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Key Performance Indicators and the Model for Achieving Digital Inclusion for Smart Cities

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***Abstract*—**The term smart city has appeared recently and was accompanied by many definitions and concepts, but as a simplified and clear definition, it can be said that the smart city is a geographical location that has gained efficiency and flexibility in providing public services to citizens through its use of technological and communication technologies, and this is what distinguishes it from other cities. Smart cities connect the various components of the city through the main and sub networks in addition to a set of applications, and thus are able to collect data that is the basis for providing technological solutions to manage resources and provide services. The basis of the work of the smart city is the use of artificial intelligence (AI) and the technology of the Internet of Things (IoT). The work presents the concept of smart cities, the pillars, standards and evaluation indicators on which smart cities depend, and the reasons that prompted the world to move towards its establishment. It also provides a simplified hypothetical way to measure the ideal smart city model by defining some indicators and key pillars, simulating them with logic circuits and testing them to determine if the city can be considered an ideal smart city or not.

***Keywords*—**Evaluation indicators, logic gates, performance factors, pillars, smart city.

I. Introduction

THE digital revolution and electronic development all over the world have affected the way systems are managed in daily life. This digital revolution also produced societies known as digital societies, which depend on digital technologies and communications instead of the usual means [1].

Through the progress in scientific fields and social development, the concept of the city has developed, especially cities that use technologies, where many terms and names for cities have appeared, including, digital city, electronic city, virtual city, knowledge city, which was considered a starting point to the switch to the term "smart city", which has become an essential term for any city that provides its services to society through digital technology, communication and knowledge [3].

The goal of establishing smart cities is to invest time and get rid of the spatial dimension of the physical components of the city, which is achieved by providing an infrastructure in which electronic services are available with high efficiency [4].

Despite the tremendous technological progress and the spread of advanced means of communication in addition to the efforts made by city administrations and governments and the pursuit of providing welfare for citizens, cities have not been able to reach the ideal level as a 100% smart city [5]. Moreover, the proportions of cities may vary depending on the many indicators by which cities are measured, and the basic pillars that cities can rely on to reach their ideal score [6].

II. General Concepts

A. Smart City

The unprecedented and wide spread of information technologies and communication networks led to the development of the concept used for cities through different eras, and this development was reflected in human life. As by the 21st century, the world has turned to information and technologies in every field of life, and this transformation has been very rapid [7].

The entry of communication and information technologies into all activities and events in daily life, has revealed many concepts and terms that later became part of our daily life, for example: e-government, e-university, e-shopping and e-mail [8]. And because the city is the site and place where all life activities are practiced, which has become completely dependent on information and communication technologies, changes have begun to occur in the general structure of the city itself in order to meet the needs of those activities [9].

After the rapid economic, electronic and social development and the impact of this development on the natural environment, the world's attention has been directed to finding alternatives and solutions that reduce the impact of this development on the environment. The increase in population density in attractive cities during the 20th and 21st centuries resulting from internal and external migration has also led to the formation of megacities (cities of more than 10 million inhabitants) such as Mexico City, Tokyo, and New York, where it is noticed that the high population density is not commensurate with the resources and services available to citizens [10]. From here, the trend towards establishing smart cities began, as it was classified using many terms, including digital cities, electronic cities, flexible city, and information city, and later appeared the term, smart city [11]. However, the rapid growth of the population and the increasing demands of life remained a real challenge for these cities. To overcome this challenge, cities had to go in two directions. The first is to be a sustainable and livable city, a smart city means smart economy, smart transportation and smart environment. The second trend is to focus on technological means and communication in designing aspects of life [12].

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Fig. 1 Smart city [2]

B. Artificial Intelligence (AI)

Intelligence is the human mental ability to analyze data, plan, collect and coordinate ideas, and obtain results to solve problems. It can also be defined as the ability of humans to adapt to the environment in which they live by coordinating the environment to suit them, change themselves, or create a new environment that suits their requirements [13]. As for AI, it is the features and characteristics possessed by computer programs that enable them to simulate the way humans work and their mental ability. One of the most important of these characteristics is the ability to draw conclusions and draw solutions about situations that have not been programmed. AI systems link with human perception to know the requirements of users and individuals. Success in AI leads to saving time and eliminating redundancy and red tape in business [14].

Fig. 2 AI [14]

C. Internet of Things (IoT)

IoT is the mainstay or backbone of a smart city. It enables devices and other things to communicate with each other through connectivity to the World Wide Web, as well as through network and cloud services. In other words, IoT is all devices that connect to the World Wide Web and collect and share data over the network, but there are some things that are not categorized as devices, so some people tend to use the word "things" instead of the word "devices" in this term, the term IoT is used for things that connect to the Internet, these things are cleverly prepared to be integrated across the embedded systems throughout [15].

The first appearance of this term when using ATMs in 1974, and it is one of the forms of IoT [16]. Despite this long period, some studies indicated that 87% of users until 2015 did not know the meaning of the truth of this term, and this is a strange paradox [16]. According to Cisco, in 2008 there were more devices connected to the Internet than humans, and that number reached 5 billion in 2015 [16].

Smart cities need three main components: hardware, connectivity, and intelligence, and these elements can be provided through IoT technology [16].

The use of IoT makes smart cities feasible, because the creation of smart cities depends on the use of all electronic devices and linking them to each other through a unified network, and this is the basis of this technology [16].

III. Smart City Levels

The smart city consists of three interconnected levels, which are:

- Human intelligence: It is the first level of the smart city, and it includes the productive groups and individuals in the field of services and manufacturing within the city, and it is represented by the people who determine the mechanism for organizing and developing work. In other words, it includes the layer of creative individuals [17].
- Collective intelligence: The second level of the smart city is the collective intelligence of the population and cooperating institutions within the city. It includes

institutional mechanisms that regulate cooperation and the flow of knowledge in the field of education and creativity, training centers, exchange of technologies and intellectual property.

- AI: is the third level, which consists of technical infrastructure, information and digital tools that create a virtual environment based on multimedia tools and interactive technologies [17].

IV. Requirements for the Establishment of Smart Cities

Communication and information technologies are the infrastructure and the basis for development in smart cities, as it consists of a group of elements connected to each other through networks.

Networks comprise a set of communicative links; satellites, radio beams, and optical fibers. These networks deal with sensors and monitoring software distributed in various geographical areas through which data is collected and processed by software [18]. These components offer many advantages and opportunities including; providing effective communications within the city, providing services and developing new ways to provide them, facilitating dealing with the government, and creating new opportunities for education and self-development [19].

The infrastructure requirements for a smart city are:

A. Data Collection Techniques

- Sensors: collect a set of data related to weather, traffic conditions, location, health status, radioactivity, weather conditions, and other information.
- Surveillance cameras: are one of the techniques for collecting information, as they photograph and transfer events to special storage warehouses [20].
- RFID technology: stores information through smart chips, where it is read by a hand-held reader. It is possible to encrypt the stored information and authorize certain people to read it to prevent cases of fraud and alteration of information [21].

B. Wide Area Networks

Networks are used to transfer data and information from sensors and other data-collecting devices to control and decision-making centers. There are two types of networks within the city:

- Wide area wired networks which include optical fiber networks and DSL networks.
- Wide area wireless networks which include Satellite Internet, UMTS, Wi-Fi, Wi-Max [22].

C. Software

It is a set of software, which are tools for simulation, manipulation, and presentation of results. Software is one of the basic tools that smart cities rely on in applications and all daily activities. The software adopted in smart cities can be divided into three groups; GPS, GIS, and CAS [23].

V. Evaluation Criteria for Performance of Smart Cities

Performance evaluation is necessary to compare cities to choose the best among them, determine the negative and positive within the smart city, know the necessary procedure, determine the opportunities and benefits of development, evaluate the current situation of the city, raise awareness and draw attention from individuals to the important issues for developing the smart city, where individuals learn about the components of their city.

Performance appraisal is a tool for development in the future. Through this evaluation, we can identify strengths and weaknesses, and thus develop the necessary solutions and analyzes [24].

Three steps can be identified to evaluate cities, namely:

- Methodology: is the methods of collecting and analyzing data and determining the cities to be evaluated.
- Objective: is to define the objective of the evaluation.
- Presentation: defines the way results are presented, analyzed and evaluated.

The assessment of cities includes the database, where the history of the data and accessibility, and the criteria used, the overall calculation mechanism, and the methods of displaying the final results must be taken into account [25].

Several important criteria and strategies for evaluating smart cities have been developed:

- The criteria of the Intelligent Communities Forum. (These criteria are based on knowledge, creativity, and communication technologies).
- The criteria of the Regional Science Center at the Vienna Technical University (in center 31 influential factors are presented, analyzed by the performance of each factor, by selecting 1-4 indicators, where the number of indicators reached 73).
- The criteria of Nicos Kemninos (depending on these criteria 40 indicators were developed that were used for the purpose of evaluating the smart city, and these indicators were classified into four groups) [26].

These criteria are characterized by their spatial scope, comprehensiveness, and detail. In addition, using standard values in order to avoid errors, and give true results [27].

VI. Conclusions

It is clear that providing welfare for citizens and visitors by transforming the city into a smart and sustainable city, or establishing a new smart city is done through the basic pillars. These pillars are linked with the factors that help to establish smart cities, which in turn depend on indicators to evaluate performance in a hierarchical relationship (see Fig. 3).

The achievement of indicators provides us with the factors and by providing the factors that complement our basic pillars, which in turn achieve the desired goal, which is to achieve an ideal smart city that combines technology and social in all aspects of daily life.

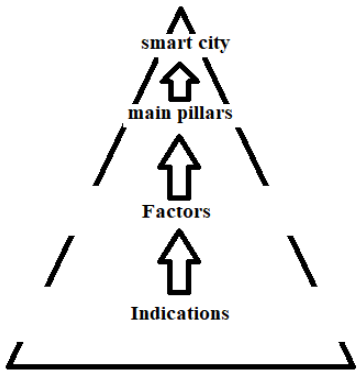

Fig. 3 The hierarchical structure of smart cities [28]

Through the criteria presented by the Intelligent Communities Forum (ICF) and the criteria of Kemninos, we find that establishing a new smart city is based on four pillars, and each of these pillars is determined by a set of factors and their indicators [26]. As for the standards of the Regional Science Center at the Vienna Technical University, the establishment of smart cities depends on six pillars, adding to the factors and indicators of these pillars.

Smart Cities in (ICF criteria)

The Intelligent Communities Forum (ICF) presented a set of pillars on which the establishment of smart cities depends, and each of these pillars has factors that must be achieved to reach ideal smart cities. These pillars included: technique pillars, social pillars, creativity and knowledge pillars, and economic pillars, as shown in Table I.

Smart Cities According to Regional Science Center of the Technical University of Vienna Criteria

The Regional Science Center of the Technical University of Vienna has identified six basic pillars for the establishment of smart cities, and each of these pillars is determined by a set of factors, as shown in Table II.

TABLE I
MAIN PILLARS AND ITS FACTORS IN ICF [25]

Smart government	Smart transportation	Smart environment	Smart life	Smart people	Smart economy
Contribute to decision making	Local transportation	Availability of natural ingredients	Cultural events	Competency level of people	Innovative spirit
Social and public services	Global transportation	No Pollution	Health conditions	Contribute to long-term education	Contracting
Government transparency	Availability of technical infrastructure	Environment protection	Personal security	Ethnic and social pluralism	Economic image and branding
	Safe and sustainable transportation systems	Natural resource management	Quality of housing	Flexibility and getting a new job	Productivity
			Educational activities	Creativity	Labor market flexibility
			Tourism and attractions	Openness	International Relations
			Social unity	Contribution to public life	

TABLE II
MAIN PILLARS AND ITS FACTORS IN SCIENCE CENTER OF VIENNA UNIVERSITY [26]

Creativity and knowledge institutions	Skills of individuals and the level of education	Creative performance	Digital components and technology services
The number of technical institutions	People with higher education degrees	Number of patents	The area covered by wired networks in the city
Number of technology transfer centers	Contributors to long-term education	Number of new brands	The area covered by Wi-Fi networks in the city
The percentage of investment financing out of total trade financing.	Fresh graduates	Number of new manufacturing projects	The area covered by the ADSL network of the city
The number of university students	Industry researchers	Number of new service projects	The number of computers
The number of university employees	Researchers in the public sector	The number of institutions that organize a research and development department	Internet connections
The percentage of spending on research and development	Researchers in the private sector	The ratio of selling new products to the trading value	Extensive communication
Percentage of people spending on research and development	The ratio of employment in higher education to total employment	Sales of new products	Users of government e-services
Percentage of institutions spending on research and development	Employment rate in manufacturing industries	Creation of new companies	Institutions that have websites on the Internet
Percentage of institutions spending on licensing	Employment rate in high-tech services	Export of high-tech products	Institutions that provide B2B and B2C services
The number of institutions that support small projects	Number of creators	Export of high-tech services	Digital service providers

Smart Cities in Nicos Kemninos Criteria

According to the Nicos Kemninos criteria, the establishment of smart cities or its transformation depends on four main pillars which include: creativity and knowledge institutions, skills of individuals and the level of education, creative performance, and digital components and technology services. Each of these pillars depends on 10 factors which are clarified in Table III.

TABLE III
MAIN PILLARS AND ITS FACTORS IN NICOS KEMNINOS CRITERIA [24]

Technique	Social	Creativity and knowledge	Economic
Wired or wireless telecommunications networks	Government roles in all areas of business	Universities and schools	Good economy
Data and analytics Centers	Expand the participation of citizens in making decision	Innovation in the private and public sectors	Technology companies
Computers and technical equipment	Promoting digital democracy	Research centers	Attracting new business owners
Applications and service programs	Incentives offered by the government to establish networks when necessary	People development through education and training	Effective Marketing for Development

TABLE IV
MAIN PILLARS AND THEIR FACTORS

Technical pillar	Social pillar	Economic pillar	Environmental pillar	Scientific pillar	Health pillar
Wired or wireless telecommunications networks	The government provides support and supplies	Good economy	Availability and management of natural ingredients	Universities and schools	Hospitals and health centers
Data and Analytics Centers	Collaborative citizens keen on development	technology companies	Protecting the environment	Innovation in the private and public sectors	The use of devices and technologies in the health fields
Computers and technical equipment	Promoting digital democracy	Attracting new business owners	Roads and the transport network	Research centers	Average age of citizens
Applications and service programs	Security and privacy for citizens and data	Effective Marketing for Development	Tourist places and attractions	People development through education and training	Health system quality

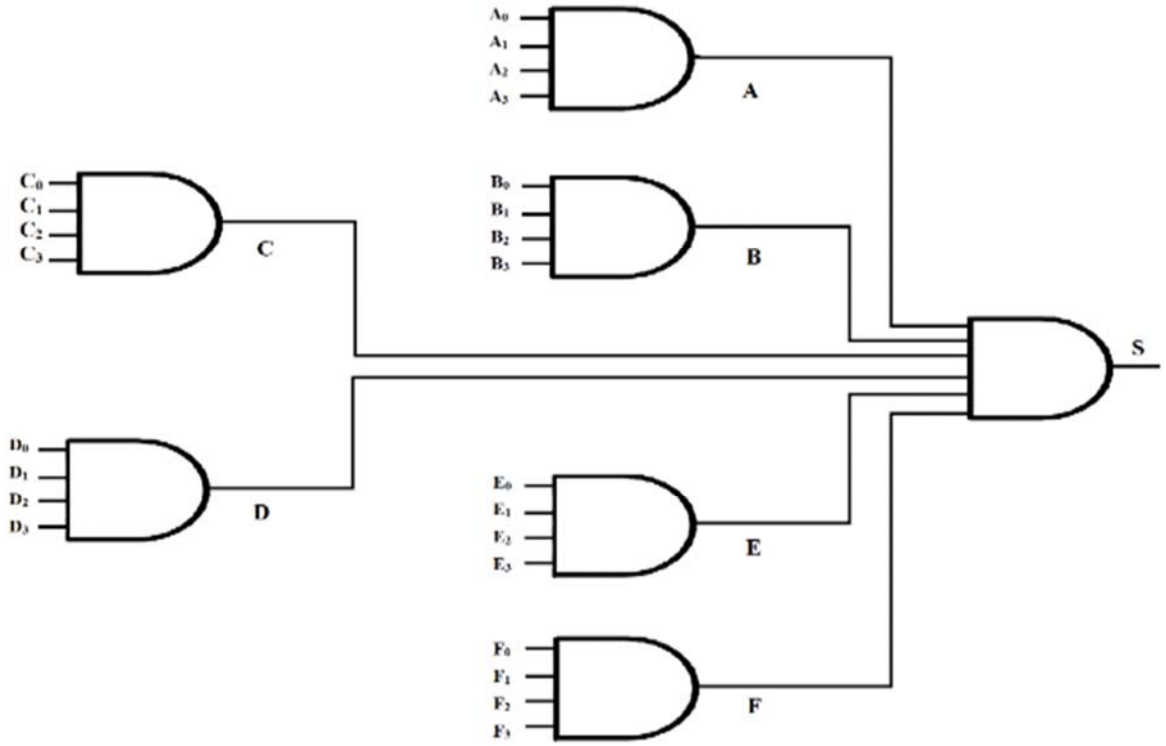

Fig. 4 Logic circuit

Main Pillars of Smart City

Through Nicos Kemninos criteria, Smart Community Forum (ICF) criteria, and Vienna Technical University Regional Science Center criteria, performance assessment indicators for smart cities and the pillars presented through previous studies, we can identify the main pillars on which the ideal smart city depends, and these pillars can be identified as: technical pillar, social pillar, economic pillar, environmental pillar, scientific pillar, and health pillar, as shown in Table IV.

Simulation of Main Pillars with Logic Gates

Table IV shows us the main pillars on which smart cities depend, and that each of these pillars depends on four factors. We can make a low-cost circuit, easy to program and apply, and available to everyone, through which we can know the extent to which all the basic pillars and factors for creating smart cities have been achieved. This circuit consists of logical gates, and in particular we can use the AND gate (AND gate gives a high output (Logic 1) if all the inputs are 1), when we have the output

of the circuit (1), this means that all the pillars and their factors are available, and the smart city became ideal.

Giving values to the pillars as main variables, as well as giving values to the factors of these pillars as sub-variables, we will have four variables and each variable has four sub-variables as shown below:

$$\text{Technical pillar} = A = A_0.\ A_1.\ A_2.\ A_3 \quad (1)$$

$$\text{Social pillar} = B = B_0\ .B_1\ .B_2\ .B_3 \quad (2)$$

$$\text{Economical pillar} = C = C_0\ .C_1\ .C_2\ .C_3 \quad (3)$$

$$\text{Environmental pillar} = D = D_0\ .D_1\ .D_2\ .D_3 \quad (4)$$

$$\text{Scientific pillar} = E = E_0.E_1.E_2.E_3 \quad (5)$$

$$\text{Health pillar} = F = F_0.F_1.F_2.F_3 \quad (6)$$

$$\text{Ideal smart city} = S = A.B.C.D.E.F \quad (7)$$

Now when we apply this variable in the circuit shown in Fig. 4, we will get $2^4 = 16$ probability, and from knowing the truth table of the circuit (AND gate), we find that the output is only one if all the inputs are fulfilled.

Through the logical circuit shown in Fig. 4 and the possibilities presented for the circuit's inputs, we find that the value of the variable (S) is achieved in the case of achieving all the main variables with their sub-variables, by obtaining an output result (1) for variable (S), we find that the factors as well as the basic pillars have been fulfilled.

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