Smart City Feasibility Study using IoT and Machine Learning

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ABSTRACT

Complexity and resource constraints accompany urban growth. According to UN figures, cities currently use 75% of the global energy, with 70% of the greenhouse gas emissions being mostly generated from transportation and residence buildings. Furthermore, city residents are susceptible to the consequences of climate change. Therefore, a feasibility study for the possibility of implementing a smart city was conducted in this paper. The results show that the current situation of the cities is/renders them far from being smart, while the environmental aspect needs to be controlled by the use of IoT sensors. The utilized Hyperd algorithm gave highly accurate prediction results.

Keywords-smart city; IoT; AI; feasbility ; linear regression ; gradient boosting

I. INTRODUCTION

The transition to sustainable cities is a crucial and politically significant goal, given the increasing population and recurring energy crises [1]. In this context, energy's pivotal significance is noteworthy, as it substantially influences the economic and social advancement [2]. Green energy technologies are environmentally friendly and their quickly expanding reliable power sources can ease the current energy problem [3]. Electric Vehicles (EVs) and Green Buildings (GBs) are renewable energy applications, which are pivotal in smart city development. Fossil fuel reserves are running low, and the need for energy is rising, which has reignited the interest in GB integration [4] and the transition to EVs [5]. Numerous studies have looked into various aspects of smart cities, such as EV use and the significance of GBs. For instance, the utilization of renewable energy, appropriate consumption habits, urban adaptability, and environmental considerations are only a few of the smart city advantages covered in [6]. The authors provided evidence of the benefits smart city development brings [6]. Authors in [7] studied ways to utilize sustainable city and community concepts to plan for future cities and manage existing ones, with an emphasis placed on energy consumption and transportation decarbonization. They looked at how well electric mobility performed in six case studies. According to the findings, using more electric vehicles is positively impacted by lowering PM2.5, PM10, and NO_2. Authors in [8] developed a novel technique based on three factors: coordination, practicality, and autonomy to respond to the power grid's peak load being increased by uncoordinated EV charging and rising additional electricity costs. Information and communication technology is utilized in a smart city to improve public services and health care for its residents, share knowledge with the public, and promote government efficiency. Parking sensors update these data in real time. The underlying technologies, such as parking for utility distribution and municipal planning, are not significantly impacted by smart city parking [9]. Smart parking keeps an eye on available parking spaces in real time, offering a practical and economical parking solution. The abundance of data collected is used to guide drivers to the best parking space. Data delivery and collection via wireless data transfers, cameras, and sensors are necessary for a workable solution [10]. Real-time parking information and traffic management will be advantageous to both automobiles and travelers [11]. The efficacy of municipal governments can be increased by parking ordinances that support the development of intelligent communities [12]. Smart parking will be essential to creating smart cities as metropolitan areas are growing today, with this growth being continued in the future [13]. To help individuals save time and money, towns and communities can deploy a number of smart parking solutions [14]. The same actions would reduce traffic and increase municipal efficiency [15]. By putting in place numerous protocols, traffic management keeps things flowing while enhancing the safety, security, and dependability of transportation systems [16]. Daily initiatives, services, and an Intelligent Transportation System (ITS) have been deployed in these attempts to improve the performance of the road network [17].

A feasibility analysis is a thorough examination of a project's viability that takes into consideration all relevant variables, including those related to technology, finances, law, and schedule [18]. A feasibility study facilitates the identification and arrangement of all the elements required to generate profitable business work [19]. Nowadays, feasibility analysis is among the most crucial instruments of strategic planning. Moreover, it is thought that feasibility analysis is a useful approach for the strategic management of projects in a range of economic and investment-related activities, which results in the decision to make an investment with the least amount of risk and uncertainty during the project's lifetime [20]. The creation of feasibility studies came from the economic theory fundamentals and was motivated by the existence of several internal and external factors related to the future, which could have an impact on decisions about investments taken under a specific level of risk and/or uncertainty [21, 22]. Since the mining business is quickly expanding internationally, there is a growing demand from investors for mining projects. Businesses involved in mining must thoroughly assess the project's potential for output before making an investment. The development of a quantitative assessment model serves as a basis for scientific decision-making by examining and analyzing whether the project is worthwhile to proceed with. This is accomplished by applying impartial assessment techniques. By effectively integrating big data, machine learning, and other information technologies, researchers have made significant scientific advancements in geological studies, quantitative prediction, and mineral resource evaluation [23, 32]. It is difficult to create a smart city in Iraq due to the numerous social, economic, and environmental barriers that exist in the country. In order to meet specific Sustainable Development Goals (SDGs) like responsible consumption and production (SDG12), creative thinking and facilities (SDG9), sustainable communities and cities (SDG11), and good health and wellbeing (SDG3), there has been an increased focus on implementing Internet of Things (IoT) technologies for smart city implementation. Internet of Things (IoT) applications in smart cities that support the SDGs include efficient buildings, astute energy and water management, intelligent traffic and parking solutions, health and environmental surveillance, connected transportation systems, intelligent waste disposal, public safety, and environment monitoring. In addition to smart cities, the international economy is impacted by the IoT technology as well. The Internet of Things (IoT) corporate market size demonstrated a slow growth rate of 14% in 2019 and 22% in 2023 for the IoT corporate market [33]. By 2030, IoT-based smart city applications are expected to have produced $5.4 trillion [34]. It is projected that there will have been over 50 billion IoT devices in operation globally by 2030 [35]. This, according to [36], has an impact on the development of smart cities. A total of 118 cities in 2021 and 141 cities in 2023 will be considered smart [35]. The utilization of IoT in smart cities has been the subject of extensive research since 2010. The Web of Science (WoS) was used as a search database, and the terms "Internet of Things," "IoT," "and/for," and "Smart Cities" had been the input. Only a small number of papers from 2010 to 2013 were found, about 100 in 2014, and over 1000 articles across several disciplines will have been detected by 2022. Fewer than 200 highly cited papers from the WoS main category, covering a variety of fields were found through the search. Notably, among the publications with more than 1000 citations, the articles [37, 38, 39] stood out. AI is becoming recognized as a potent instrument for developing smart cities. Applications with AI capabilities are still in their infancy and have not yet reached their full potential [40]. But the rise of AI has already highlighted the possible "double-edged sword" impact, according to which a techno-optimistic mindset might cause unintended negative effects to go unreported. Authors in [41] state that more investigation is required to determine whether AI has any drawbacks when it comes to smart cities. Consequently, the energy-related components of a smart city would be taken into account, especially in relation to ethical conundrums, including environmental issues and possible legislations. In fact, the development of smart cities is increasingly centered on decarbonization. Cities have long been associated with substantial emissions of greenhouse gases. Accordingly, two of the main sources of greenhouse emissions in cities are the transportation sector and stationary energy [42]. Most significantly, it appears that a limited number of urban regions contribute disproportionately to the global carbon footprint; thus, this degree of concentration implies that national and local governments often have equal influence over emissions [43]. This call to action is necessary since, global energy-related carbon dioxide emissions reached a record-breaking 36.3 billion tons in 2021, a 6% rise [43, 44].

The current paper's goal is to create a framework for smart city feasibility studies and explain how to use a combination of AI and IoT to make sure that a specific location can have a smart city. The secondary aims were to build a management monitoring system utilizing sensors and AI to maintain sustainable cities by following the rules of the feasibility studies for the building of smart cities.

II. METHODOLOGY

Initially, a feasibility study concerning building a smart city in Iraq based on legal, economic, and environmental terms (Table II) was conducted.

Employing a quantitative data collecting approach, primary data were gathered to gain a larger perspective and a closer look at the real situation in Iraq. The respondents (Figures 1-3) were consultants, experienced engineers, specialist engineers, and project managers from the building sector. A total of 75 respondents answered the questionnaire. They were asked about the effect of these aspects on the smart city performance. The answers were based on the Likert 1-5 scale with 1 representing not effective and 5 being very effective.

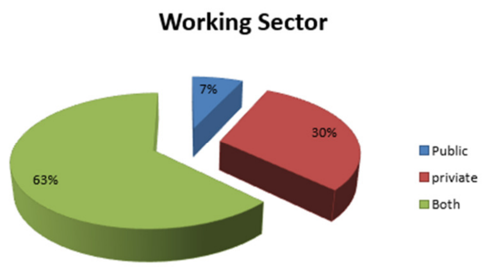

Fig. 1. Work sector of the respondents.

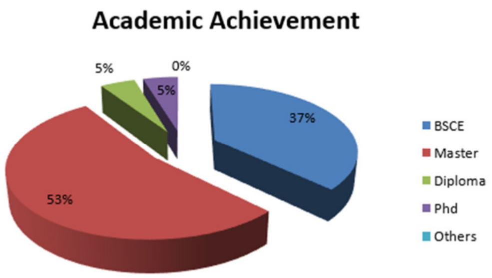

Fig. 2. Academic achievements of the respondents.

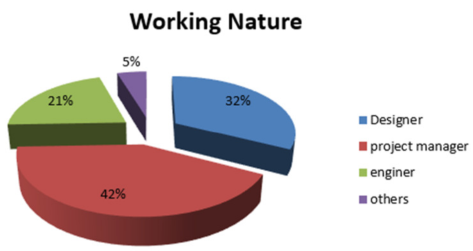

Fig. 3. Working nature of the respondents.

Ultimately, the information gained was utilized to investigate how the Iraqi construction industry perceived the smart city feasibility and the best way to divide it into phases. Field data regarding the current situation were gathered. The next stage involved the assessment of the environmental index of smart cities regarding the IoT aspect. IoT sensors were used to measure the environmental conditions. Temperature, gases, and CO_2 levels were measured (as indicators) in different places of the Dailya governorate for a duration of six months. Subsequently, the Hyperd algorithm, which constitutes linear regression along with gradient boosting was used. Linear regression [45, 46] was employed as the most basic ML approach. The forecasting performance function F is defined as a linear expression of the input vector x, which was a combination of the measured data and the questionnaire results. The least-squares method was deployed to evaluate the results. Because of its ease of use and widespread application in the field of artificial intelligence, this study opted to begin with regression modeling as its model-generation method. Gradient boosting is a strategy that builds a series of decision trees and adds their individual predictions to produce the overall prediction D(x). It is based on the ensemble learning concept [47-49], which can be represented mathematically by:

$$D(x) = dtree1(x) + dtree2(x) + \dots \quad (1)$$

Following the first constructed tree, another tree is constructed to bridge the gap between the objective function F(x) and the present ensemble forecast. The ensemble prediction D now includes two trees [10]. Tree 3, which is the next tree in the ensemble, will be taught in a manner that complements the present trees while minimizing the group's learning failure. Ideally, the next tree ought to be positioned in a way that:

$$D(x) + dtree3(x) = F(x) \quad (2)$$

The method teaches trees to recoup the distinction among the target function and the group's present prediction in order to improve the final prediction. The present study referred to this fluctuation as the remnant:

$$R(x) = F(x) - D(x) \quad (3)$$

A decision tree makes all of its correct predictions when it fully reconstructs R(x). As this never occurs in reality, the process of generating trees iteratively continues. A decision tree is a very simple classifier that divides a space of features into regions using conditional. Gradient boosting, which makes use of the entire ensemble, combines a set of weak learners, or individual decision trees that are not particularly strong predictors on their own, to increase prediction accuracy. Each tree's predictions are weighted based on the performance of the tree that came before it. Additionally, the more exact a result is, the more heavily it is weighted. Depending on the weightings of its results, each tree will contribute differently when the full ensemble of trees is utilized to create a single prediction.

III. RESULTS AND DISCUSSION

The aspects of the questionnaire are divided in three main categories (economic, social, and environmental). They can be see, along with the Relative Important Index (RII) results in Table I.

The application of IoT in smart cities has several advantages, including: Improving the efficiency and decreasing the cost of local government services by collecting information about how city services are used. IoT allows for the tracking of air quality and energy use. Utilizing this knowledge, the pollution levels in the city may then be reduced. The results of the IoT sensor measurements over a period of six months can be observed in Table II. The information received indicates that the CO_2 and temperature at various times of the year are above average. In order for a building to meet the energy performance criteria of EN 16789-1:2019 [50], its indoor air temperature must be between 18 and 28 ^{o}C throughout the year. The human body's metabolic rate is significantly influenced by environmental temperature. According to estimates, a person who is dressed and at rest at 18 °C will have a 15% greater metabolic rate than a person at 28 °C [51]. Therefore, it is reasonable to assume that, irrespectively of other factors that might affect it (such as activity level, drug use, health issues, etc.), the synthesis of metabolic CO_2 in the temperature ranging from 18 to 28 °C would solely fluctuate due to environmental temperature.

TABLE I. SMART CITY FEASIBILITY STUDY ASPECTS AND QUESTIONNAIRE RESULTS

Sub	Smart city	Index	RII
Social	Social	Asset protection	0.77
		Public transportation	0.75
		Public support and authorities involved	0.80
		Advertising, retail, leisure	0.78
		Taking security over assets, current and future income	0.82
		Smart crime prevention	0.79
	Economic		0.69
		It is possible to be designated both the lender and beneficiary on insurance plans.	0.67
		Rules for asset ownership.	0.75
		Restrictions on Foreign Direct Investment (FDI) and currency controls.	0.77
		Dividends and capital invested cannot be repatriated in whole.	0.79
		Limitations on foreign employees. (conversely, perks for foreign investors).	0.80
			0.83
	Environmental	Waste and pollution control and usage	0.88
		Land clearance	0.87
		Safety measures	0.85
		Safety standards	0.82
Economic	Social	Improving project teams' attention.	0.8
		Identification of new possibilities	0.75
		Acqioring vital details to make a "go/no-go" judgment.	0.78
		Narrows down the company options.	0.88
		Identifies a solid rationale for starting the construction work.	0.81
		Improves success rate for assessing numerous parameters.	0.84
		Supports project decision-making.	0.81
		Identified reasons not to proceed.	0.87
	Economic	Capital expenditures	0.82
		Cost–nenefit analysis	0.93
		Electricity cost	0.87
		Life cycle analysis	0.82
		Life cycle cost	0.87
	Environmental	Carbon storage and consumption	0.9
		Enhanced oil recovery	0.88
		Environmental and techno-economic assessment	0.87
		Emission trading system	0.92
		Mass and energy balances	0.89
		Levelized cost of building	0.94
Environmental	Social	Carbon footprint	0.89
		Air quality	0.89
		Pollution production	0.94
		Groundwater utilization	0.95
		Resilience to climate change strategy	0.95
		Population density	0.86
		Outdoor space per citizen	0.86
	Economic	Carbon storage and consumption	0.82
		Enhanced oil recovery	0.93
		Environmental and techno-economic assessment	0.87
		Emission trading system	0.82
		Mass and energy balances	0.87
		Levelized cost of building	0.89
	Environmental	Waste recycling rate	0.93
		Comfort level	0.94
		Quality of available water	0.96
		Urban greenery	0.93
		Satisfaction with the cleanliness of the city	0.98
		Sustainable management of natural resources	0.95
		Green infrastructure and green city initiatives	0.97
		Quality of water resources and water bodies and quality control	0.91
		Efficiency of generation, distribution, and use of water	0.89
		Total annual water consumption (cubic meters per capita)	0.88
		Efficient and intelligent collection, disposal, and treatment of solid waste.	0.92
		Percentage of recycled waste.	0.95
		Air quality index/pollution concentration levels	0.98

The aim of using AI to improve the smart city quality is to classify whether the city is healthy or not. The data used in the classification are a product of merging the questionnaire RII values and the IoT sensor data, as illustrated in Table III. A classification result of 1 or 0 represents healthy and unhealthy, respectively. The confusion matrix can be seen in Figure 4.

TABLE II. IOT SENSOR DATA

Input	Temperature	CO_2	Gas sensor
1	22.1	54.2	670
2	18.4	54.1	641
3	17.8	54.1	642
4	17.4	54.1	640
5	16.8	54.1	616
6	25.5	54.1	780
7	27	54.1	639
8	29.1	54	564
9	33	54.1	797
10	36	54.1	740
11	38	54.1	887
12	39	54.1	627
13	40	54	564
14	41	53.9	743
15	43	53.9	620
16	44	53.9	637
17	47	53.9	576
18	47	53.9	559
19	48	53.9	552
20	49	53.9	551
21	50	53.9	546
22	50	53.9	543
23	48	54	501
24	47	54	537
25	44	54	533
26	41	54	556
27	38	54	543
28	36	54	526
29	33	54	534
30	31	53.9	548

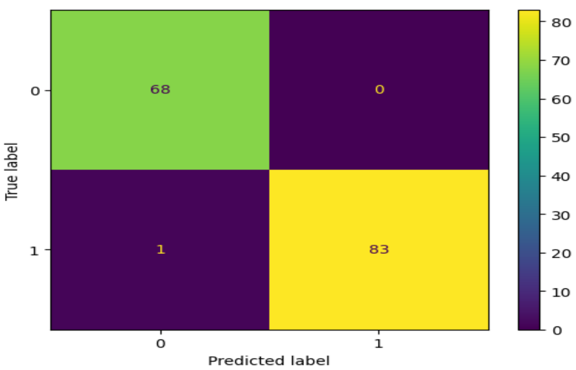

Fig. 4. Confusion matrix.

The algorithm's accuracy is 99.34%, which is considered very high. The shift in the air temperature from 15 °C to 50 °C resulted in a statistically significant change in the CO_2 content under the HVAC system's recirculation mode. The air relative humidity also has an effect: it increases as the temperature decreases.

TABLE III. SAMPLE OF THE DATA USED IN AI

Carbon Footprint	3.3	3.4	4.1	3.9
Air quality	3.1	2.4	3.1	4.9
Comfort level	3.3	4.4	3.1	2.9
Percentage of recycled waste	3.7	3.8	3.3	3.1
Climate resilience planning	3.3	3.7	4.1	3.9
Quality of water resources	3.6	3.6	4.8	3.8
Temperature	44	33	24	33
CO_2	55	40	53	45
Gas	543	543	543	543
Classification	0	1	0	0

Future studies will verify the findings of the field study conducted in a climate chamber with prolonged measurements of human volunteers. The results indicate that the main factors in the development of smart cities are to monitor the sustainable impact and the weather conditions. In order to enable locals to take responsibility for their carbon footprint, reducing pollution emissions also necessitates citizen participation. This may be accomplished through education, awareness campaigns, and reduction incentives. For example, automobile use and emissions can be reduced via smart city bike-sharing programs. Deploying smart city measures decreases carbon footprint [52]. Although there are many opportunities to reduce emissions by utilizing smart city components, their relative significance varies. It is important to take the smart city and its constituent parts into account when approaching sustainable urban development. Metropolitan regions may promote sustainable economic growth and become more resilient and sustainable by putting these policies into practice.

IV. CONCLUSIONS

IoT is used in the smart city context by integrating various gadgets, sensors, and data analytics into the city infrastructure to build a network of interconnected devices for real-time data gathering, analysis, and decision-making aimed at optimizing city operations and services. The findings demonstrate that regulating temperature and the emitted gases is necessary to create an ecologically sound foundation for a smart city. Deploying affordable data sources, air pollution levels are projected, with a focus on particulate matter. This study examines linear regression with gradient-boosting-based approaches for predicting the environmental pollution in smart cities. The processing approach for environmental contamination data is introduced, along with the creation of an accurate LR-GB. The feasibility study results showed that more than 85% of the participants indicate that the environment has a significant impact on smart cities. The accuracy of the proposed algorithm in predicting the environmental effect on smart cities is considered very good.

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