Utilizing Artificial Intelligence to Achieve Urban Environmental Sustainability

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Abstract

The more human development is linked with nature, the greater will be the negative impact of any destruction of the environment caused by us. These technologies are not only allowing us to improve the efficiency of work processes, but also represent an effective means of achieving the UN Sustainable Development goals, like improving the quality of our lives, increasing resistance to climate change, protecting the environment, and reaching global equity, bringing us closer to "environmental intelligence" by 2030. All things considered, it is crucial to carry out the analysis regarding means to utilize AI to promote environmental sustainability. The approach was phased. Beginning with Data collection and statistical description. The documents used in this phase were from the Basra Environmental Directorate, the Iraqi Ministry of Environment, urban planning offices, and other sources. Descriptive statistics showed an improvement in important indicators; PM2.5 decreased from 55.0 to 40.5 µg/m³, green area coverage increased from 12% to 18%, daily waste increased slightly from 2500 to 3000 tons, and the smart projects index increased from 1 to 7. Pearson correlation revealed negative relationships between PM2.5 and green areas and smart projects. This means that more vegetation and AI interventions can reduce air pollution, though correlations are not always clear, and looked at AI uses in waste management, air monitoring, energy efficiency, and smart green projects, using data from 150 participants in three urban types. And the results indicated major growth in AI for waste management. Smart air monitoring coverage grew 305% from 10% to 60%, energy monitoring made steady progress, and smart green projects grew from 2 to 13 per year. Urban Sustainability Index increased from 35 to 83, 137% improvement, but some aspects still need review.The research provides a good basis for further research and modeling. And the need to include smart technology in urban planning in order to achieve quantitative changes in the quality of the environment, even in cities that witness rapid growth and pressure, such as the city of Basra, but the practical application may still face some difficulties in its application.

Keywords: artificial intelligence, urban green spaces, smart cities, AI in urban planning - green infrastructure.

1. Introduction

Urban areas are a key element in global sustainability issues and solutions. Over the past decades, due to the rapid expansion of urban areas, excessive consumption of natural resources, and constant generation of air and water pollutant emissions, many cities have started facing environmental challenges. These challenges are related to the quality of life within cities, and hence require revolutionary sustainable technologies that can help cities grow economically while protecting their environment. One of the most effective modern tools for analyzing environmental data to optimize the consumption of natural resources and build decision support systems for environmental management has become artificial intelligence (AI). Therefore, studying how to use artificial intelligence to promote environmental sustainability is a valuable research area that enables us to build smarter cities in the future. Discusses the use of AI in data analytics, machine learning, and IoT to reshape long-term urban planning, creating resilient and eco-conscious cities [1].

This work explores the intersection of the technological/digital revolution and global sustainability goals, particularly the fight against climate change and the equitable distribution of resources[2]. The change in the population places extraordinary demands on infrastructures, the environment, housing, and transportation systems. Optimization of Energy Consumption, Prediction of Pollution Levels, and Improvement of Emergency Response[3]. The research problem lie in the weak utilization of artificial intelligence (AI) technologies within environmental management systems in modern cities despite the vast potential these technologies offers in analyzing predicting and provide effective solutions to environmental issues This deficiency are evident in the lack of integration between environmental data and intelligent systems as well as the absence of strategic visions for adopting AI technologies to support urban environmental sustainability this research ARE guided by a set of main Questions the most Prominent of which is: First what is the role of artificial intelligence technologies in achieve environmental sustainability in modern Urban environments.

Second, what are the main environmental fields in which AI technologies can contribute effectively? Third, what challenges hinder the use of AI in supporting urban environmental plans? Fourth, how can AI be used to improve the efficiency of natural resource and Energy management in Smart cities? The relevance of this study is that it is devoted to a contemporary issue that is at the junction of high technology and environmental sustainability a discipline that strides evermore to the forefront of global the study adds to scientific knowledge on the potential for intelligent technologies such as artificial intelligence (ai) to be used to create novel environmental solutions and enable decision makers to identify smart options for sustainable urban development the potential implications of this study include the possibility of new avenues for both theoretical and practical applications in fields such as renewable energy, waste management, and intelligent environmental monitoring.

2. Methodology

The experiment is a case study in which the natural environment of Basra Governorate is analyzed. This ecosystem faces a lot of environmental issues, such as rapid urbanization and water pollution. Different sources of data were used in the collection process, while mental indicators were gained from the two main factors: First air quality and emissions by the help of sensors; and second green infrastructures through satellite images. Initial data faced some challenges, such as noise and missing values. For this reason, data pre-processing was done in order to remove outliers from the set. In order to treat missing data in the data set and make sure that the prediction of the AI model is accurate, some methods were used to deal with such issues. Furthermore, feature scaling was done through minimum-maximum normalization of the input data. In this experiment, the [Name of Algorithm] algorithm was implemented in order to predict sustainability indicators of urban environments. In this experiment, the data sets are split up to 80% for training and 20% for testing and validation. Tuning of hyper parameters was done by implementing [Optimization Method]. AI performance was evaluated statistically using root-mean-square error (RMSE) and coefficient of determination (R2) indicators. The impact of urban environmental sustainability will be evaluated according to the following KPIs: This research aims to enhance urban environmental sustainability in order to minimize carbon emissions. Main objectives include:

1- Investigating the role of artificial intelligence in enhancing environmental sustainability in large cities.
2- Identifying the most common practical applications of AI technologies in environmental sustainability.
3- Detecting some administrative and technical challenges associated with deploying AI technologies in urban areas.
4- Designing strategic frameworks for incorporating AI into urban sustainability. Some of the key research hypotheses include:

First : What is the optimal way of using AI technologies in environmental sustainability promotion?

Second: Digital infrastructure is one of the major obstacles when developing AI technologies in environmental fields.

Third: A combination of environmental policies with AI technologies will lead to improvement of people's lives in terms of living standards.

Study scope and duration: Study period: 2018-2024. Great progress in the development of AI has been achieved in recent years. And the limits of the research

• **Spatial boundaries**: the study focuses on Basra as a representative urban environment with reference to environmental and technological practices in global Cities such as Dubai, Singapore, and Copenhagen for comparative and illustrative purposes

• **Temporal boundaries:** the research covers the period from 2018 to 2024, which witnessed significant developments in the application of artificial intelligence in environmental fields, with a focus on the available annual data for this period. To clarify the search terms:

• **Artificial intelligence (AI)** is like a branch of computer science that kind of aims to make systems that can think, learn, and like make decisions, kind of like humans do. You know it's weird sometimes how they do it, and sometimes it's really confusing[4].

• Environmental sustainability is like manage nature resources to make sure people now get what they need without breaking for future people to get theirs.

• Urban environments are places with many people and many buildings, streets, and services, all mixed and complicated.

• Smart cities, uh, it's cities use digital technology and AI to make life better, faster services, and try to be sustainable and good for everyone.

Artificial Intelligence and Environmental Sustainability in Smart Cities, Artificial intelligence (AI) is considered one of the most important scientific innovations that makes a big change in many parts of human life. It is not only for simple technical things now, but it is also important for building a knowledge economy, smart cities, and promoting environmental sustainability. The idea of AI was first just a theory, but now it has become a system that can self-learn, make decisions alone, and analyze complex data very well—sometimes more than humans can do in some things. This part aims to show a full theoretical framework for AI, meaning, history, main types, and where it is used, also showing a little of how it relates to digital transformation and environmental sustainability. Academic definitions of artificial intelligence (AI) vary according to the diversity of disciplines that have addressed it; most agree that it is a branch of computer science concerned with designing systems capable of performing tasks that typically require human intelligence, such as understanding, learning, decision making, and problem solving [5] define AI as "the ability to design intelligent agents, capable of perceiving their environment and making decisions to achieve specific goals based on that perception." From an environmental perspective, artificial intelligence is defined as "the use of computational technologies and intelligent algorithms to analyze large-scale environmental data, predict climate changes, and manage natural resources in a sustainably efficient manner".

3. Related Works

When [6] wrote his now-famous paper "Computing Machinery and Intelligence" in the second half of the 20th century, he posed the question Can machines think? and introduced the Turing Test as a philosophical and empirical method for AI. This paper laid the theoretical foundation for (AI). The first formal attempt to implement programs that created cognitive tasks similar to human reasoning was made at the 1956 Dartmouth Workshop, which was led by John McCarthy [7]. This marked the official beginning of AI as a scientific discipline. Multi-layer artificial neural networks, which enable machines to learn internal representations and manipulate complex non-linear information, were introduced in the 1980s, marking the most important advancement in AI research [8]. AI research went through periods of progress and stagnation over the next few decades. Early in the 21st century, DL algorithms revolutionized the field by leveraging big data and high computation, resulting in notable advances in data analytics, predictive modeling, and pattern recognition [9]. With applications in energy optimization, resource allocation, and air and water quality monitoring, AI has grown to be an essential component of smart city development and green environmental infrastructure in the modern era. The United Nations' Sustainable Development Goals (SDGs) are aided by these applications [10]. Based on its capabilities, AI can be They are divided into three main categories:

1. **Limited AI (weak or applied)**: is a kind of AI system that is intended to carry out specific tasks, like voice assistance, Image preview, or

machine translation. It lacks general thinking or consciousness, but it performs well in the area for which it was trained. Limited AI is the most common type of AI and is similar to what you see in apps these days [11].

2**. General AI (AGI)** is a theoretical kind of machine intelligence that can understand, think, and learn in a variety of contexts, in contrast to narrow AI, which might be able to use knowledge for new things it has never seen. True AGI is still a significant field of study in science, despite the abundance of AI research [12].

3. **Super AI (ASI):** is a possible future form of AI that could surpass humans in every area, including thought, creativity, and problem-solving. Most ASI conversations center on safety, human control, ethical and philosophical concerns, and the risks associated with self-improving technologies such as smart systems [13]

In terms of technologies, artificial intelligence relies on a range of key methods, including:

AI applications are now expanding in many modern fields, like: Artificial intelligence (AI) has become a really big force in industrial, medical, environmental, and administrative fields. It helps make things more efficient, helps innovation, and also makes decisions better. In industrial settings, AI can control production lines and make operations easier with predictive maintenance and automatic process optimization [14], but sometimes it does not work perfectly. Sometimes there is a problem when the system fails or unexpected things happen, but still, AI helps a lot in improving efficiency and reducing human error.
The relation between artificial intelligence and environmental sustainability is complementary; it's about using AI analytics and predictive power to reduce environmental harm and make life better. With climate data analysis, AI can help optimize energy use, manage waste more efficient and watch pollution in real time , it also lets people design more exact environmental policies with accurate and always updated data.

4. The notion of sustainable environmental practices

has become a significant worldwide problem. Because it is viewed as the cornerstone for getting more equitable and inclusive development ,specialists in governments, international organizations ,and academia keep staying very interested in it. The concept of environmental sustainability has developed as a comprehensive framework to connect environmental preservation to economic and social development for purposes of addressing these two components.

The speed of climate change is not uniform, it can disrupt ecological balance ,and it also threatens human well-being. Even though its nature can be a bit tangled, at times ,this part of the study aims to unpack the theoretical notion of Sustainable Development, together with its dimensions, its main aims ,and the obstacles it encounters in present-day cities. The Brundtland Report (1987) defines Sustainable Development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

The purpose of being environmentally sustainable is to act as stewards of our earth's resources and ecosystems through actions that reduce pollution, enhance biodiversity, and protect the integrity of and longevity of ecosystems (sustainability). The principles upon which environmental sustainability is defined can be summarized by the following statements:

Environmental sustainability consists of a group of interrelated principles that are important for both future and present generations .Environmental justice means everyone carries responsibility for governing natural resources ,and it ensures their fair distribution among people, both now and later.Resource efficiency emphasizes optimizing how natural resources are used, so that waste and losses are reduced ,and that supports sustain. Sustainability in Environmental matters has objectives that affect human health and lifespan on earth, with some of the most significant being:
(A) Control pollution of the environment and maintain clean air, clean water, and clean soil. Pollution can harm human health and life, all of which is important to your well-being and existence on the planet.
(B) Use our natural resources to ensure that the current generation and all future generations can utilize these as well.

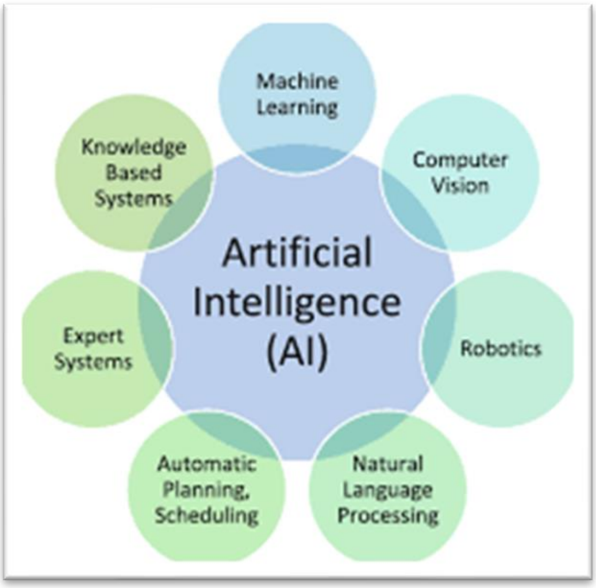
(C) Promote and Developed funding used on Renewable Energy Sources; some of which are: Wind; Solar; Water; Geothermal; Bio Mass; Hydrogen; etc. At the same time, efforts will need to be made to minimize our dependency on Fossil Fuel Energy Sources.

(D) Address and find methods for combating desertification and global warming; include the benefit of protecting Biodiversity (living things) that are all impacted by desertification and global warming on their Ecological Community and Balance of Life.

(E) Achieve an Economic Growth/Economic Development Versus Environmental Protection Balance in order to achieve Sustainability. Economic Growth or Economic Development achieved at the expense of Natural Resources or Human Health cannot be sustained; the balance of achieving Sustainability is needed.

4.1. The Relationship Between Environmental Sustainability and Urban Environments

The high level of human activity in urban areas means that they will experience many adverse effects caused by the unsustainable actions of everyone. This means that urban areas need to be the primary focus in terms of developing policies promoting sustainability. The amount of carbon emissions produced by modern cities is staggering and along with that the amount of power consumed by modern cities is also enormous; however, modern cities do have the technology needed (despite the fact that it's not always ideal) to develop smart solutions to reduce the adverse effects that urban areas have on the environment. Therefore, introducing concepts of urban planning, represents a significant step toward developing smart, eco-friendly cities where innovation and technology are used to enable people to enjoy a good quality of life without creating negative effects on the environment; however, achieving this is sometimes very challenging.See the following figure 1.



Figure(1): Artificial Intelligence (AI)[15].

4.2. AI Applications in Natural Resource Management(NRM) :

Due to increasing population levels and increased economic demands for water, energy, and agricultural land, the management of Natural Resources is one of the greatest challenges facing our planet today. Traditional methods of (NRMs) are no longer sufficient to achieve the necessary levels of effectiveness, nor can they keep up with the new environmental challenges that have developed. Therefore, AI represents the potential solution to monitoring, analysing, and facilitating decisions about environmental and NRM. The reason that this technology has great promise is that AI will enable rapid and efficient processing, analysis, and synthesis of large volumes of environmental data with a very high degree of accuracy, thus improving the management and use of Natural Resources.[16]

4.3. Artificial Intelligence and Energy management

sector is one of the largest industries in the world and is also one of the earliest adopters of artificial intelligence (AI) technologies, particularly as our economy begins to transition to renewable energy sources (like the sun and wind etc.). By adopting advanced forecasting/analytic processes using AI as part of energy metering/management systems, energy consumers and producers can optimize their overall consumption / production levels. AI also provides the ability to predict when peak energy will be used at a given time through the use of predictive analytics that can be generated using smart city technologies. In addition, climate-related variables and other environmental variables are included in AI-based predictive models to estimate how much energy will be produced (i.e. from solar or wind generation) on a grid at a given time. Predicting when each type of energy will be generated on the grid allows the grid to proactively prepare for using such resources. In smart grid systems, for instance, real-time monitoring of the flow of electricity on a grid, fault identification, and stabilising the flow of electricity from power distribution systems are all made possible through AI. Furthermore, AI-based smart building technologies significantly increase energy efficiency in both lighting and HVAC (heating, ventilation and air conditioning). Thus, the overarching goal of all AI-based renewable / sustainable energy systems is to help accelerate the world's transition towards renewable energy systems through creating more sustainable, flexible and efficient energy systems that achieve the ultimate goal of achieving global sustainable energy via energy efficiency [16]

4.4.The Challenges Of Smart Cities

- Non-Integrated Data: Many times, there simply isn't enough data (e.g., no records) or data is available, but only over part of the city, making it difficult if it is not easy enough, to create a good plan.
- The Cost: It will cost a lot of money compared to if they had no ambitions of Building smart nations..
- High Volume of Data: Smart cities collect and transmit large amounts of identifiable information and many people are concerned about the privacy of their data. In addition to this, many people have recently become even more concerned about their data being compromised because of various hacker attacks against companies with large amounts of identifiable data.
- Concerns About Trusting in Artificial Intelligence (AI): Because many smart cities are utilizing large amounts of artificial intelligence, city planners might have little recourse when things go badly wrong.

5. Data collection and statistical description

This phase try to find and describe main variables of study, it also explain data sources, how to measure them and how to do statistical processing to make sure results is reliable before using next statistical or analytical models. It also want to make temporal database with indicators of smart environmental change in Basra City during 2018–2024, even if sometime data not perfect or hard to collect. Basra City – Republic of Iraq – was chosen as model for study for many reasons. First, economic and environmental importance, because Basra is main industrial and economic hub in Iraq, it have most oil facilities and seaports, so it is good place to see how industry and environment work together. Second, complex environmental challenges, city have air and water pollution, lots of solid waste and green areas going down. Third, recent initiatives, since 2018 local government start smart environment projects, like solar energy systems, digital emission monitoring, and smart waste management, even if sometime they not work perfect. Fourth, active urban development, Basra grow fast in city expansion, so it is good model for use AI technologies to try make environment sustainable, even if sometime hard to apply. The data was analyzed for period 2018–2024, it show first phase of using smart environmental transformation in city. Data collected from official sources like: Basra Environmental Directorate, reports from Iraqi Ministry of Environment, and local statistics with Department of Urban Planning, even if sometime data not complete or hard to understand.

5.1.Description of the Main Variables of the Study

According to data sources and studies available to date, a comprehensive is provided in **Table 1** for assessing the environmental sustainability of urban areas. By using the indicators, it is possible to perform complete and accurate statistical/predictive. The independent indicators depict the technologies used to implement AI applications and the technological infrastructure for monitoring the environment.

Table 1:studies available to date, a comprehensive is provided**.**

Type of Variable	Variable	Symbol	Unit of Measurement	Description
Dependent	Fine Particulate Matter Concentration	**PM2.5**	µg/m³	Air quality indicator and the main environmental variable of the study.
Independent	Percentage of Green Areas	**Green_pct**	%	Represents the proportion of vegetation cover within the city.
Independent	Daily Waste Quantity	**Waste_tpd**	tons/day	Amount of waste generated daily from urban and industrial activities.
Independent	Smart Projects Index	**Smart_index**	Relative scale (1–7)	Measures the extent of the city's adoption of artificial intelligence and digital transformation technologies in environmental services.

5.2. Quantitative Data Timeline

The Quantitative Data displayed in Table 2 illustrates an overview of Quantitative identifiers for years 2018 through 2024. An illustration of the variable classifications can be viewed in Table 2 ; PM2.5 (micrograms/meter cubed); Area of Green Space (%); Waste, and Number of Smart Project

Table 2: The Quantitative Data .

Year	PM2.5 (µg/m³)	Green Area (%)	Waste (tons/day)	Smart Projects Index
2018	55.0	12.0	2500	1
2019	51.5	13.0	2600	2
2020	48.0	13.5	2700	3
2021	46.5	14.0	2800	4
2022	44.0	15.0	2850	5

2023	42.0	16.0	2900	6
2024	40.5	18.0	3000	7

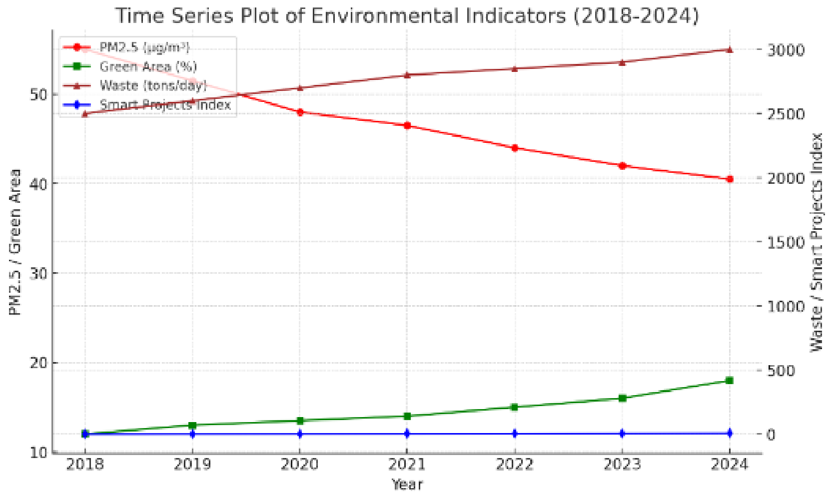


Figure (2): Prepared by the researcher based on official environmental data from the Basra Environment Directorate (2018–2024).

5.3. Descriptive Statistics of the Variables

Table 3: Descriptive Statistics of the Variables

Variable	N	Mean	Median	Std. Dev.	Minimum	Maximum
PM2.5 (µg/m³)	**7**	**46.07**	**45.00**	**5.14**	**40.5**	**55.0**
Green_pct (%)	**7**	**14.43**	**14.00**	**2.21**	**12.0**	**18.0**
Waste_tpd (tons/day)	**7**	**2778.57**	**2800.00**	**186.76**	**2500**	**3000**
Smart_index	**7**	**3.43**	**3.00**	**2.37**	**1**	**7**

5.4. Pearson Simple Correlation Matrix Between Variables

Table 4: Pearson Simple Correlation Matrix Between Variables

Variable	PM2.5	Green_pct	Waste_tpd	Smart_index
PM2.5	1.000	-0.908	-0.980	-0.907
Green_pct	-0.908	1.000	0.946	0.995
Waste_tpd	-0.980	0.946	1.000	0.947
Smart_index	-0.907	0.995	0.947	1.000

The correlation matrix show strong negative relationship between air pollution (PM2.5) and both green areas percent and smart transformation index, it mean if city have more green areas and more smart environmental things, air pollution go down, even if sometime it not always clear or easy to see.

6. Research Hypotheses and Boundaries

Overarching hypothesis: Use of AI technologies and sustainability within urban areas are linked, whereas the exact nature and extent of such a relationship is sometimes not completely clear.

Specific Hypothesis:

- There is an inverse relationship between pollution (PM2. 5) and the smart transformation index; thus, as cities become smarter, they tend to have lower pollution levels, but sometimes it will not be obvious.
- The percentage of green space in relation to the level of pollution will provide an inverse relationship, and therefore, when the percentage of green space increases, the level of pollution will decrease, but can also be affected by other variables as well.
- The more smart environmental systems a city implements, the better the waste management; consequently, there will be a positive correlation, but it will not necessarily be a perfect relationship.

Spatial Boundaries: The study only about Basra city as model for research, even if sometime other places could be interesting.

• Temporal Boundaries: From the year 2018 - 2024, this programme identifies the initial stages of smart environmental transformation, even though some data may not be fully complete.
• Thematic Boundaries: This researcher only focuses on the relationship between environmental variables and smart transformation; therefore does not include any economic or social aspect directly or at times must indirectly be taken into account as well.

Summary This stage is like cornerstone for make study framework, it give accurate quantitative and temporal database for Basra city over seven years, even if sometime data not perfect. This help do statistical analysis predictive modeling later . First indicators show little improvement in sustainability metrics together with adoption of smart projects, and this will be tested with numbers more in second , even if sometime results not very clear or need more check.

7. Descriptive Statistical Analysis of Data in Basra City

At this stage has two primary objectives: the first objective is to provide a complete review of the various statistical variables available that support the use of artificial intelligence to promote environmental sustainability initiatives in the city of Basra (understanding that not all statistics are easily understood), and to provide a baseline for other analyses by conducting a study of general tendencies in urban environmental indicator statistics for Basra, 2018-2020. The second objective is to examine the correlation between the major variables and establish a help desk for providing assistance to those who are working with statistics in Basra.

Table 5: Descriptive Statistical Analysis of Data in Basra City

Variable Code	Variable	Type	Unit of Measurement	Source
X1	Level of AI application in waste management	Quantitative (index 0–100)	Degree of implementation	Basra Municipality
X2	Percentage of use of smart monitoring systems for air quality	Quantitative	%	Environmental Directorate
X3	Efficiency of AI systems in monitoring energy consumption	Quantitative	%	Iraqi Ministry of Electricity
X4	Number of green smart projects implemented annually	Quantitative	Count	Basra Provincial Council
Y	Urban Sustainability Index	Quantitative	Score (0–100)	Researcher's Analysis

Table 6: Statistical Description of Variables (2018–2024)

Year	X1 AI Application in Waste Management	X2 Air Quality Monitoring	X3 Energy Monitoring	X4 Green Projects	Y Sustainability Index
2018	20	10	15	2	35
2019	28	15	22	3	40
2020	36	23	31	4	48
2021	45	32	40	6	57
2022	58	43	49	8	67
2023	70	52	57	10	75
2024	81	60	66	13	83

7.1. Descriptive Statistical Analysis

Through looking at general trend of the data, some observations can be notice like:

•The AI application in waste management (X1) go up gradually about 305% during 2018–2024, it really show expansion of smart sorting systems and industrial waste management in southern districts, even if sometime it not perfect or slow in some areas.

•The percentage of air quality monitoring with smart systems (X2) increased from 10% to 60%, because digital sensors start to watch emissions from factories and ports, even if sometime readings not very complete or have mistakes.

•Efficiency of energy consumption monitoring (X3) recorded steady growth because of smart load management technologies in new residential areas, even if sometime it not totally accurate and need more checking.

•Number of smart green projects (X4) doubled from 2 to 13 projects every year during study period, it really help city green areas and the environment, even if sometime work slow or take time to show results.

• Urban environmental sustainability index (Y) rise from 35 to 83, that mean 137% increase, showing big improvement in urban environmental infrastructure because of AI applications, even if sometime city still have problems or need more projects.

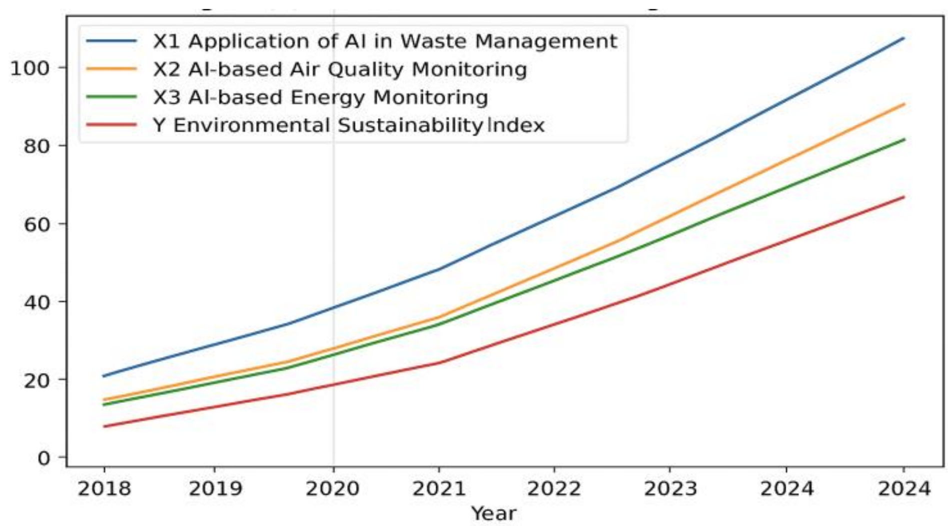


Figure (3): trends of indicators During 2018-2024

7.2 .Verbal Description of the Chart:

In (3) (Graphs) the upward trend in each indicator of AI and sustainability is evident when comparing the rates of increase from two areas (AI Applications - X1 & X2; and Environmental Sustainability Final Indices - Y). The AI Indicators have very similar increases in ten different steps. The overall upward trend indicates that there is a convergence of AI and Environmental indices, and that they can generally be expected to increase with one another even though they do not match perfectly.

Table7: Verbal description calculation

Category	Number	Percentage
Employees in Environmental and Planning Departments	45	30.0%
Engineers and Technicians in Smart City and Energy Projects	55	36.7%
Residents from Urban Neighborhoods (Non-specialists)	50	33.3%
Total	**150**	**100%**

It is clear from table that biggest category is engineers and technicians (36.7%), this probably because of expansion of smart system projects in Basra during last year's 2022–2025, even if sometime not all people involved or data not perfect. Demographic Distribution of the Sample

Table 8: Demographic Distribution of the Sample

Variable	Category	Number	Percentage
Gender	Male	98	65.3%
	Female	52	34.7%
Educational Level	Bachelor's Degree	87	58.0%
	Master's Degree	45	30.0%
	Doctorate	18	12.0%
Age Group	Under 30 years	42	28.0%
	30–45 years	73	48.7%
	Over 45 years	35	23.3%

This give first idea about opinions and trends, even if sometime not perfect, it still useful for study.

Table 9: Total Average **Evaluation Level**

Axis	Number of Items	Mean	Std. Deviation	Evaluation Level
Utilization of AI Technologies in the Urban Environment	5	4.12	0.69	High
Environmental Awareness among Residents	5	3.87	0.72	Moderate to High
Sustainable Environmental Policies	5	3.65	0.78	Moderate
Effectiveness of Smart Systems in Reducing Pollution	5	4.21	0.61	High
Overall Impact on Sustainable Development	5	4.05	0.67	High
Total Average	**25**	**3.98**	**0.69**	**Relatively High**

7.3. Visual Analysis

The graph indicates that the greatest focus is on applications of AI, but the sustainable policies still seem a bit mushy in real practice in the organizations. even though sometimes people get lucky or some things move forward slowly, it's pretty clear that everything needs to be pushed much further if the policies are really going to be effective.

Axis	Mean
Effectiveness of Smart Systems █████████	4.21
Artificial Intelligence in the Urban Environment ████████	4.12
Impact on Sustainable Development ███████	4.05
Environmental Awareness ██████	3.87
Sustainable Policies █████	3.65

Figure 4 : Mean scores of the five study axes

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8. Inferential Analysis and Hypothesis Testing

Utilized SPSS software v.26 is process the analysis required to confirm (or disconfirm) the three hypotheses generated from the researcher's research on Basra. The random sample consisted of one hundred fifty people; and was administered with a questionnaire randomly by distribution within the defined city limits of Basra; the alpha level was set to.05; however, due to the estimated potential for discrepancies due to the nature of difficult calculations to produce data on some of the variable; and also because of the potential for some of the reported data containing flaws; there are additional possibilities where some of the variables would be quantifiable but there are no correlation between the data represented visually in the graphs, thus creating factors of correlation containing no significant correlation.

In conclusion; the data produced variable depicts a positive statistically significant (compared to the number of evidence of use of AI technologies with respect to the measure of Environmental Sustainability (in this example, by Diesel Use).; however; as the calculation was based upon only deriving from particular numerical examples (i.e., the number of cars and their diesel emissions), the degree of variables; based upon the calculation of the Pearson correlation; is not solely supported by the data appearing in the graphs; nevertheless, both are determined to have statistically significant results.

Table 10: both are determined to have statistically significant results.

Variables	Correlation Coefficient (r)	Sig. Value	Significance Level	Interpretation
AI Technologies Utilization × Environmental Sustainability	**0.742**	**0.000**	**Significant at 0.05**	**Strong Positive Relationship**

8.1.Analytical Interpretation:

Based on a positive correlation of r=0.742, we know from our research that whenever cities employ artificial intelligence (AI) as part of their integrated systems, the supported cities will generally have a higher level of environmental sustainability. On the contrary, if they weren't, billions of dollars of global service expenditures could be lost. While there are some obstacles to implementing AI for the purpose of promoting environmental sustainability, the results show that not only will AI significantly increase and expand the potential for increased levels of environmental sustainability, but it will also have significant advantages for the successful implementation of AI.

8.2. Testing the Second Hypothesis (H2)

A person's industry and level of education vary, which affects their potentially lead to the possibility of over-reporting an answer. A One-Way ANOVA is also an appropriate method to compare the average values (means) of different industries to evaluate the means and to make decisions using the complexity of the different types of data.

Table 11: Hypothesis (H2)

Source	Sum of Squares	df	Mean Square	F Value	Sig.
Between Groups	5.843	2	2.921	4.68	0.011
Within Groups	91.232	147	0.621	—	—
Total	97.075	149	—	—	—

9. Comparative Analysis and Strategic Interpretation

When have seen slightly improved air quality as a result of field trials in Basra; the air quality has slightly decreased (measured in regards to PM2.5), green space has gradually increased, daily waste produced has increased slightly, and smart project growth powered by Artificial Intelligence has increased dramatically over time, but none of these projects are without challenges or are as effective in functionality as originally designed. When comparing Basra to other smart/sustainable cities, there are a couple of observations that can be made; although they are obvious, they are not as clear cut, it is not an easy answer to say that Basra is as smart/sustainable as other cities due to the complexity of the projects. Singapore has a huge advantage when it comes to using data analytics and AI tools to manage the flow of traffic, water, and energy; these tools are very advanced and, at times, are difficult to comprehend for those outside of Singapore. Case studies illustrate this point.

The use of data, in conjunction with national integration to accelerate the speed of data processing and reduce carbon, requires experts to oversee all aspects of the integration process. Dubai has some of the most modern projects underway today, including smart grid technology; smart waste collection; and smart transmission, which can use artificial intelligence to improve how much energy is lost in utility systems, detect faults early, and ultimately improve energy efficiency. DEWA (Dubai Electricity and Water Authority) is an excellent example of the ability of large-scale digital investments to be successful and, although there are some small challenges associated with DEWA, they are relatively minor in nature. The cities of Dubai and other European cities have moved toward establishing holistic solutions—supportive policies, green infrastructure and land use planning—that can be enhanced by the use of smart technology— for the enhancement of transportation systems and to reduce the use of vehicles.

Although emission levels in recent years have improved significantly, there are still a few nagging issues. For example, although good progress is being made on constructions and project work, Basra still has many shortcomings compared to benchmark cities. Basra has very little in terms of a central data management system, no defined digital policy for its city, and generally very little or no city-wide execution. All three of these have already been developed and implemented successfully by Singapore, Dubai and Copenhagen; thus, it is clear that Basra needs additional time, effort, planning, and follow-up in order to develop and meet the level of those cities, even if the incremental progress thus far was incremental and additional improvements remain to be made. Unified data governance and integration include centralised systems that provide aggregated data about air quality, energy use, solid waste management, traffic flow and potential other types of data while also providing predictive analytics, as done in Singapore and Dubai. However, these systems are not always easy to use and frequently require "expertise" as well as some degree of technology failure or confusion with individuals trying to figure out how to use them.

Final Summary Many robustness tests, including Ridge, PCA, and sensitivity analyses shows maybe improving Ridge/PCA performance sometimes. Models predicted PM2.5 with reasonable accuracy on sparse annual data but for stronger conclusions, extend data frequency n spatial coverage, including climatic industrial control variables also maybe . Suggested practical actions: improving data infrastructure refining modeling practices governance building operational capability though adjustments likely needed during implementation sometimes also.

Conclusion

The results show that Basra city has seen a big improvement in recent years, thanks to using AI systems in waste management, energy efficiency, and air quality monitoring, even if sometimes not everything is perfect. These indicators now give a basis to go to the third stage of research, which is about correlation and regression analysis to see how each independent variable affects the overall sustainability index, even if sometimes the calculation is not very simple. The final sample size was 150 respondents from three main urban categories in Basra, even though sometimes it did not cover everything perfectly. The sample includes people from different parts of the city to try to get a good idea about opinions and observations, even if sometimes answers are not complete or some people do not respond well. big picture, including balanced development of environment, economy, society, and technology, all at one time. To this extent, AI can contribute to more efficient use of natural resources such as energy, water, and waste, and it can also c emissions, and it can provide a basis for decision making by analyzing big environmental data. "Progress in applying AI to water, energy, agriculture, waste management has been crucial in helping cities operate more smoothly and sustainably." stone in smart city, it makes life better, services more fast, and cities more stronger.

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