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A Methodological Comparison of Smart Cities' Performance Evaluation

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ABSTRACT

Smart cities have emerged as a solution to the long-standing challenges facing cities, including population growth, infrastructure strain, escalating service costs, diminishing social services, pollution, and environmental deterioration. These challenges have necessitated innovative solutions to enhance the sustainability and efficiency of cities, leading to the rise of smart cities. Consequently, this research aims to evaluate the performance of well-performing smart cities by examining six dimensions, each with specific factors. The study aims to develop a methodology for assessing the performance of smart cities by analyzing the three most widely recognized international approaches: Nicos Komninos' approach, the Intelligent Community Forum (ICF) approach, and the approach of the Centre of Regional Science at Vienna University of Technology (VUT). Subsequently, determining the most appropriate method for evaluating smart cities in the Arab Republic of Egypt and implementing it in alignment with local priorities (such as education, health, transportation, economy, governance, and environment) and the specific requirements needed to achieve sustainable development and enhance Egyptian cities.

KEYWORDS

Smart Cities (Intelligent Cities), Performance Evaluation, International Approaches, Factor, Dimensions.

1. INTRODUCTION

Smart cities have emerged as an influential concept in urban development circles, transforming traditional cities into interconnected urban areas based on modern data and technologies. By leveraging innovative technologies and solutions, countries seek to enhance efficiency standards, promote environmental sustainability, and enhance the quality of life of their population. Smart cities play a pivotal role in shaping the future of urban life because of their significant economic and social impacts.

The research problem addressed in the study aims to identify the most in-depth comprehensive criteria for evaluating the performance of smart cities, intending to enhance their strengths and mitigate their weaknesses. **The paper aims at the following:**

- Comparing best practices.
- Identifying the driving forces of smart cities, pinpointing weaknesses, and determining the effort needed to overcome them.
- Defining the relative advantages of smart cities, and their potential development opportunities
- Contributing to the understanding of the components of the smart city and its position within the group of cities.
- Identify strengths and weaknesses of the studied cities in a comparative way.

Researchers have developed numerous criteria and indicators to evaluate the performance of smart cities, enhance their competitiveness, and assist investors in making

informed decisions. However, there is no consensus on which is the most in-depth comprehensive criteria. **The research methodology and structure adopt the following sequence:**

- The concept of a smart city.
- Dimensions of smart city.
- An in-depth study of three global criteria for evaluating the performance of smart cities.
- Determining the dimensions of the methodological analysis for evaluating the performance of smart cities.
- Concluding a methodology for evaluating the performance of smart cities by comparing the three global standards.
- The most crucial assessment techniques suitable for Egypt's circumstances and the means by which they are put into practice.

2. THE CONCEPT OF SMART CITYIES

The concept of smart cities has evolved through several stages which represent the main directions for cities. There are three directions to the concept of smart cities:

2.1 First Direction (Kim, 2012)

It is built upon the integration of **(Digital Amenities)** within the city using Information and Communication Technology (**ICT**) as a means to: enhance cities, improve efficiency, effectiveness, and quality of urban services and mobility, reduce costs and resource consumption, and foster better citizen engagement (see Figure 1). The primary objective of smart cities in this direction is to enhance the (**Quality of Human Life)**[1] as a fundamental requirement for existence through:

- Index of human life sustainability.
- Index of human well-being.
- Index of human entertainment and enjoyment.

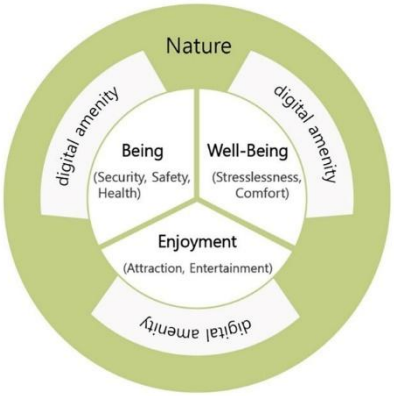

Figure (1): Digital amenity.
Source: (Kim, 2012)

2.2 Second Direction

Represents the principles of smart city growth, which aim to intelligently manage urban expansion through a set of principles for land use and development. These principles are

[1] The Universal Declaration of Human Rights provides a list of factors that can be considered in assessing the quality of life, including the following: freedom from slavery and torture, equal protection under the law, freedom from discrimination, freedom of movement, right to privacy, right to rest.

designed to enhance the quality of life, conserve the natural environment, and achieve long-term cost savings. After the Environmental Protection Agency **(EPA)** in the United States identified a set of general principles for smart growth, certain aspects of this direction became clear as follows (U.S., 2011):

- Approval of mixed land use.
- Taking advantage of utilizing compact building design.
- Providing a range of housing opportunities and choices (see Figure 2).
- Creating pedestrian-friendly residential neighborhoods.
- Encouraging uniqueness, a sense of place, and creating attractive communities.
- Preserving open spaces and agricultural lands.
- Enhancing and directly developing existing communities.
- Providing a variety of transportation choices.
- Making development decisions cost-effective.
- Encouraging community cooperation and collaboration with stakeholders in development decisions.

Figure (2): Missing Middle Housing.
Source: (Parolek, 2020)

2.3 The Third Direction

The 10 principles of smart urbanism that guide the creation of integrated urban designs and programs. This direction's main purpose is to achieve intelligent synergy among various urban planning objectives. The ten fundamental principles of smart urbanism form the basis of smart urban principles, which have been established by the International Congress of Modern Architecture (CIAM) as trends in urban planning **(Centroidpm, 2017, November 17):**
Principles of intelligent urbanism:
Principle 1: Balance with Nature.
Principle 2: A Balance with Tradition.
Principle 3: Appropriate Technology.
Principle 4: Conviviality.
Principle 5: Efficiency.
Principle 6: Human Scale.
Principle 7: Opportunity Matrix.
Principle 8: Regional Integration.
Principle 9: Balanced Movement.
Principle 10: Institutional Integrity.

3. DIMENSIONS OF SMART CITIES (Giffinger R., 2007)

The dimensions of smart cities are linked to traditional theories of development and urban growth, such as transportation, economy, natural resources, and quality of life. The six distinctive dimensions of smart cities can be identified as shown in Table (1).

Table 1. Dimensions of Smart Cities

Dimension	Characterization
Intelligent Economy	• Global and regional competitiveness. • Entrepreneurial spirit and innovation. • High levels of productivity. • Providing broadband networks for all citizens and companies to support business opportunities. • Freedom to choose a location and the potential benefits for rural residents. • E-commerce operations (electronic banking services, online shopping, electronic tenders).
Smart Life	• High quality of life in various social aspects such as education, healthcare, public safety, and housing. • Access to high-quality healthcare services, including telehealth or remote health monitoring, and electronic health record management. • Smart homes and smart services. • Facilitating access to all electronic social services.
Intelligent environment	• Ongoing monitoring of pollution. • Use of sustainable technology. • Environmental and sustainable energy consumption. • Reducing energy consumption by promoting energy conservation and material reuse. • Technological innovations enhancing energy conservation and material reuse.
Human intelligence	• Social and human capital. • Qualified, creative, and educated citizens. • The ability to make use of information and communication technology-based smart services (ICT-based smart services). • Providing a more consistent educational experience in both urban and rural areas.
Intelligent Mobility	• Accessibility. • Safe transportation. • Innovative technology. • Efficient utilization of mobility networks for vehicles, people, and cargo to alleviate traffic congestion. • New social patterns, such as car sharing and the diverse use of cars and bicycles. • More effective and smarter transit systems.
Smart government	• Decision-making. • Public and social services. • Transparency. • Democratic processes and integration. • Linking government organizations and administrations. • Improving community access to services.

Source: (Giffinger R., 2007)

4. AN IN-DEPTH STUDY OF THREE GLOBAL CRITERIA FOR EVALUATING THE PERFORMANCE OF SMART CITIES

Assessing smart cities' performance is thought to be a useful tool for their continued growth. Strengths and weaknesses can be determined via this examination, which helps to formulate plans and goals for development. This study examines the three most widely accepted international standards for assessing the effectiveness of intelligent cities: the method developed by **Nicos Komninos**, the criteria established by the Intelligent Community Forum (ICF), and the criteria developed by the Center of Regional Science at Vienna University of Technology (VUT), all of which have been thoroughly examined. These criteria are distinguished by their reliance on recent data, their use of normative values to prevent errors arising from the lack of data, and their spatial extent. The comprehensive findings displayed at the dimension level are the most notable aspect (Mora, 2019).

4.1 Nicos Komninos Method

Nicos Komninos created forty metrics to assess smart city effectiveness. These are divided into four categories, as Table (2) illustrates (N. Komninos, & Sefertzi, E, 2009):

Table 2. Forty indicators for capturing intelligent cities performance

Education and skills of the population	Knowledge and innovation institutions	Digital infrastructure and e-services	Innovation performance
1. Population with tertiary-level education (% of 25-64 years age class)	1. Number of university students (% of total population)	1. City area covered by cable networks (% of total area)	1. EPO patent applications (per million of population)
2. Participation in life-long learning (% of 25-64 years age class)	2. Number of university staff (per million of population)	2. City area covered by Wi-Fi networks (% of total area)	2. New trade marks (per million of population)
3. New S&E graduates (% of 20-29 years age class)	3. Total R&D expenditure (% of GDP)	3. City area covered by xDSL networks (% of total area)	3. Innovative enterprises-manufacturing (% of all manufacturing enterprises)
4. Researchers in industry and services (% of total workforce)	4. Public R&D expenditure (GERD as % of GDP)	4. Computers (per million of population)	4. Innovative enterprises-services (% of all services enterprises)
5. Researchers in the public sector (% of total researchers)	5. Business R&D expenditure (BERD as % of GDP)	5. Internet connections (% of population)	5. Enterprises having internal R&D department (% of all enterprises)
6. Researchers in the private sector (% of total researchers)	6. Business spending for licensing (% of turnover)	6. Broadband connections (% of population)	6. Sales of new-to-market products (% of turnover)
7. Employment of tertiary-level graduates (% of total employment)	7. Number of incubators (per million of population)	7. Users of e-gov services (% of population)	7. Sales of new-to-firm not new-to-market products (% of turnover)
8. Employment in medium and high-tech manufacturing (% of total workforce)	8. Number of S&T Parks (per million of population)	8. City enterprises owning a website (% of total enterprises)	8. New companies creation (% of total enterprises)
9. Employment in high-tech services (% of total workforce)	9. Number of Technology Transfer and Innovation Centers (per million of population)	9. City enterprises involved in B2B or B2C (% of total enterprises)	9. Exports high-tech products (% of total exports)
10. Creative class (% of employment in creative industries)	10. Venture capital funding (% of total business funding)	10. Digital services providers (% of ICT companies)	10. Exports high-tech services (% total exports)

Source: (N. Komninos, & Sefertzi, E, 2009)

Four major axes for the development of smart cities can be identified based on these requirements. Knowledge institutions, skills, and digital gaps are the three input-related axes; innovation is the output-related axis.

Keeping in mind the four categories indicated above, the Nicos Komninos technique can be applied in the following manner using the previously mentioned (N. Komninos, 2009):

1. **Skills**

- **Educational Attainment**: Percentage of the population with tertiary education.
- **Technical Skills Training**: Availability and uptake of technical skills training programs.
- **Employment in High-Tech Sectors**: Percentage of the workforce employed in high-tech and innovation-driven sectors.

2. **Knowledge Institutions**

- **University and Research Centers**: Number of universities and research centers in the city.
- **Research and Development (R&D) Spending**: Investment in R&D as a percentage of GDP.
- **Industry-Academia Collaboration**: Number of collaborative projects between industry and academic institutions.

3. **Digital Gaps**

- **Broadband Coverage**: Percentage of households with broadband internet access.
- **Mobile Connectivity**: Coverage and adoption rates of mobile networks (4G, 5G).
- **Digital Inclusion Programs**: Initiatives aimed at increasing digital literacy and access among underserved populations.

4. **Innovation**

- **Startup Ecosystem**: Number of startups, incubators, and accelerators in the city.
- **Patent Applications**: Number of patent applications filed per year.
- **Smart City Projects**: Number and impact of smart city projects implemented (e.g., smart grids, intelligent transportation systems).

4.2 Intelligent Community Forum (ICF) Method

The Intelligent Community Forum (ICF) method for evaluating smart communities goes beyond simply assessing the technological infrastructure of a community. Instead, it incorporates a holistic set of criteria that address various aspects of community life, ensuring that the community is not just "wired" with advanced technology but also exhibits other key characteristics that contribute to its overall intelligence and sustainability. Here is a detailed explanation of the five criteria set by the ICF, as illustrated in (Komninos, 2006) Figure (3):

Figure (3): Criteria for Evaluating Smart Communities.
Source: Author

1. Broadband communications: among residential areas, government events, the business sector, and providing incentives to the government through organizing and establishing needed networks.

2. Effective education and training: by developing individuals' capabilities, and establishing a capable knowledge workforce (knowledge workers).

3. Public-private partnership programs: that promote digital democracy by expanding citizen participation in decision-making and bridging the digital divide to ensure that all sectors of society benefit from technologies and communications.

4. Public-private sectors Innovation: starting from the powerful supportive role of e-government initiatives, and efforts to establish economic communities, in addition to funding new business institutions that are considered the engine of economic growth.

5. Effective marketing: for economic development contributing to attracting new business owners (Townsend, 2013).

These criteria are primarily based on information and communication technologies, knowledge, and innovation. These criteria aim to evaluate digital communications, and individuals' ability to work in knowledge-based activities, measure communities' ability to create an innovative environment attracting individuals and institutions, in addition to evaluating government programs and the private sector, (Public-private partnerships programs), to overcome the digital divide and achieving competitiveness among cities (van Winden, 2007).

Through the above, the criteria for evaluating smart communities **through this forum result in two strategies (Jurado, 2018):**

1. Focusing on information technologies with its various elements: represented in wide-ranging communications, technology training, electronic services, etc..., For example:

- **a. Singapore (Thalesgroup, 2023, Feburary 20):** Known for its Smart Nation initiative, Singapore utilizes advanced information technologies to improve urban living. It features extensive high-speed internet coverage, smart healthcare systems, and a robust framework for digital services.
- **b. Seoul** : With initiatives like the "u-Seoul" project, Seoul has implemented widespread Wi-Fi coverage, mobile government services, and smart traffic management systems.
- **c. Taipei (Lee, 2019 May13)**: Taipei has integrated information technologies through its Smart City project, which includes smart transportation, digital healthcare, and extensive public Wi-Fi networks.

2. Focusing on knowledge-based development (Jurado, 2018): by integrating new economic structures for innovation, through global technology clusters, and innovation centers equipped with infrastructure and electronic services, for example:

- **a. Florida**: Home to numerous innovation hubs and technology parks, Florida fosters a dynamic environment for tech startups and research institutions, particularly in fields like aerospace, biotech, and information technology.
- **b. Glasgow**: Known for its focus on innovation and research, Glasgow has developed technology clusters and innovation centers, such as the Glasgow City Innovation District, to support economic growth and technological advancement.
- **c. Yokosuka**: As part of Japan's efforts to promote innovation, Yokosuka hosts technology clusters and research centers, focusing on telecommunications and information technology.
- **d. Waterloo**: Often referred to as Canada's "Silicon Valley," Waterloo has a strong emphasis on innovation and technology, supported by institutions like the University of Waterloo and numerous tech companies and startups.
- **e. Stockholm**: Recognized as a leading hub for innovation, Stockholm has a thriving tech scene with numerous startups, research centers, and innovation clusters, particularly in the fields of information technology and sustainability.

4.3 The Centre of Regional Science, Vienna University of Technology (VUT) Method (Giffinger, 2010)

The researchers' method of using specific indicators to evaluate the performance of smart city workers provides a structured and detailed approach to understanding smart city

development. By selecting relevant indicators for each worker, they ensured a thorough assessment of various aspects of smart city performance, which helps in identifying strengths, weaknesses, and areas for improvement. The comprehensive set of 74 indicators allows for a holistic view of the city's smart initiatives, making it possible to draw meaningful conclusions and recommendations for future development.

The idea of "smart cities", which describes contemporary areas that make use of ICTs (information and communication technologies), or **"smart industries",** which incorporate ICTs into manufacturing processes, served as the foundation for the selection of the criteria. And cities that want to improve their school systems. Put differently, urban areas that cultivate knowledgeable citizens (Hollands, 2008).

This concept encompasses the relationship between the government and citizens, as well as the integration of modern technologies into daily life; this encompasses not only information and communication technologies but also modern transportation technologies. In addition, this concept is linked to many other concepts such as security, safety, sustainability, and energy.

The evaluation of smart cities is conducted using a hierarchical structure, which allows for a systematic and comprehensive assessment of various dimensions of a smart city. Here's a detailed explanation of how this hierarchical structure works:

The hierarchical structure of the evaluation process consists of multiple levels. Each level builds upon the information and analysis provided by the preceding level. This structure ensures that the evaluation is detailed and considers all relevant aspects of smart city performance.

1. **Top Level: Dimensions (Nam, 2011)**
   - **Definition**: Dimensions represent broad categories or themes that are crucial for the evaluation of smart cities.
   - **Examples**: Common dimensions include governance, technology, environment, public services, and community engagement.
2. **Middle Level: Factors (Nam, 2011)**
   - **Definition**: Each dimension is broken down into several factors. Factors are specific components or aspects within a dimension that need to be evaluated.
   - **Role**: Factors provide a more detailed focus within each dimension, helping to identify specific areas of performance.
   - **Examples**: Within the dimension of governance, factors might include decision-making processes, transparency, and public participation.
3. **Bottom Level: Indicators (Nam, 2011)**
   - **Definition**: Indicators are measurable metrics or variables that represent each factor.
   - **Role**: Indicators are used to quantitatively or qualitatively assess the performance of each factor.
   - **Examples**: For the factor of public participation, indicators might include the number of public consultations held, the percentage of residents participating in local elections, and the level of citizen satisfaction with government responsiveness.

The hierarchical structure of evaluation, characterized by dimensions, factors, and indicators, provides a robust framework for assessing the performance of smart cities. Figure (4) Each level of the hierarchy builds upon the preceding level, ensuring a thorough and comprehensive evaluation process. This method allows for detailed analysis and helps identify

specific areas for improvement, ultimately contributing to the development of more effective and sustainable smart cities (Hsu, 2021).

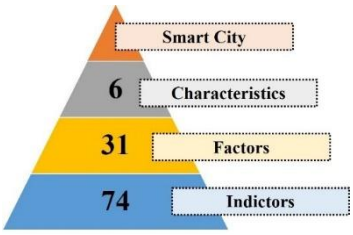

Figure (4): H ierarchical structure of smart citiesassessment.
Source: Author

4.3.1 The Main Objectives of The Evaluation (Correia, 2011)

European smart cities were evaluated on the basis of the following objectives:

1. Clarifying the distinctive features of each city.
2. Transparent evaluation of a selected group of cities.
3. Ability to compare the cities under study.
4. Identifying strengths and weaknesses to develop strategies.

4.3.2 Evaluation Methodology

A comprehensive methodology has been developed for evaluating European smart cities. The evaluation focused on medium-sized European cities, considering development challenges. Criteria were set for selecting cities based on several indicators (C. F. Rudolf Giffinger, Robert Kalasek, January 2007):

1. Cities within the European Union, this criterion applies to 1600 cities.
2. Cities with a population ranging between 100,000 and 500,000 inhabitants **(this criterion applies to 584 cities).**
3. Cities that include at least one university **(this criterion applies to 364 cities).**
4. Cities that are not a part of regional clusters **(this criterion applies to only 256 cities).**

This number has been reduced to **(70)** due to easier data access. The evaluation methodology has been developed based on a set of factors and indicators, as shown in Table (3) , along with weighting rates (Giffinger R., 2007).

Table 3. Smart Factors and Indicators

Dimension	Factor	Indicator	Number of Indicators	Weighting Rates
Smart Government	Participation in Decision-Making	• City representatives per resident. • Political activity of inhabitants. • Importance of politics for inhabitants.	**3**	**33%**
	Public and Social Services	• Expenditure of the municipal per resident in PPS. • Share of children in day care. • Satisfaction with quality of schools.	**3**	**33%**
	Transparent Governance	• Satisfaction with transparency of bureaucracy. • Satisfaction with Figure ht against corruption.	**2**	**33%**
Smart Mobility	Local Accessibility	• Public transport network per inhabitant. • Satisfaction with access to public transport. • Satisfaction with quality of public transport.	**3**	**25%**

Dimension	Factor	Indicator	Number of Indicators	Weighting Rates
	(Inter-) national accessibility	• International accessibility.	**1**	**25%**
	Availability of ICT-infrastructure	• Computers in households. • Broadband internet access in households.	**2**	**25%**
	Sustainable and Safe Transport Systems	• Mobility sharinga. • Traffic Safety. • Green mobility share (non-motorized individual traffic. • Use of economical cars.	**4**	**25%**
Smart Environment	Availability of Natural Elements	• Sunrise hours. • Green space share.	**2**	**25%**
	Pollution	• Summer smog (Ozon). • Particular environmental Problem. • Fatal chronic lower respiratory diseases per inhabitant.	**3**	**25%**
	Environmental Protection	• Individual efforts on protecting nature. • Opinion on nature protection.	**2**	**25%**
	Natural Resource Management	• Efficient use of water (use per GDP) (Gross Domestic Product). • Efficient use of electricity (use per GDP).	**2**	**25%**
SmartLiving	Cultural Facilities	• Cinema attendance per inhabitant. • Museums visits per inhabitant. • Theatre attendance per inhabitant.	**3**	**14%**
	Health Conditions	• Life expectancy. • Hospital beds per capita. • Doctors per inhabitant. • Satisfaction with the quality of health system.	**4**	**14%**
	Individual safety	• Crime rate. • Death rate by assault. • Satisfaction with personal safety.	**3**	**14%**
	Housing quality	• Share of housing fulfilling minimal standards. • Average living area per inhabitant • Satisfaction with personal housing situation.	**3**	**14%**
	Education facilities	• Students per capita. • Satisfaction with access to the educational system. • Satisfaction with the quality of the educational system.	**3**	**14%**
	Touristic Attractivity	• Importance as a tourist location (overnights, sights). • Overnights per year per resident.	**2**	**14%**
	Social cohesion	• Perception of personal risk of poverty. • Poverty rate.	**2**	**14%**
Smart People	Level of Qualification	• Importance as a knowledge center (top research centers, top universities). • Population qualified at levels (5-6) International Standard Classification of Education (ISCED). • Foreign language skills. • Higher education for the population.	**4**	**14 %**
	Affinity to lifelong learning	• Book loans per residen.t	**3**	**14 %**

Dimension	Factor	Indicator	Number of Indicators	Weighting Rates
		• Participation in life-long-learning in percentage%. • Participation in language courses.		
	Social and ethnic plurality	• Share of foreigners. • Share of nationals born abroad.	**2**	**14 %**
	Flexibility	• Perception of getting a new job.	**1**	**14 %**
	Innovation	• Share of people working in creative industries.	**1**	**14 %**
	Cosmopolitanism / Open-Mindedness	• Voters turnout at European elections. • Immigration-friendly environment (attitude towards immigration). • Knowledge about the EU.	**3**	**14 %**
	Participation in public life	• Voters turnout at city elections. • Participation in voluntary work.	**2**	**14 %**
Smart Economy	Innovative spirit	• Research and Development (R&D) expenditure in percentage% of GDP. • Employment rate in knowledge-intensive sectors. Patent applications per capita.	**3**	**17 %**
	Entrepreneurship	• Self-employment rate • New businesses registered.	**2**	**17 %**
	Economic Image & Trademarks	• decision-making Importance as decision-making center. (corporate headquarters: HQ etc.)	**1**	**17 %**
	Productivity	• GDP per employed capita.	**1**	**17 %**
	Flexibility of the labor market	• Unemployment rate. • Proportion in part-time employment.	**2**	**17 %**
	International Relations and Embeddedness	• Companies with HQ in the city quoted on the national stock market. • Air transport of passengers. • Air transport of freight.	**3**	**17 %**
Total			**74**	**100 %**

Source: (Giffinger R., 2007)

4.3.3 Evaluation Results

Numerous inferences about the evaluation of smart cities' success based on different indicators may be made from the preceding table. These indicators are broken down into primary dimensions, with distinct variables inside each dimension and indicators being used to assess each aspect. The following are some conclusions:

1. **Equitable Importance Distribution:** Every aspect of smart urban development is deemed equally significant, and each dimension's indicators are given the same weighting rates.
2. **All-encompassing Assessment:** The assessment procedure covers a number of facets of smart urban living, such as smart mobility, smart environment, smart living, smart people, and smart government.
3. **Indicators Used:** A wide range of indicators **(74 in all)** are used in the evaluation, enabling a thorough and in-depth analysis of the smart city.

4. **Hierarchical Evaluation:** This methodical technique to performance evaluation assesses each dimension based on several elements, each of which is assessed using a variety of indicators.
5. **Relative Weight of Indicators:** The relative weight of each dimension establishes its influence on the overall assessment, assisting in the concentration of attention on the most crucial elements within each dimension.
6. **Evaluation Flexibility:** If the indicators are updated or modified, the evaluation can be readily modified because of the equal importance distribution.
7. Luxembourg achieved the best rating in Smart Economy, followed by British and Danish cities. While the Smart people dimension was led by Danish and Scandinavian cities. Figure (5) shows the final ranking chart for the smart city dimensions illustrating the variation between cities as well as the strengths and weaknesses of each city (Giffinger R., 2007).

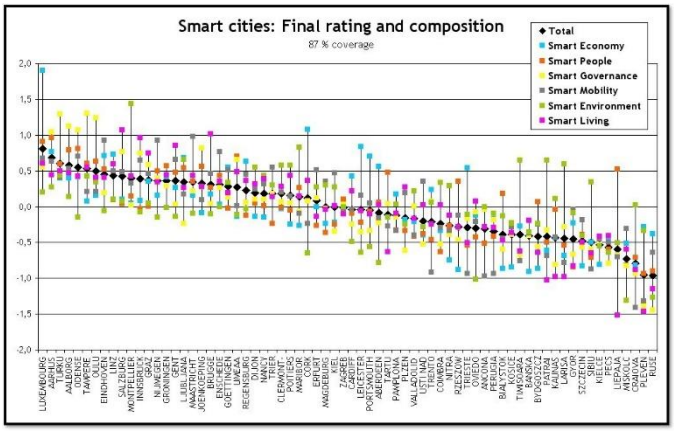

Figure (5): Final rating with characteristics.
Source: (Giffinger R., 2007)

The previous graph illustrates the heterogeneous characteristics of each city. Illustrating the total rating on the dimension level gives a general idea about the strengths and weaknesses of each city. The dimensional analysis is considered necessary due to, the heterogeneity of the dimensional level. Figure (6) shows the final results of the smart cities evaluation, **(the darker the color, the higher the IQ)** (Giffinger R., 2007)

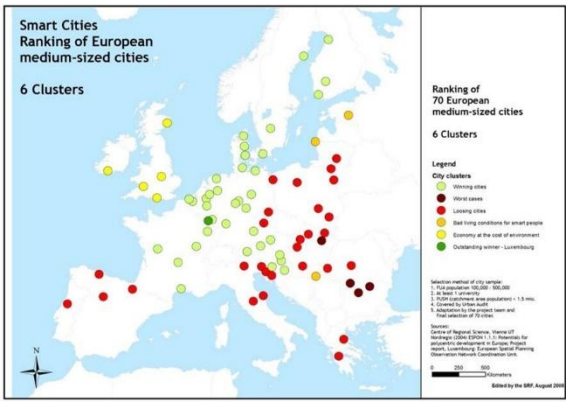

Figure (6): The Final Results of Smart Cities' Evaluation (The darker the color the better the rating)
Source: (Giffinger R., 2007)

4.3.4 Advantages and Disadvantages of Evaluation

This approach offers a thorough and trustworthy framework for impartially and methodically assessing smart cities. However, because of their complexity, reliance on the availability of data, and impreciseness in data collecting, they provide significant challenges for appropriate use and evaluation.

5. DETERMINING THE DIMENSIONS OF THE METHODOLOGICAL ANALYSIS FOR EVALUATING THE PERFORMANCE OF SMART CITIES

Five dimensions were proposed for analyzing the methodology of evaluating smart cities' performance, as outlined in Table (4). This proposal is based on the study and analysis of three widely recognized methods for evaluating smart cities: the Nicos Komninos method, the Intelligent Community Forum (ICF) method, and the method by the Centre of Regional Science at Vienna University of Technology. The analysis considered the indicators of essential dimensions of smart cities, such as skills, knowledge institutions, digital gaps, innovation, smart governance, smart economy, smart environment, smart society, broadband infrastructure, knowledge power, digital sustainability, and governance and transparency. These dimensions and their indicators are crucial as they provide a comprehensive and accurate assessment of smart cities' performance (HamaMurad, 2022).

Table 4. Dimensions of the methodological analysis of smart city's performance evaluation

Dimension	The indicator
The Authorship and Publication	• **The author and the type of publication:** These indicators are derived by identifying the entities responsible for preparing and publishing reports and studies on smart cities. These entities can be research institutions, universities, consulting firms, or international organizations. The type of publication may include research reports, scientific articles, or case studies.
Database	• **The time range of the data used:** This indicator analyzes the extent to which the data used in the evaluation covers a specific time period, ensuring that the data is up-to-date and continuous. • **Available data sources:** These indicators involve analyzing the sources of data used, such as official statistics, field surveys, sensor data, or international databases. • **Methods for calculating the final results:** These indicators include how data is processed and analyzed to arrive at final results, such as using statistical methods, mathematical models, or qualitative analysis.
Indicators Level	• **The number of indicators:** This indicator determines the number of indicators used in the evaluation to cover various aspects of smart city performance. • **Calculation method (using normative values):** These indicators include how the final values of the indicators are calculated, such as using standard values or percentages, to ensure fair comparison between cities.
The Spatial Dimension	• **Ranking (cities on a European scale):** This indicator analyzes the geographical status of the cities included in the evaluation, such as focusing on certain cities based on their size or importance. • **The number of cities:** This indicator includes the number of cities that have been evaluated in the study. • **Criteria for the selection of cities:** These indicators include the criteria used to select the cities included in the evaluation, such as population size, level of economic development, or technological readiness.

Dimension	The indicator
Final Results	• **The results of the final evaluation:** These indicators include the final evaluation results, which can be in the form of rankings, scores, or detailed performance reports.

Source: Author

A thorough assessment of the performance of smart cities may be obtained by segmenting the study into these five dimensions. This will facilitate the identification of areas that require improvement and aid in the making of strategic decisions that will benefit smart development.

6. CONCLUDING A METHODOLOGY FOR EVALUATING THE PERFORMANCE OF SMART CITIES BY COMPARING THE THREE GLOBAL STANDARDS

Based on the previous Table (5), the methodology for evaluating the performance of smart cities can be examined through several aspects, including the database, the use of indicators, the spatial dimension, and the final results, as illustrated in Table (10).

Table 5. Methodological comparison for evaluating smart city's performance

Dimension		Researcher Nicos Komninos' methodology	Intelligent Community Forum methodology	The Centre of Regional Science, Vienna University of Technology (VUT) methodology
Authorship and publishing	• The author and the type of publication.	Nicos komninos	Intelligent community forum	A group of researchers at the center
Database	• Timeframe of the data used.	--	--	Recent data
	• Available data sources.	--	--	EU documents
	• Methods of aggregating the final results.	--	--	Standardizing values
Indicators basis/level	• Number of indicators.	40 Indicators	--	74 indicators
	• Calculation method	--	--	Standardizing and aggregating values
The spatial dimension	• Ranking.	Global	Global	European Union
	• Number of cities	--	--	70
	• Selection criteria	--	--	A set of criteria (**population, being within the European Union, including a university**)
Final Results	Final evaluation results	general	general	detailed

Source: Author

Comparing the previous criteria, we find that the criteria of the Centre of Regional Science (ICF) at Vienna University of Technology (VUT) are the most comprehensive, objective, and in-depth. These criteria stand out from others in terms of spatial scope by including the countries within the European Union. Besides that, they also include standards for selecting case study city samples. Moreover, it uses standard values to avoid errors that may arise from data absence and to depend on recent data. Furthermore, one of their key features is the presentation of detailed and applicable results at the dimensional level. The ICF criteria contribute to evaluating the performance of smart cities, enhancing their strengths, and

mitigating their weaknesses. Therefore, ICF criteria can be relied upon to transform any city into a smart one by applying the six dimensions of smart cities.

7. THE MOST CRUCIAL ASSESSMENT TECHNIQUES SUITABLE FOR EGYPT'S CIRCUMSTANCES AND THE MEANS BY WHICH THEY ARE PUT INTO PRACTICE

The study's last section will **focus on 25 indicators** that were chosen to be appropriate for Egypt. In order to do this, certain requirements to support sustainable growth and fortify Egyptian cities were taken into account, along with local goals in the areas of education, health, transportation, economy, governance, and the environment. Based on the implementation of the six aspects of smart cities, the cities will be categorized using standards created by the Vienna University of Technology's Regional Science Center (ICF) (VUT). Table (6) displays the indicators that were specifically identified.

Table 6. Distribution of importance among different indicators to achieve an appropriate evaluation of smart cities in the Arab Republic of Egypt

The Dimension	Factor	Indicator	Number of Indicators	Weighting Rates
Smart Governance	Participation in Decision-Making	• City representatives per population. • Political engagement per individual. • Relevance of politics to individuals.	3	100%
	Social and Public Services	• Municipal expenditure per population. • Children's involvement in care facilities. • Individual satisfaction with school quality.	3	
	Government Transparency	• Satisfaction with transparency. • Consensus on anti-corruption efforts.	2	
Smart Mobility	Transport and Technological Infrastructure	• smart public transport usage Percentage. • Number of electric vehicles charging points. • smart mobility app usage percentage.	3	100%
Smart Environment	Environmental Protection and Sustainability	• Renewable energy use Percentage. • Number of certified eco-friendly buildings. • Reduced carbon emissions percentage.	3	100%
Smart Living	Social Cohesion and Community Engagement	• Number of community events organized using modern technologies. • Percentage of citizens participating in smart social platforms. • Participation rate in online surveys and opinions.	3	100%
Human Intelligence	Smart Education	• Educational institutions equipped with modern learning technologies Percentage. • Number of online educational programs. • Percentage of students engaged in remote learning.	3	100%
Smart Economy	Innovative Spirit	• Number of tech startups. • Number of registered patents. • Percentage of investment in research and development.	3	100%
	Smart Labor Market	• Percentage of high-tech workforce. • Employment rate in smart industries.	2	

The Dimension	Factor	Indicator	Number of Indicators	Weighting Rates
Total			25	
Weighting is the approximate result obtained by dividing (100) by the number of factors				

Source: Author

To ensure that smart cities meet and effectively implement performance evaluation criteria, a set of mechanisms and means must be followed to help collect, analyze, and assess data. Here are some proposed mechanisms for implementing smart city performance evaluation standards, as outlined in Table (7):

Table 7. Proposed Methods for Implementing Smart City Performance Evaluation Standards

Mechanisms	Assisting Tools for Implementing Mechanisms
Data collection	**Surveys and Polls:** • Using surveys to gather citizens' opinions on government services and transparency. • Conducting regular polls to measure residents' satisfaction with various aspects of the smart city.
	Government Data: • Relying on available data from government bodies such as annual reports and official statistics. • Utilizing government databases to obtain information about public spending and political involvement.
	Technology and Smart Systems: • Employing smart city systems to continuously collect data, including traffic and environmental management systems. • Making use of smartphone apps and websites to gather feedback from citizens.
Analysis and evaluation	**Analysis Tools:** • Using statistical analysis software like SPSS and R to analyze collected data. • Applying Big Data analysis tools to understand patterns and trends.
	Comparison with Global Indicators: • Comparing performance with global smart city indicators such as those of the United Nations and the World Bank. • Identifying gaps and areas needing improvement.
Transparency and participation	**Report Publication:** • Regularly publishing reports on the smart city's performance for citizens and relevant authorities. • Openly providing data on electronic platforms to enhance transparency.
	Citizen Engagement: • Organizing workshops and public meetings to discuss evaluation results. • Enhancing community participation through social media platforms and electronic opinion polls.
Monitoring and continuous improvement	• **Periodic Review:** • Making periodic reviews of policies and procedures to ensure compliance with performance standards. • Updating goals and procedures based on evaluation results and reviews.
	Training and Development: • Offering training programs for government officials to improve their skills in managing smart cities. • Strengthening collaboration with universities and research centers to develop innovative solutions.
Cooperation and partnerships	**International Collaboration:** • Working with global smart cities to exchange experiences and best practices. • Joining international networks for smart cities to make use of shared resources.
	Local Partnerships: • Enhancing partnerships with the private sector and civil society to support smart city projects. • Promoting local initiatives that help improve public services and transparency.

Source: Author

By implementing these mechanisms, smart cities can enhance their performance and successfully meet evaluation criteria, ultimately improving the quality of life and increasing citizen satisfaction.

8. RESULTS

The phrase "smart city" refers to a range of ideas that emphasize creativity and problem-solving as essential components of intelligence. Smart cities prioritize social and environmental aspects while addressing urban difficulties through the use of digital tools. They promote community involvement and include sustainability concepts. The characteristics of a smart city, which include things like economy, natural resources, transportation, quality of life, and community involvement, are intimately tied to classical ideas of urban growth and development.

The criteria of the Regional Science Center at the Technical University of Vienna are the most comprehensive due to its transparent evaluation methodology. It includes standards for selecting cities (case study samples), as well as clear indicators and detailed applicable results. On contrary to Nicos Komninos' criteria, which focused on four axes and fundamentally neglected the environmental dimension in the evaluation, the ICF criteria addressed various dimensions of the smart city.

9. RECOMMENDATIONS

The notion of a smart city comprises six primary aspects: smart mobility, smart administration, smart people, smart environment, smart life, and smart economy. The following actions are suggested by the researcher based on these dimensions: Establish public policies, plans of action, and efforts to advance smart governance and information technology while guaranteeing ongoing innovation and creativity in this area. Manage the process of smart transformation by providing assistance and direction to information planning competencies. To aid in this transition, create, build, and launch a smart apps site. Create and implement high-quality smart city programs for the general public, business community, and government. Create an institutional framework to support long-term ICT skills. Establish a highly effective digital environment that protects user privacy and security. Provide an enabling legal and regulatory environment

To maximize the benefits of the 25 indicators suitable for the Egyptian context, a comprehensive strategy must be implemented. This strategy should include developing technical infrastructure by enhancing communication networks and providing high-speed internet access across all areas. It should also focus on raising awareness and providing training through campaigns that educate citizens and officials about the benefits and usage of modern technologies. Additionally, investing in research and development is crucial, encouraging investments in projects that promote technological innovation. Improving transparency and participation is essential by enhancing government transparency and encouraging community involvement in decision-making. Lastly, environmental sustainability should be prioritized by implementing eco-friendly solutions across all sectors and widely adopting renewable energy. By leveraging these indicators and implementing the appropriate strategies, the performance of smart cities in Egypt can be effectively assessed, leading to significant improvements in various areas.

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مقارنة منهجية لتقييم أداء المدن الذكية

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ملخص البحث

جاءت المدن الذكية كحل للتحديات التي واجهت المدن منذ فترة طويلة بسبب زيادة معدلات النمو السكاني والضغط على البنية التحتية وارتفاع اسعار الخدمات والتراجع في مستوى الخدمات الاجتماعية والتلوث والتدهور البيئي واستلزمت هذه التحديات حلولاً مبتكرة لجعل المدن اكثر استدامة وفاعلية، مما أدى إلى الحاجه لظهور المدن الذكية. وبناءً على ذلك اتجه البحث لدراسة تقييم أداء المدن الذكية ذات الاداء الجيد من خلال دراسة ستة أبعاد مع عوامل محددة لكل منها. ويهدف البحث إلى التوصل لطريقة لتقييم أداء المدن الذكية من خلال تحليل لاشهر ثلاثة طرق عالمية معترف بها على نطاق واسع لتقييم اداء المدن الذكية: طريقة (Nicos Komninos)، وطريقة منتدى المجتمعات الذكية، بالاضافة إلى طريقة مركزالعلوم الاقليمي في جامعة فيينا التقنية، ومن ثمه تحديد الطريقة المناسبة لتقييم أداء المدن الذكية في جمهورية مصر العربية من الثلاثة طرق، وكيفية تطبيقها وآليات تنفيذها بما يناسب الأولويات المحلية (التعليم، الصحة، النقل، الاقتصاد، الحوكمة، البيئة) والاحتياجات المحددة لتحقيق التنمية المستدامة والارتقاء بالمدن المصرية.

الكلمات المفتاحية: المدن الذكية، تقييم أداء، طرق عالمية، عوامل، أبعاد.