and distinguished government, pioneering in meeting the needs of individuals and society.
b. Place: A smart and sustainable city with clean, healthy, and sustainable environmental elements.

c. Living: A preferred place to live and a preferred destination for visitors, offering the best educational, health, and housing services, and a safer, more vibrant, and globally distinguished city.
d. Economy: A key pillar of the global economy, it enjoys sustainable economic growth and is one of the world's most important business centers.
e. Society: A cohesive, cohesive, and diverse society that possesses the demographic foundations for sustainability is compatible and builds shared human values.
f. Individuals: Creative, pioneering, and productive in all fields. They are educated, cultured, and healthy. They are empowered, full of pride and happiness, and engaged with Dubai's renaissance and development in all areas [17].

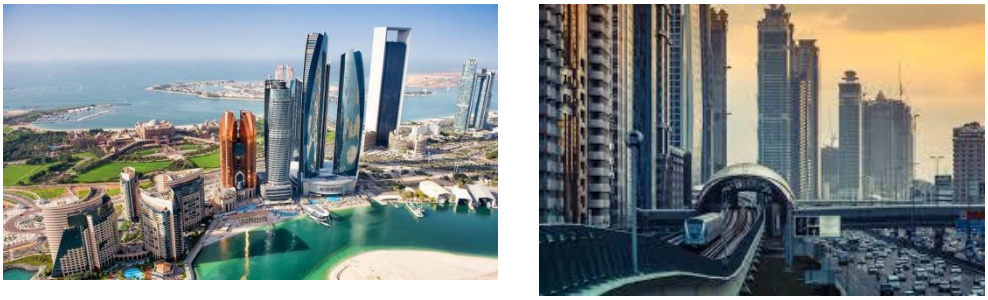

Figure 2. Pictures of the city of Dubai (Internet).

3.1.3. Seoul

It is the capital of South Korea and is considered one of the world's most prominent smart cities, (See Figure 3) boasting an advanced system of technological solutions aimed at improving the quality of life and engaging citizens effectively. The most important aspects of this system are:

a. Digital Transformation and Infrastructure: Seoul has one of the fastest wireless networks in the world, facilitating access to the Internet and enhancing communication.
b. Smart Transportation: Seoul has an integrated network of public transportation, such as the metro and buses, with applications that provide users with direct information about travel times. There are also smartphone applications that help residents track transportation and plan trips efficiently.
c. Energy management: Increasing use of renewable energy through projects such as solar panels on public buildings. Modern technology is being implemented to monitor and control energy consumption.
d. Smart health care: Seoul provides remote medical consultation services and online appointment booking, and uses wearable technology application to monitor health and fitness.
e. Security and Safety: CCTV systems equipped with facial recognition technology are being used to improve city safety, and applications are being provided that allow citizens to quickly report emergencies.
f. Community Participation: Online platforms are provided for sharing opinions and ideas, which enhances citizen participation in decision-making.
g. Smart Education: Educational institutions in Seoul provide electronic educational resources and interactive applications to enhance the educational experience [20].


Figure 3. Pictures of the city of Seoul (Internet).

3.1.4. Masdar City - UAE

Masdar Smart City is considered one of the most important models in the field of sustainable cities in terms of managing natural resources according to an economic, environmental and social vision using information and communication technologies in all aspects of human life and a strong infrastructure based on the latest technologies in exploiting natural resources and involving society in an integrated process with the aim of making a city successful and achieving a sustainable city [21], See Figure 4.

Masdar City has worked on many sectors and public services, where it established a strong, advanced and integrated infrastructure using smart city technologies and the latest scientific research and innovations, including:

a. Roads and Transportation: Innovative solutions were provided in the transportation sector without impacting traffic and ensuring ease of movement, utilizing public and private transportation systems (eco-trains, parking spaces for non-residents, and designated parking spaces for visitors).
b. Green Fabric: Diverse, high-tech, and high-quality methods were used through three types of green extensions within the city (a harmony between the use of open and covered outdoor spaces, such as pedestrian walkways, water features, and plants, providing a comfortable natural environment for residents and visitors, resembling a green forest). This protects residents from the external influences of the desert environment.
c. Energy and water consumption: This is achieved by reducing water and energy demand by 40% through a combination of smart design and high-performance buildings that utilize materials in accordance with global sustainability standards, as well as the construction of solar power plants using photovoltaic panels [22].
d. Waste management: The city is working to reduce waste to zero, using biological waste to produce rich soil and fertilizers, and converting some of this waste through incineration, which in turn is used as a source of additional energy. Industrial waste, such as plastic, is recycled [22].

This is why it is considered a fully sustainable city that runs on solar and renewable energy [23]. It uses artificial intelligence in energy management, transportation, and urban planning. It relies on self-driving electric vehicles and smart building technologies to reduce energy consumption [21].


Figure 4. Picutres of the city of Masdar (Internet).

3.1.5. Smart City Barcelona – Spain

It is the capital of Spain and one of the first cities to adopt smart city technology, see Fugure 5. It has gained a reputation for pioneering civic innovation. Barcelona has relied on new technology and infrastructure to encourage economic growth and change the lifestyles of its citizens. Among the most important technologies it has adopted are:

a. LED street lighting: Barcelona has adopted an LED-based lighting system, which saves energy and reduces costs. It also enables the integration of a comprehensive and free Wi-Fi system and tracks a variety of different factors, such as measuring pollution and temperature.
b. Waste disposal: Barcelona was one of the first to adopt a smart container system that uses vacuum technology to move waste and store it underground.
c. Smart multi-story parking: Barcelona's multi-story parking lots have benefited from smart technology. They are equipped with sensors to help drivers find vacant spaces. This system also increases parking revenue.
d. Barcelona has also relied on smart sensors to efficiently manage water and electricity resources [24].

Figure 5. Pictures of Barcelona (Internet).

3.2. Data Analysis and Discussions

3.2.1 Answering Question One of the Study

In response to the first question of the study, data was collected from all smart cities within the current study, and the method of utilizing artificial intelligence in each design phase was included, The design phases were divided into six stages, and details of the tasks related to each stage were included, along with the method of utilizing artificial intelligence to achieve the specific task of each stage. as shown in Table 4.

Table 4. Design stages for projects in light of artificial intelligence (Researcher).

Stages	Media Steps	Important Details	Application of Artificial Intelligence
First	1. Design statement Present the design problem and collect all data about the project	Understand the nature of the project Know the project requirements and purpose, determine the project size, and list all project milestones until project completion.	AI can identify, aggregate, and classify different types of data, find possible relationships between data sets, and generate and recognize results. It can be used to speed up data preparation tasks, including creating data models and helping to explore missing data.
	2. Documenting data and information, defining the ultimate goal, understanding all constraints (such as sources, regulations, laws, etc.) and preparing a comprehensive	After identifying and listing all the information necessary for the work, the initial design drawings for the project are prepared.	AI contributes to the analysis of shapes, colors, and visuals. Ats tools can be used to make design choices based on real, reliable data. Machine learning algorithms are used helping the designers to create visual collages in panels called

Stages	Media Steps	Important Details	Application of Artificial Intelligence
	statement of all project requirements		mood boards.
Second	Concept Statement and Preliminary Schematic Design, i.e. Defining and developing a design concept that expresses the main ideas and approach behind the proposed design solution	Designing 2D and 3D drawings, defining and allocating spaces and designing styles. Also determining spatial relationships to the nature of the activity (zonings).	The power of AI lies in the speed with which it can analyze massive amounts of data and suggest design modifications with zero error rate and high quality. The designer can then select and approve the modifications based on the available data.
Third	Determining the project timeline based on the work and initial project cost, and presenting it to the client for approval.	It includes estimating the time required to complete the project work, after which the expected budget to complete the project is estimated.	Machine learning algorithms can be used to provide estimates of project duration, resources, requirements, and projected budget. View, manage, and adjust price change orders. Artificial intelligence can make predictions using stored data to streamline workflow.
Forth	Project Risk Management: Identifying potential and anticipated problems before they occur and trying to capitalize on them to avoid them. Risk management continues throughout the project's lifespan.	Risk management	AI can update project sequencing and task management, keeping all project stakeholders informed of project status. AI enables risk managers to respond more quickly to new and emerging exposures and make informed decisions about project duration, cost, and strategy.
Fifth	Execution: Everything that was previously planned is put into effect.	Contractors are selected (compared through tenders), work is scheduled in the correct sequence, materials necessary to complete the project are inventoried and ordered and human resources are hired for the project.	Artificial intelligence can be used in project human resources management. Data from previous projects is used to build workflows, estimate workloads, track employee schedules and vacations, determine the training requirements for each employee, and even suggest new hires based on applications in the job portal that match the project's required skills.
Sixth	Post-Occupancy Evaluation (POE): Collecting all data related to the building's end users (feedback)	It may include questionnaires, personal interviews, or a direct examination with the project's end users. Any modifications or revisions are studied to improve the final outcome of the project.	POE can be applied to all project details to collect a wealth of data about the actual usage, needs, and behavior of the project's end users, which helps in building new algorithms that can be used in future projects.

3.2.2 Answering Question Two of the Study

To achieve the research objectives, indicators of artificial intelligence use were compared with the technological strategies and solutions used in the samples selected in the current study, as shown in Table 5.

As shown in Table 5, the five cities have the technological infrastructure index, i.e., the use of digital technologies and data to improve public services. Regarding sustainability, which is represented in the table above as four (2-5) points, three cities (Singapore, Dubai, and Seoul) achieved all sustainability indicators. Masdar City and

Barcelona achieved three of these indicators and lacked only one indicator, namely the use of smart containers to reduce waste. As for the mobility factor, all five cities achieved these indicators. As for healthcare, we find that all artificial intelligence indicators were achieved in Singapore and Seoul, unlike Masdar City, which did not achieve any of these three indicators. As for Dubai, it achieved two indicators and lacked the use of smart health solutions such as surgical robots and self-diagnosis. Regarding education, we find that the use of digital education is implemented in all five cities. Finally, the last factor that reflects artificial intelligence, the digital economy, is only present in Singapore.

After verifying the extent to which indicators of artificial intelligence use were achieved in the cities sampled in the study, the availability of sustainability indicators in those cities was verified, as shown in Table 6.

Table 5. Comparison of indicators of artificial intelligence use with the extent to which the indicator was achieved in the selected samples.

Indicator of the use of AI				The extent to which the indicator is achieved in the sample cities				
				Singapore	Dubai	Seoul	Masdar	Barcelona
1	technological infrastructure	1	Using digital technologies and data to improve the effectiveness of public services and increase citizen engagement	✓	✓	✓	✓	✓
2	Sustainability	2	Using a power-to-heat system that uses renewable energy to generate heat for city buildings	✓	✓	✓	✓	✓
		3	Smart street lighting to improve lighting system efficiency and adjust light intensity according to traffic flow.	✓	✓	✓	✓	✓
		4	Reducing waste by using smart containers	✓	✓	✓	✗	✗
		5	Implementing modern technology to monitor and control energy consumption	✓	✓	✓	✓	✓
3	Transportation	6	Developing a digital twin platform enables the collection of data on traffic and other aspects.	✓	✓	✓	✓	✓
		7	Provides an integrated network of various public transportation means with applications that provide information on smartphones	✓	✓	✓	✓	✓
4	Health Care	8	Medical data analysis and identification of diseases and epidemics	✓	✓	✓	✗	✓
		9	Developing smart healthcare solutions such as surgical robots and self-diagnosis	✓	✗	✓	✗	✓
		10	Underground parking, green spaces	✓	✓	✗	✗	✓
5	Education	11	Digital education relies on computer and internet technologies that enable the	✓	✓	✓	✓	✓

	Indicator of the use of AI			The extent to which the indicator is achieved in the sample cities				
				Singapore	Dubai	Seoul	Masdar	Barcelona
6	Digital economy	12	creation of an interactive environment rich in applications. Providing free databases that help innovation in the city	✓	✗	✗	✗	✗

Table 6. The extent to which sustainability indicators were achieved in the selected samples.

	Sustainability indicators in sustainable Urban cities	The extent to which the indicator is achieved in the sample cities				
		Singapore	Dubai	Seoul	Masdar	Barcelona
1	Reducing the consumption of non-renewable resources	✓	✓	✓	✓	✓
2	Developing cities and urban areas in a manner that takes into account the environmental, social and economic needs of society	✓	✓	✓	✓	✓
3	Using resources wisely and efficiently	✓	✓	✓	✓	✓
4	Using modern technologies such as artificial intelligence and data analysis to support informed decision-making	✓	✓	✓	✓	✓
5	Balancing conservation and urban development	✓	✓	✓	✓	✓
6	Reducing the negative impact of projects on the environment	✓	✓	✓	✓	✓
7	Reducing water consumption and protecting water quality	✓	✓	✓	✓	✓
8	Adding new environmentally friendly technologies (such as artificial intelligence) falls on the operations and maintenance staff.	✓	✓	✓	✓	✓
9	Recycling and reusing industrial goods	✓	✓	✓	✓	✓
10	Using modern technologies in environmentally friendly projects to increase the return and return on investment regardless of the cost.	✓	✓	✓	✓	✓

Comparing AI Table 5 with Sustainability Table 6 reveals that AI plays a significant role in achieving sustainability. However, it was also noted that some cities lack certain components within certain indicators. For example, in Masdar City and Barcelona, only one component of the Sustainability Index is not achieved in either city—the use of smart containers to reduce waste. All other indicators are achieved, proving the effective role of AI in achieving sustainability.

Thus, we find that the selected samples are considered sustainable urban cities, as they achieved very high sustainability indicators.

4. Conclusions

At the end of the research, two types of conclusions were reached: conclusions based on the theoretical aspect and conclusions based on the practical aspect:

4.1. Theoretical Conclusions

By presenting theoretical propositions, identifying indicators of artificial intelligence, and observing the extent of their application to selected samples, the following conclusions were reached:

a. The potential for leveraging artificial intelligence in planning and designing sustainable urban projects from the early stages of the design process by accelerating and accurately generating data to create designs for sustainable projects based on modern technologies and environmentally friendly materials.
b. Artificial intelligence assists in analyzing data and providing recommendations with precise specifications based on design specifications, helping to reduce costs and limit human error.
c. Artificial intelligence enhances design quality by better balancing aesthetic, functional, and economic aspects using innovative solutions.
d. The challenges that arise in applying artificial intelligence technologies lie in the availability of wireless networks, the internet, and digital technology to maximize benefits in achieving urban sustainability.

4.2. Practical Conclusions

By applying AI application indicators and their alignment with sustainability indicators, it was found that, despite not meeting all indicators in some cities, such as Masdar City and Barcelona, they are considered smart cities and fulfill many sustainability requirements. This indicates that the use of AI, even if partial, achieves the desired goals, most importantly sustainability requirements.

REFERENCES

[1] S. Awad, F. Salman, R. Abd, R. Rasheed, F. Ali, and H. Sahbeeh, "Sustainable Green Buildings and Their Impact on Reducing Pollution," Diploma Thesis, Middle Technical University, Kut, Iraq, 2021.

[2] M. H. Al-Bayat, "The Role of Artificial Intelligence in the Smart Cities Environment," *Journal of Al-Zaytoonah University of Jordan for Legal Studies,* pp. 2-18, 2024.

[3] Y. I. M. Al-Shaboul, "Evaluating the Use of Artificial Intelligence Technologies to Improve Design Planning Processes in Government Architecture," *JASPSS,* pp. 424-435, 2024.

[4] M. Rasmi, "Civil Liability Arising from the Use of Artificial Intelligence Technologies in Jordanian Legislation," MSc Theis, Middle East University, 2022.

[5] Y. Hamdy, "Application of Artificial Intelligence in the Development of Interior Design Operations Management," (in en), *Journal of Design Sciences and Applied Arts,* vol. 3, no. 2, pp. 239-245, 2022.

[6] T. H. A. Al-Raoud, "Civil Liability for Damages Caused by Artificial Intelligence-Based Technology Operators: A Comparative Study," PhD Thesis, Mansoura University, 2022.

[7] I. B. Kjartansdóttir, S. Mordue, P. Nowak, D. Philp, and J. T. Snæbjörnsson, *Building Information Modelling BIM*. Civil Engineering Faculty of Warsaw University of Technology, Warsaw, 2017.

[8] E. Avrami, "Sustainability and the built environment: Forging a role for heritage conservation," 2011.

[9] N. Wang and H. Adeli, "Sustainable building design," *Journal of civil engineering and management,* vol. 20, no. 1, pp. 1-10, 2014.

[10] A. Nikitas, K. Michalakopoulou, E. T. Njoya, and D. Karampatzakis, "Artificial intelligence, transport and the smart city: Definitions and dimensions of a new mobility era," *Sustainability,* vol. 12, no. 7, p. 2789, 2020.

[11] R. A. I. Al-Hayarat, "Sustainable Urban Planning: The Role of Architects in Improving the Urban Environment " *Municipalities,* pp. 397-416, 2024.

[12] A. Thatcher and K. Milner, "Changes in productivity, psychological wellbeing and physical wellbeing from working in a'green'building," *Work,* vol. 49, no. 3, pp. 381-393, 2014.

[13] A. Hussein, "Sustainable urban planning for the urban environment in historical areas case study (Historic Cairo)," *Journal of Architecture Arts Humanistic Sciences,* vol. 6, no. 3, pp. 30-50, 2021.

[14] M. Babcock, "Sustainable Architecture Design: Environmental and Economic Benefits," Senior Honors Thesis, Liberty University, 2016.

[15] K. Kooduvalli, B. Sharma, E. Webb, U. Vaidya, and S. Ozcan, "Sustainability indicators for biobased product manufacturing: A systematic review," *Journal of Sustainable Development,* vol. 12, no. 1, 2019.

[16] V. Albino, U. Berardi, and R. M. Dangelico, "Smart cities: Definitions, dimensions, performance, and initiatives," *Journal of Urban Technology,* vol. 22, no. 1, pp. 3-21, 2015.

[17] B. Maleki, "Assessment of Smart Cities: The Case of Dubai," MSc Thesis, Eastern Mediterranean University, 2020.

[18] S. Naseri, "AI in Architecture and Urban Design and Planning: Case studies on three AI applications," *GSC Advanced Research and Reviews,* vol. 21, no. 2, pp. 565–577, 2024.

[19] Y. Du, T. Sun, and Y. Huang, "A Comprehensive Review of Smart City Initiatives in Singapore Technological Advancements and Urban Planning from 2015 to 2023," *Journal of Latex Class Files,* vol. 14, no. 8, pp. 1-4, 2015.

[20] J. Yang, Y. Kwon, and D. Kim, "Regional smart city development focus: The South Korean national strategic smart city program," *IEEE Access,* vol. 9, pp. 7193-7210, 2020.

[21] N. I. Ismael, "Sustainability criteria used in designing energy-efficient smart cities A study of Masdar City as a model for one of the smart cities that realize the idea of sustainable development," *International Journal of Advanced Engineering and Business Sciences,* vol. 4, no. 1, pp. 42-71, 2023.

[22] B. Tayeb and A. Waheeba, "The Reality of Smart Cities and the Achievement of Sustainable Development: Arab Experiences (Smart Dubai City - Masdar Sustainable City)," *Journal of Social and Human Sciences,* vol. 14, no. 2, pp. 45-63, 2024.

[23] A. A. Zboun, "Investment in Smart Cities in the UAE and its Role in Achieving Sustainable Development: Masdar City as a Model," *Iraqi Journal of Economic Sciences,* pp. 176-190, 2023.

[24] S. Madakam and R. Ramachandran, "Barcelona smart city: the Heaven on Earth (internet of things: technological God)," *ZTE Communications,* vol. 13, no. 4, pp. 3-9, 2015.