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Smart City Assessment: Initiatives of Mashhad Smart City

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ABSTRACT: The smart city, as the future of urban infrastructure, has a wide range of benefits, including better utilization of scarce resources and more welfare for citizens, and is a necessity for sustainable development. An increasing number of smart city projects have been implemented and many others are under development worldwide. There are many economic, environmental, and social challenges to develop a smart city. One of these challenges is the smartness assessment. Key Performance Indicators (KPIs) are important for measuring and comparing the grade of smart city maturity. The International Telecommunication Union (ITU) has established the United for Smart Sustainable Cities (U4SSC) to standardize and release a KPI set for measuring smart city development from various aspects. In this paper, we expand the standardized KPIs and map it to contextualized KPIs, which concerns the challenges and priorities for the specific case under study. By combining the standardized and contextual KPIs, a comprehensive assessment model is created and used for smart city development. As a case study, we also briefly report the assessment of Mashhad city smartness using the proposed method and the ITU's U4SSC verification process. We defined the smart tourism and Smart Water Management as the contextualized KPIs for Mashhad and evaluated component of smart tourism and Smart Water Management ecosystem.

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1- Introduction

More people have lived in urban areas than rural areas in the last few decades. According to the United Nations [1], in 1950, only 30% of the world's population were living in urban environments, but in 2018, this number increased to 55%. It is also expected that the urban population will increase to 68% by 2050. Furthermore, about 2.5 billion will be added to the urban population by 2050, with almost 90% of this growth happening in Asia and Africa. Therefore, we will encounter more challenges that need to be solved for urban environments. For example, cities currently consume nearly 70% of the global energy demand and produce about 80% of greenhouse gas emissions [2], which will be more challenging. A smart sustainable city recruits the emerging technologies and digitalization of government to overcome the urban challenges, focusing on three dimensions: city policy, city management, and technology [3].Smart technologies offer new effective and efficient integrated city systems, infrastructures, and service provisioning solutions [4]. Employing smart city solutions is an excellent opportunity to achieve sustainable development, realized by optimum resource consumption, production, and saving transportation and shopping time using connected devices, Internet of things, smart mobile phone, and Information technology. Although every city's strategy and road map for smartness should be customized, the first common phase is usually an assessment of the city-state. Standardization bodies, including International Telecommunication Union (ITU) and ISO, have defined some Key Performance Indicators (KPIs) for a unified assessment of city smartness from various viewpoints. By developing KPIs for smart sustainable cities, standardization bodies intend to achieve coherent, consistent, and suitable parameters, indicating how much an assessed city achieved the sustainable development goals.Choosing the most proper index framework for a city smartness assessment needs expertise, which is not usually available in municipalities. Therefore, it is a risky and challenging selection for city managers and could have significant disadvantageous consequences. This study considers the main differences between the current international smart city index standards, and reports using the appropriate KPI for the case of the city of Mashhad.The rest of this paper is structured as follows: Section 2 overviews the preliminaries, including the related concepts of smart city and smart city assessment methodology, which consists of standardized and contextual KPI assessments; then standardized and contextual KPI assessments will be described in Section 3 and Section 4, respectively; Section 5 describes our case study on the maturity of Mashhad smartness; Section 6 present the results of the case study; and finally, Section 7 concludes the paper.

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2- Preliminaries

In this section, we introduce the concept of smart city to cover the preliminaries and then we explain KPIs to measure the maturity of a smart city, focusing on the ITU and U4SSC initiative, which we have used in this research. Existing literature does not thoroughly analyze the multidimensional nature of smart cities' drivers considering desired outcomes [5]. One of these drivers is the global trend and standardization activity on developing Information and Communication Technology (ICT) infrastructure and IoT, which play an essential role in transforming traditional urban lifestyles toward smart cities.

2- 1- The Concept of Smart City

The buzzword "smart" is used to describe technological, economic, and social developments fueled by advanced and interconnected technologies relying on sensors and actuators, big and open data, advanced data communications, and information exchange including Internet of Things, RFID, and NFC, as well as inferring and reasoning abilities. The term "smart city" describes efforts aimed at using smartness and advanced technologies innovatively in cities to achieve resource optimization, effective and rational governance, sustainability, and quality of life [5, 6].

Smart cities have different components to cover various challenges in urban areas. The components of smart cities have been discussed in [7], consisting of: smart economy, smart environment, smart government, smart living, smart mobility, and smart people

A concept model for smart city formulates strategic guidelines for the success of smart city initiatives and identifies a set of key factors that directly affect the smart city, including technological, organizational, and political aspects [8, 9]. Some conceptual models for smart city are found in the literature. In [10], five conceptual smart city models are compared: (1) Europe smart city model [11], (2) The basic component of smart city model [12], (3) Smart city initiatives framework [13], (4) the basic element of smart city model [14], and (5) relationship component and characteristic smart city model [15].

2- 2- Smart City Assessment Methodology

To measure and compare the maturity of smart cities, KPIs should be used. In [16], a conceptual model for measuring the smartness of a smart city is proposed. The model operates in two phases:

Standard KPI Assessment: capturing the smartness measure of a particular smart city through observing the KPIs of a city along the dimensions adopted by the ITU, and

Contextual KPI Assessment: capturing the context of the city being assessed in an attempt to allow proper comparability.

The standard KPI assessment follows the evaluation of the smartness index derived from international standards (e.g. ITU). The context KPI assessment concerns the dimensions which are important for a city and may be used in the strategic plan of the city's smartness.

We proposed the KPI transformation concept which is a mapping from standard KPIs to the contextual or native KPIs,

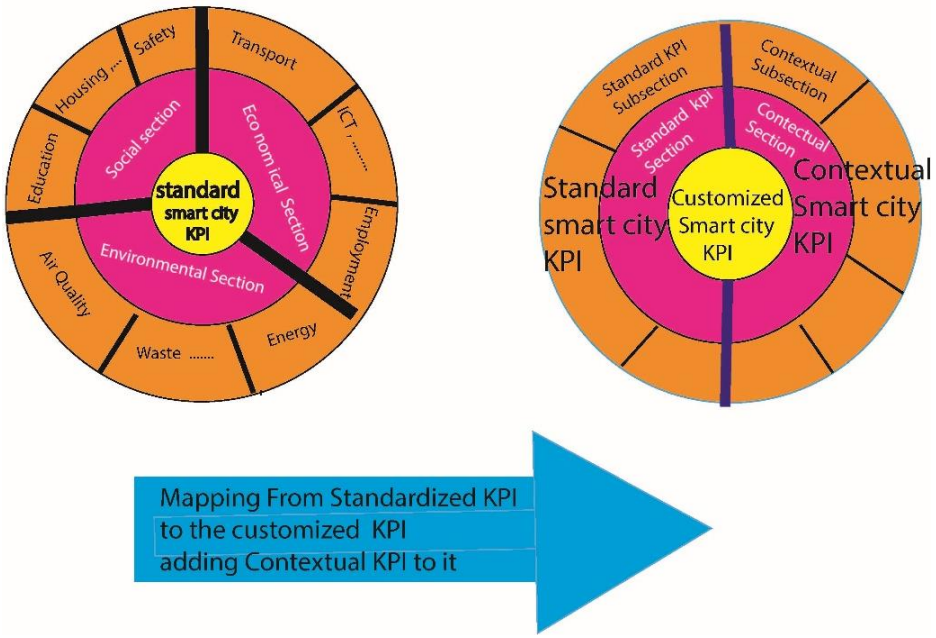


Fig. 1. Mapping from standard KPIs to the contextual or native KPIs

Table 1. Criteria for KPI

KPI Property	Description
comprehensiveness	The set of KPIs should be complete and cover all aspects of Sustainable Smart City.
Availability	The KPI should be easily collectable, the correct data should be online accessible.
Simplicity	The concept of each indicator should be simple and understandable for each stakeholder.
Adaptable	For new aspects of smart city, the ability to define new KPIs, including contextual KPIs.

as shown in Fig 1. For example, Mashhad is Iran's most popular religious tourist destination, and it affects selecting smart tourists as one of the most important smartness dimensions. Moreover, Mashhad faces some challenges, including urban transportation, air pollution, and water shortage. As shown in Fig. 1, the contextual KPIs categorizes the standard KPIs into two parts: the general standard KPIs and the contextual native KPIs.

3- Standardized KPI assessment

The ITU U4SSC has introduced the appropriate KPIs for smart city evaluation, having a unified character and creating an integrated framework to compare the cities' progress in smartness over time. Moreover, these KPIs provide a benchmark for comparing the cities' performance and adopting the best practices through analysis and sharing their experience. Table 1 lists the KPIs and their brief descriptions.

One of the most useful applications of KPIs is its usage as decision support for planning smart city development. To successfully develop smart city projects, the managers should also make their activities and decisions transparent to the citizens. Using KPI in data dashboards increases this transparency and encourages citizens to contribute to their city's smartness activities and spread smart social culture [17].

The basic process for assessing KPIs contains the following five major phases:

Analysis phase: The appropriate KPIs, customized for the city, and collection methods are decided in the analysis phase.

Implementation phase: After KPI identification, the implementation phase starts, and the assessment framework is developed.

Preparation phase: In this phase, the required input data for evaluation is collected.

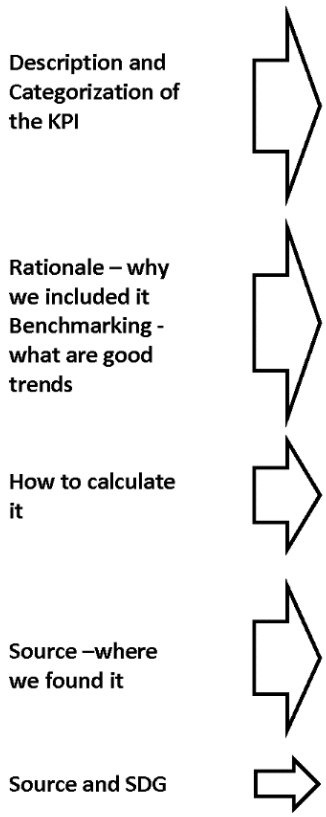
Verification phase: In this phase, ITU verifies the KPI measurement source, processes, and results.

Visualization phase: The evaluated output KPIs are presented in easily understandable forms (e.g. tables and diagrams in the last phase).

As part of the U4SSC KPI program, benchmarks of most KPIs are developed during the verification phase.

The KPIs are categorized into two classes: 1) core KPIs, available for all cities to provide basic smartness and sustainability information, and 2) advanced KPIs that provide deeper smartness and sustainability information [7].

Although many index frameworks and tools for assessing urban sustainability and smartness exist [18], the standardized frameworks of city indicators have been recently introduced. Three institutions, including ISO, ITU, and a coalition of European standardization bodies CEN, CENELEC, and ETSI, carried out International standardization on the smart city indicators [18]. The Urban Indicators Working Group of the Sustainable Cities and Communities Committee has developed ISO standards for sustainable cities. "In Europe, standardization activities on smart sustainable cities with the joint efforts of CEN, CENELEC, and ETSI in the Association of Smart and Sustainable Cities and Communities (SF-SSCC), established in January 2017, following a similar coordination group" [18].



Dimension	Economy				
Sub-Dimension	ICT Infrastructure				
KPI Name	Household Internet Access				
KPI No.	EC: ICT: ICT: 1C	Type:	Core	Type:	Smart
Definition / Description	Percentage of households with Internet access				
Rationale / Interpretation / Benchmarking	This indicator demonstrates the access to information and technology connectivity given that connectivity across regions and between countries is correlated to economic prosperity, development and growth. This in turn underscores a city inhabitant's access to knowledge, data, news and communication to use for economic productivity, i.e. training, education, research, business management, ideas exchange, etc. Data that includes any household's access via a fixed or mobile network at any given time should be collected. An increasing trend and higher values are considered positive.				
Methodology	Calculate as: Numerator: Number of households with internet access. Denominator: Total number of households. Multiply by 100				
Unit	Percentage				
Data Sources / Relevant Databases	The data may be collected from the local statistics department, or may need to be extrapolated from national data. Annual surveys of households may be another method for data collection to obtain the percentage of households with internet access. This percentage will then be applied to the in-scope population. The data may also be collected from local internet service providers and telecommunications companies				
SDG Reference(s)	SDG Indicator 17.8.1: Proportion of individuals using the Internet.				

Fig. 2. Standard definition of U4SSC KPI [20]

3- 1- United for Smart Sustainable Cities (U4SSC) Initiative

The International Telecommunication Union (ITU) has decided to support cities worldwide to evolve into sustainable smart cities. Therefore, ITU has established public policy frameworks and a set of international recommendations on KPIs for sustainable smart cities to help them become smarter and more sustainable. Moreover, ITU has provided a tool for smart cities' self-assessment.

ITU has also produced a set of guidelines that define the role of ICT in sustainable smart cities. For this purpose, ITU formed the United for Smart Sustainable Cities (U4SSC) initiative, which has facilitated knowledge sharing and partnership building on smart cities to formulate strategic guidelines to implement the New Urban Agenda. The U4SSC KPIs offer a standard format to report the progress of smart, sustainable city strategies. These indicators also enable cities to measure their progress relative to the United Nations SDGs.

3- 2- U4SSC Key Performance Indicator

A KPI is a type of performance measurement that helps cooperation get insight into their organization or department's performance. In cities, it indicates the current performance level of smartness and sustainable development goal.

ITU's KPIs evaluate cities' smartness in three different dimensions: Economy, Environment, and Society and Culture. The Economy KPI concerns ICT, Productivity, and Urban infrastructures. The index category of this dimension is ICT Infrastructure, Water and Sanitation, Drainage, Electricity Supply, Transport, Public Sector, Innovation, Employment, Waste, Building, and Urban Planning. The Environment KPI concerns the environment and energy, including Air Quality, Water and Sanitation, Waste, Environmental Quality, Public space and nature, and Energy. The Society and Culture KPI focuses on Education, health and culture, Safety, Housing, and Social Inclusion. The index category of this dimension is Education, Health, Culture, Housing, Social Inclusion, Safety, and Food Security. Fig. 2 shows the standard definition of U4SSC KPI [20].

4- Contextual KPI Evaluation

Contextual KPIs are specified concerning the challenges and priorities of the specific case under study. These KPIs depend on several factors including economic, social, and environmental challenges, smart city phase (e.g. planning phase or operation phase), smart city development evaluation

time (e.g. occasional, seasonal, annual), geographic scale (e.g. district, city, and country), and the purpose of assessment (e.g. project control, monitoring, official reporting, strategic planning, target setting, self or cross-city benchmarking, marketing). This section briefly introduces Mashhad and its challenges to become a smart city [21], concerning its main contextual KPIs.

Mashhad, located in the northeast of Iran, has a population of 3,001,184, according to the 2016 census. After the capital, Tehran, it has the second largest population in Iran. Mashhad is mostly known as a religious city for Muslims, and many tourists come to visit the Holy Shrine of Imam Reza (AS), the eighth Imam of Shias. However, many other great tourist attractions in Mashhad make tourism a very important contextual dimension of the city. Therefore, it might fulfill the smart tourism KPIs. Other important contextual KPIs for Mashhad include urban transportation, air pollution, and water shortage. Mashhad suffers from a water shortage crisis, mainly because of drought and an imbalance between water resources and water consumption. Therefore, another crucial contextual KPIs for Mashhad is Smart Water Management (SWM). In this section, Mashhad's contextual smart tourism KPIs and contextual Smart Water Management KPIs are explained, then the maturity of Mashhad's smartness will be overviewed.

4- 1- Contextual KPI for Smart Tourism

Smart tourism is a recent buzzword, describing the increasing reliance of tourism destinations, related industries, and their tourists on emerging ICT technologies that transform massive amounts of data into value propositions, especially some Asian countries have concerted efforts to drive the smart tourism agenda forward. According to [22], tourism is "a social, cultural and economic phenomenon which entails the movement of people to countries or places outside their usual environment for personal or business/professional purposes".

The widespread adoption of social media has accelerated smart tourism development [23]. It has also caused a rapid move toward realizing mobile tourism in recognizing the high mobility of tourism information and tourism consumers [24, 25].

Smart tourism involves multiple layers and components supported by ICT (Fig. 3) [26]:

The smart destinations are special cases of smart cities that apply smart city principles to urban, and consider both residents and tourists to support mobility, resource availability and allocation, sustainability, and quality of life or visits.

The smart experience component concentrates on technology-mediated tourism experiences and enhancement by personalization, context-awareness, and real time monitoring [27]. The main drivers of smart experiences are information aggregation, ubiquitous connectedness, and real time synchronization [28].

The smart business ecosystem refers to the complex business ecosystem of smart tourism that supports the exchange of touristic resources and the creation of the tourism experience. This business component of smart tourism is characterized by dynamically interconnected stakeholders, digitalization of core business processes, and organizational agility [27].

4- 2- Contextual KPI for Smart Water Management

One of the significant concerns and challenges of Mashhad smart city is the lack of water due to the long-term drought caused by climate change and the rusty water distribution network. Therefore, Mashhad should initiate the smart water project to prevent leakage in its deteriorated existing water facility and compensate for the lack of water resources. With Smart Water Management in Mashhad, the water resources would be secured by reducing water loss in pipelines without expanding resources, such as dams and underground reservoirs. The intelligent part of the Smart Water Management project is a Central Monitoring System (CMS), which enables the collection of real-time household water consumption, water pressure, and other water flow-

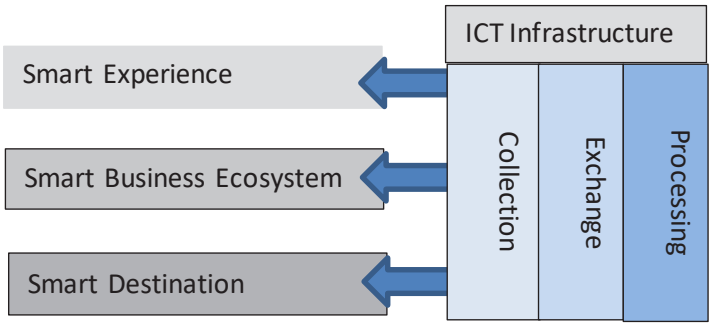


Fig.3. Components and layers of smart tourism [26]

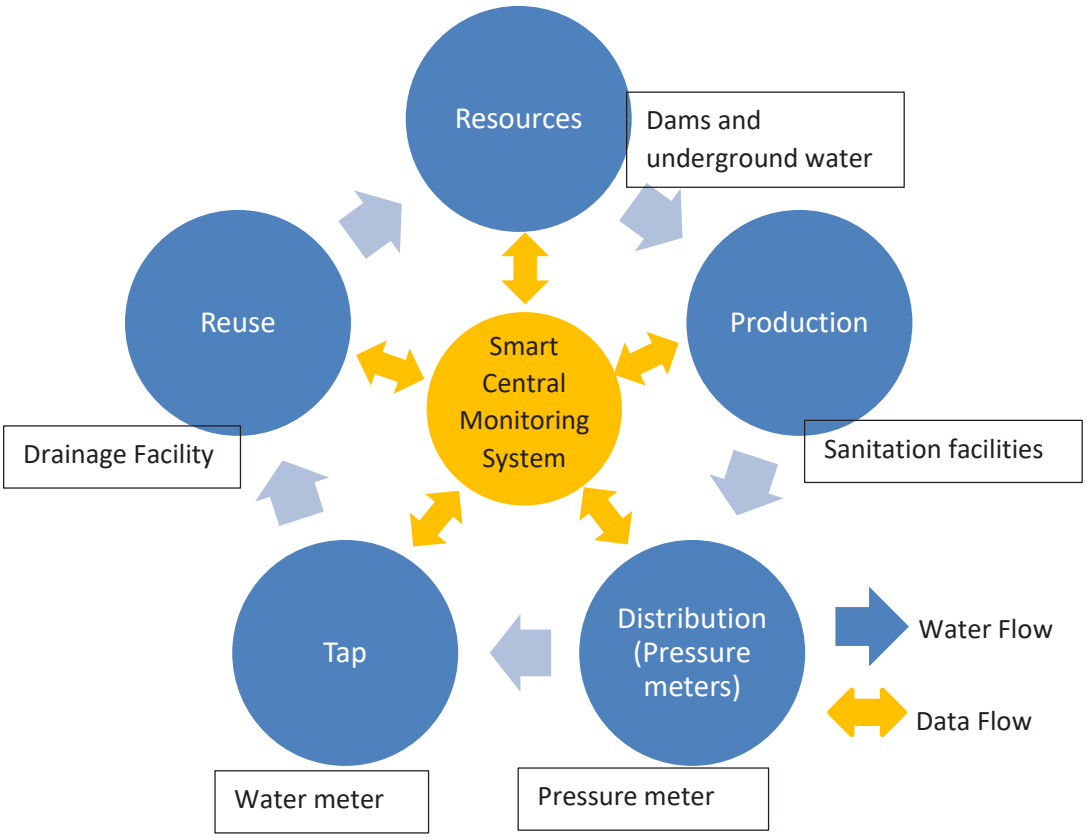


Fig. 4. Smart Water Management (SWM) ecosystem

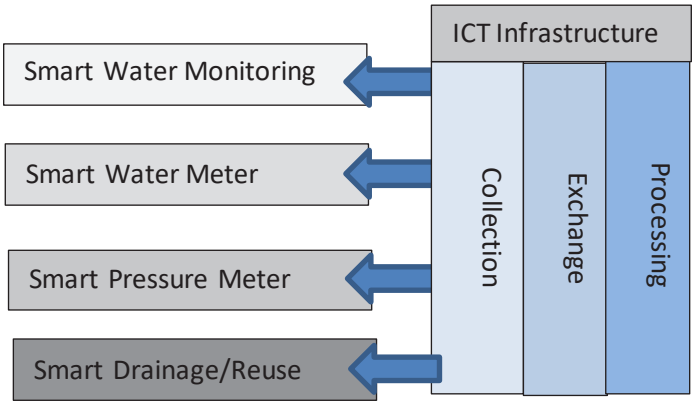


Fig.5. Components and layers of smart tourism

related data. By installing smart meters at each point and establishing an IoT network, collected data is exchanged with CMS. CMS is able to narrow down the leakage points and facilitate rapid leakage detection and restoration. We can analyze the customer usage pattern and reduce water leakage to the customized water pressure by using artificial intelligence.

Smart Water Management is the best solution for a region with a water crisis like Mashhad, in which we add IT facilities to the traditional water supply ecosystem. Fig. 4 shows SWM, consisting of a traditional water management ecosystem as the outer circles and the smart Central Monitoring System in the center of the figure. The traditional water management cycle includes the following components: resource, production, distribution, tap, and reuse, showing the flow of water. The SWM facilitates data communication and processing among

the traditional components equipped with smart sensors and actuators.

Smart Water Management involves multiple layers and components supported by ICT, as shown in Fig. 5:

Smart water monitoring is the central part of SWM with these main functionalities:

Integrated real-time data acquisition from the smart sensors located in traditional elements.

The platform for transmission storage and integration of collected data.

Analysis and visualization of aggregated data and provide decision support information.

Smart water meter consists of real-time smart sensors used to measure household consumption patterns.

Smart pressure meter consists of real-time smart sensors used to measure the pressure in the water distribution network.

Smart drainage/reuse consists of real time smart sensors, used to measure draining and reusing generation.

5- Maturity of Mashhad Smartness

Mashhad is the first Iranian city to implement, measure, and report the U4SSC KPIs for its smart city implementation in 2021. After selecting the ITU KPIs for the project of Mashhad smart city, the implementation of KPIs, and Mashhad Improved Electronic Services and ICT Infrastructure are explained in this section.

The Mashhad municipality has dedicated reasonable budgets and efforts to promote its smart city by introducing a series of policies. Generally, if policies are not realistic and do not comply with the practice, they may have limited effectiveness in an application. Mashhad has an acceptable practice in improving city smartness with good practices in improving ICT and smart city infrastructure. Mashhad has strengthened the city's ICT backbone. One great action is implementing a metropolis data center and corresponding disaster recovery sites that store and maintain more than 1000 physical servers for urban IT services and management. Mashhad has also installed more than 400 km of urban optical fiber to improve service reliability and capacity to facilitate reliable communication. Furthermore, more than 150 electronic services have been developed in the following five main urban services sections [21]:

Urban planning and civil construction
Transportation services
Public and green spaces services
Cultural and social services
Contact center

Among the 150 developed electronic services, 57 electronic services are accessible for citizens through a municipal One-Point portal, sm.mashhad.ir. This web-based portal is a centralized service platform by which the citizens submit and track their requests in various areas, including (but not limited to) [21]:

Payment of construction and car tolls
Payment of city taxes
Cargo permits
Parking subscriptions
Renting of public sports halls
Shared bike registrations
Councils Charging the city NFC card
Registration of NFC cards for the disabled equations
Tree planting and removal requests
Membership in neighborhood social

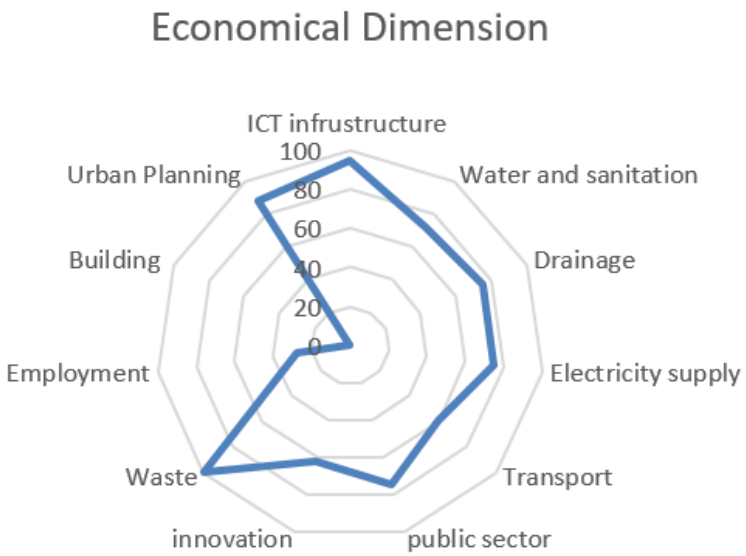


Fig. 6. The "economical" dimension scores against the current U4SSC benchmarks [29]

Table 2. Mashhad verification KPI summary

		Total	Reported	Verified	% KPI verified
Economy	Core KPIs	23	22	22	96
	Advanced KPIs	22	18	18	82
Environment	Core KPIs	12	11	11	92
	Advanced KPIs	5	5	5	100
Society and Culture	Core KPIs	19	16	16	84
	Advanced KPIs	10	8	8	80
Overall	Core KPIs	**54**	**49**	**49**	**91**
	Advanced KPIs	**37**	**31**	**31**	**84**
Total		**91**	**80**	**80**	**88**

6- Results

The assessment results were reported by the verification report and factsheet documents [29]. Table 2 summarizes Mashhad's data collection and reports under the standardized KPIs and the verification process.

The result of scoring "economy", "environment", and "society and culture" dimensions of the city is explained in the coming subsections.

6- 1- Economy Dimension

In fact, the key issue evaluated by economic performance indicators is the level of ICT implementation. A Sustainable Smart City (SSC) needs an IT infrastructure that includes fixed and mobile communications to facilitate the development of smart and sustainable cities and to promote and enhance sustainability through efficiency in city operations by promoting civic participation. Fig. 6 summarizes the measured performance for this part in the city of Mashhad.

The economic dimension in the evaluation of sustainable smart cities includes the sub-dimensions of ICT, productivity, and infrastructure. In this section, indicators in the areas of ICT infrastructure, water and sewage, drainage, electricity supply, transportation, and public sector are measured. This part aims to evaluate the availability and proper use of ICT infrastructure in cities, which facilitates sustainable smart urban services. In Mashhad, the full score for the KPIs in the ICT part shows the proper deployment of ICT infrastructure in the city.

Productivity includes key indicators related to innovation and employment. The purpose of these indicators is to assess the impact of ICT on the economic development of cities. They cover innovation, job creation, business, and productivity. Measuring these key indicators in Mashhad and evaluating the acceptance of ICT in the city shows not a good score. The city should provide more opportunity for innovation and job promotion to improve business and productivity.

The field of infrastructure is related to water and sewage, waste, electricity supply, transportation, buildings, and urban planning. The purpose of these key indicators is to assess the impact of ICT on the above infrastructure of the city. The scoring of Mashhad is almost good and the city can improve by implementing the integrated support of ICT in city infrastructure to fill the remaining gap. The score of Mashhad in the building sector is the worst, which indicates that there is no control over the intelligence of the building in Mashhad and the relevant data may not be available. Therefore, building evaluation and monitoring is very important in terms of resource management and should be considered in city planning.

6- 2- Environment Dimension

Environmental indicators are composed of sub-dimensions of environment and energy. Indicators related to the environmental dimension include those for air quality, water and wastewater, waste, environmental quality, and public space and nature. The purpose of environmental indicators is to assess the use of ICT in improving urban environmental services as well as improving the overall quality of the environment in cities.

The energy sub-dimension contains all the indicators that

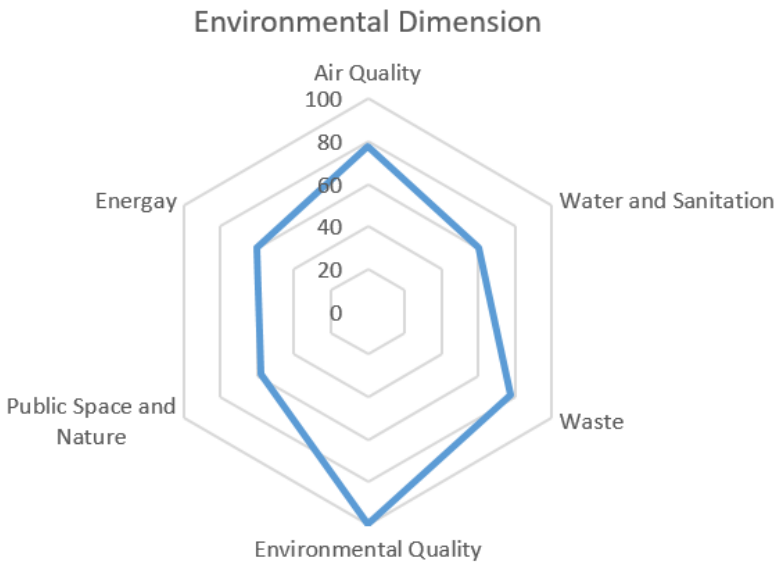


Fig. 7. The "environmental" dimension scoring against the current U4SSC benchmarks [29]

Fig. 8. The "society and culture" dimension scoring against the current U4SSC benchmarks [29]

give information about energy. The purpose of these key indicators is to assess the use of renewable and sustainable energy sources, as well as energy efficiency measures and energy reduction in the city. This dimension assesses the level of use of ICT infrastructure in environmental sustainability and energy efficiency, which provide a key basis for future comparisons since achieving efficient use of resources through ICT is essential for the long-term environmental sustainability of Mashhad and any sustainable city.

Fig. 7 summarizes the performance of Mashhad KPIs with the details of the categories in the environmental dimension against the U4SSC criteria. In the environmental dimension, it has been shown that the city is good in environmental quality. Water and sewage, public space, and energy should be given more attention in the next planning of the smart city plan.

6- 3- Society and Culture Dimension

The third dimension of U4SSC Sustainable Smart Cities Evaluation Indicators is society and culture, which includes the sub-dimensions of education, health and culture, as well as safety, housing, and social inclusion.

The Key Performance Indicators in the sectors of education, health, and culture are aimed at evaluating the impact of ICT in each of these areas, and in fact, the extent of its impact on the quality of life of citizens.

Key indicators in the field of safety, housing, and social inclusion include indicators that measure the impact of ICT

in society. The purpose of these key indicators is to assess the impact of the use of ICT to promote urban equality, citizen participation and increase social inclusion. The indicators focus on issues of openness, public participation, and transparency in government.

In general, these indicators emphasize the fundamental development that allows the creation of electronic platforms to use in public and private sectors. Such platforms provide the basis for more transparent and efficient governance and maintain the inclusion of city dwellers as stakeholders who are important in city decision-making processes. They ensure that health, education, and safety services are provided electronically and automatically with minimal disruption, waiting time.

Fig. 8 shows a summary of the performance of the city of Mashhad in this section with details of the categories in the community and culture dimension in the U4SSC criteria. As shown in this figure, the food score is complete and other sub-dimensions except culture are also above average in the indicators of society and culture. Therefore, culture should be given more attention.

6- 4- Mashhad Contextual KPIs

The contextual KPIs for Mashhad, mainly concerned with smart tourism and Smart Water Management, have been derived based on mapping of the related standard

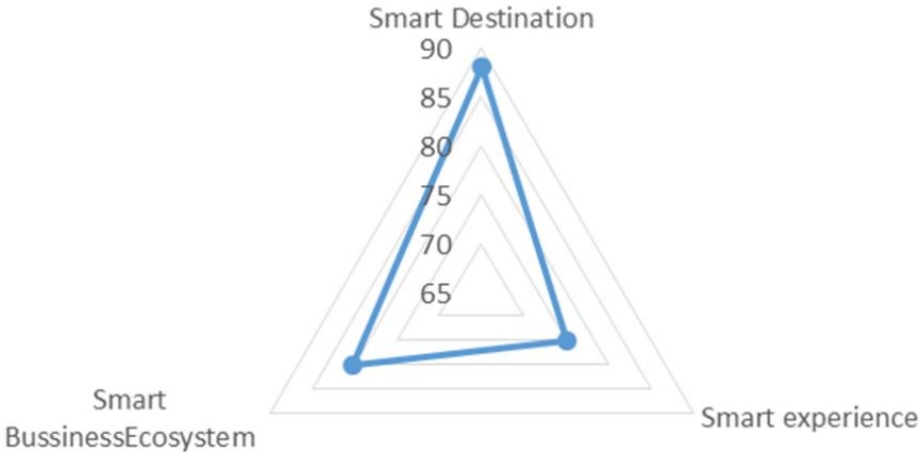


Fig. 9. The smart tourist factors, measured for Mashhad

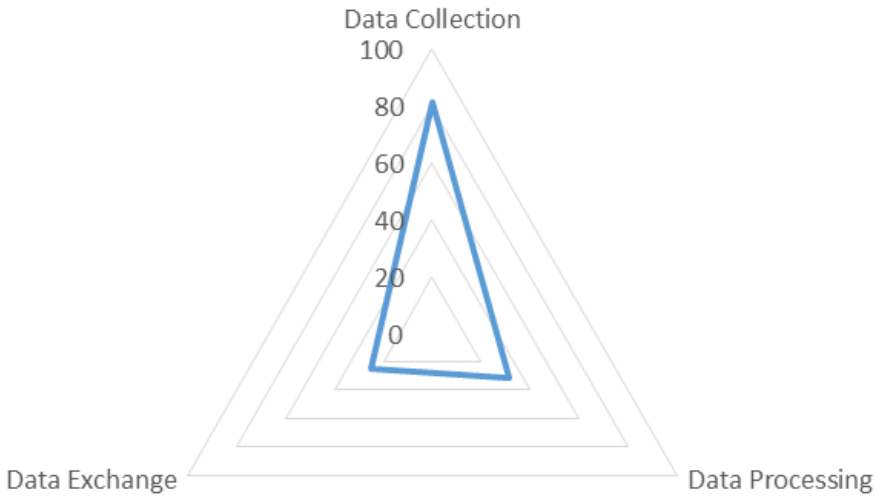


Fig. 10. The ICT Infrastructure parameters, measured for Mashhad

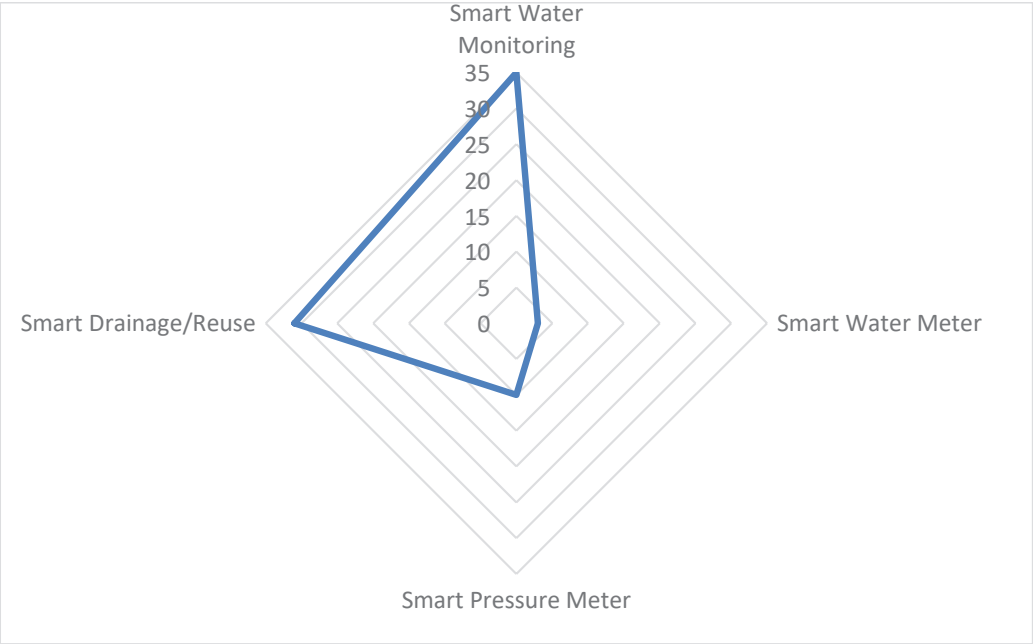


Fig. 11. The Smart Water Management (SWM) KPIs measured for Mashhad

KPIs regarding their definition. These KPIs include smart tourist factors, Smart Water Management, and related ICT infrastructure parameters. The smart tourist factors comprise smart destination, smart business ecosystem, and smart experience (Fig. 9). Similarly, ICT infrastructure parameters comprise data collection, data exchange, and data processing (Fig. 10).

The Smart Water Management factors comprise smart water monitoring, smart water meter, smart pressure meter, and smart drainage/reuse, mapped from standardized KPIs, and their percentages are shown in Fig. 11.

7- Conclusion

The smart city provides a better lifestyle for citizens and optimizes the consumption of scarce resources such as water, fuel, and electricity. In order to develop a smart city, there is a wide range of economic, environmental, social, and technological challenges. One of the critical challenges is the smartness assessment studied in this research, considering the case of Mashhad city.

This paper proposed a novel assessment method, using international standardized KPIs beside the contextual KPIs concerning the target city challenges and priorities. In this method, we map standardized KPIs to contextual KPIs and generate a comprehensive set of KPIs to be used for smart city development roadmap.

We have used this method for the case of Mashhad KPI evaluation, based on the evaluation of U4SSC standard KPIs, emphasizing smart tourism and Smart Water Management as the major contextual PKI sets.

The proposed method expands the standardized assessment models and takes care of the context and situation of each city individually by adding contextualized KPIs. This method could be used in the course of smartness of any city to focus more on the native challenges, problems, and opportunities.

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