Urban Planning

Extracting the main characteristics of a city to be smart

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Abstract

Despite there are too many different viewpoints and definitions of the "Smart City" notion, the management part of a particular city needs to formulate a special definition of this concept for the city, based on its specific characteristics and priorities. The main question of this research is "What are the general characteristics of the smart city concept, and how we can derive customized characteristics for a particular city using these general characteristics"? This paper provides an approach to determine a set of validated, customized and prioritized characteristics for the target city. These characteristics can be used for formulating a desired definition for the city. In addition, they can serve as an input for strategic planning of the city and a criterion for prioritizing the urban projects for the target city. The first phase of our approach is based on a systematic review on the literature in order to take a valid range of different characteristics of the smart city notion. The second phase relies on the characteristics resulted in the first phase and determines a set of particular characteristics for the target city, based on its upstream documents and stakeholders' opinions. In order to illustrate the second phase as well as showing the usability of our approach, we applied this approach to Tehran, the capital of I.R. Iran. Our study resulted in 35 common characteristics which are candidate for all cities. Then, 10 main characteristics were particularly extracted for the future Smart Tehran. These characteristics were used to derive the mission, vision, and values of Smart Tehran, as well as prioritizing the six main components of smart cities for this city in the following order: smart economy; smart mobility; smart living; smart governance; smart people; smart environment.

Keywords: Smart city, Smart city characteristics, Smart city planning, Future smart Tehran.

1. INTRODUCTION

Among many related notions in the literature, including "Digital City", "Intelligent City", "Information City", "Knowledge City", "Creative City", etc., smart city is the only term that encompasses all technological, human and institutional factors Fig. 1. To be more precise, in addition to the technological factors (like physical infrastructure, smart, mobile, virtual and digital technologies), the notion of smart city is concerned with knowledge, innovation, development, knowledge-based processes and economy, and human and society assets. In other words, smart city considers all functions, services and processes of the city management.

The world is moving towards smart city. Fig. 2 shows that so many valid international papers and reports have been proposed around this term. Moreover, this figure compares the number of papers on the notions of digital city and smart

city in recent years and states that the studies are moving towards the smart city concepts. It should be noted that in our systematic review (described in Sections 3 and 4) we found 188 unique definitions related to the smart city concept. A summary of the findings is shown in Table 1 which indicates the number of occurrences of each concept in the studied definitions. As this table shows, the existing definitions are mostly concentrated on the smart city concept.

In the process of making smart cities, concepts like social capital and sustainable environment and economy are secondary, compared to that of the application of ICT. An important point is that the concept of smart city is evolving in time, and consequently, its border with other related concepts, like digital city, information city, creative city, etc., is not obvious enough. Also, the adjective "Smart" is vague and it is not clear that which parts of a city are going to be smart. For example, a city may consider the development of the mobile communication infrastructure as the basis of smartness, while in another city the pollution control metrics are considered as the appearance of smartness. Different cities may consider themselves smart, without referencing to a valid standard.

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Specific projects and experiences in cities and their practical success have influenced this concept.
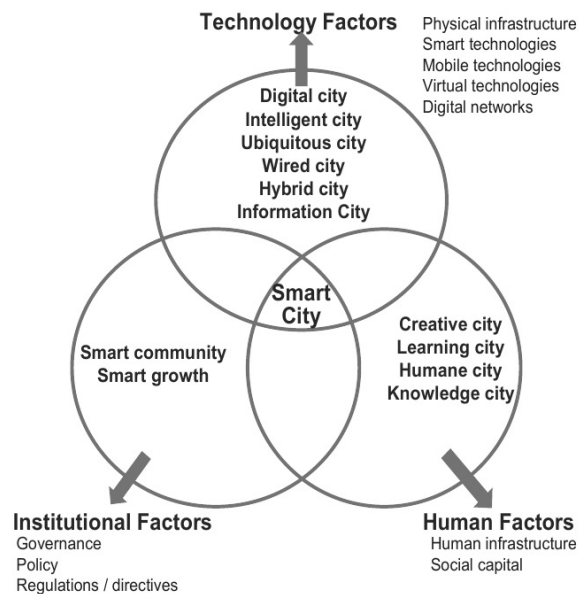

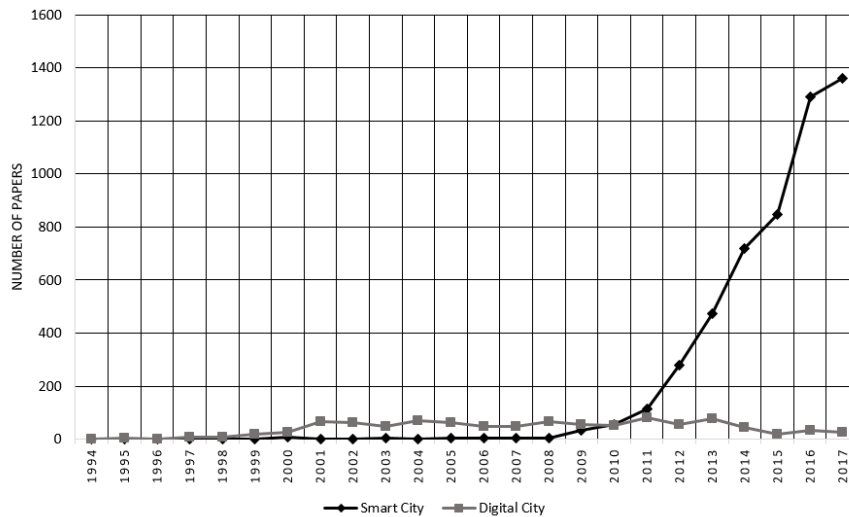**Fig. 1** Different aspects of the smart city notion [1]

Fig. 2 Papers on smart and digital city from 1994 to 2017

Table 1 Number of occurrences of concepts related to city management

Concept	Number of occurrences
Smart city	152
Green city	1
Digital city	12
Ubiquitous city	2
Eco city	4
Techno city	1
Intelligent city	3
Sustainable city	7
Wired city	1
Knowledge city	2
Information city	2
Learning city	1

Regarding the above description, there are different views and definitions about what exactly a smart city is. Therefore, each city could have its own customized definition of this concept. Definition for each city should be based on its special characteristics, goals, priorities, issues, restrictions, experiences, etc. It worth mentioning that despite of various definitions, there are six world-wide accepted components of smart cities with which every smart city definition should be aligned with. These six components whose indicators are illustrated in Fig. 3 include smart government, smart environment, smart economy, smart people, smart mobility and smart living.
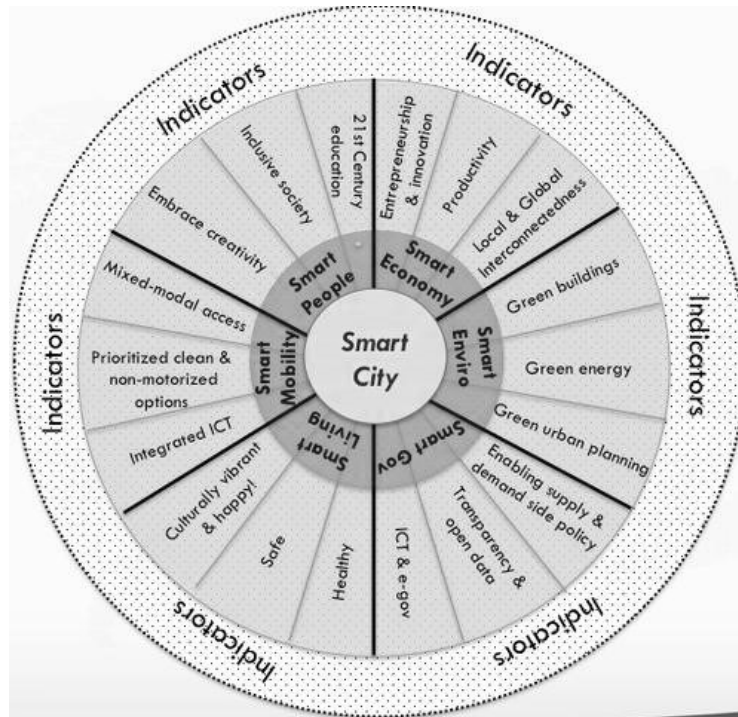

Fig. 3 The main components of smart cities with their indicators [2-3]

In this paper, we propose an approach that can help cities have their own specific definition of smart cities. This approach has two phases. The results of the first phase are common for every city, and thus, can be applied for various cities without any change. The second phase is what a city may follow in order to establish its specific definition of what they want to be as a smart city.

We can distinguish this work from other publications in the literature in the way that, this work neither intends to introduce a new definition or viewpoint on the smart city notion nor aims at presenting existing definitions and viewpoints of this notion and determining which of these definitions and viewpoints are more appropriate. Instead, we try to provide the urban management part with an approach to determine their own definition of smart city and consider a useful and logical set of smart city characteristics for their own city. The resulting characteristics have the following applications as well:

• They constitute a main input for the strategic planning of a smart city. Especially, the vision, mission, goals, policies and values of a smart city are mainly affected by its special characteristics derived based on the proposed two-phase approach.

• They help adjusting the main goals of the city management based on the smart city concept.

• They help prioritizing the six main components of smart cities for a specific city. For this purpose, the extracted characteristics have been mapped to these six components in the first phase. In addition, these characteristics are ranked in the second phase. These two activities together give us an estimated ranking of the six main components for the target city. Based on this ranking, the city managers can prioritize city projects more effectively.

So as to show that the proposed approach is applicable, we applied it to Tehran, the capital of Iran, as a case study. The reasons for selecting Tehran as our case study are as follows:

1- Tehran is the most populous city of Iran and is ranked among the 40th cities with largest metropolitan areas[1].

2- Tehran municipality has established a project to prepare "ICT Master Plan for Tehran City Management". This project was outsourced to Shahid Beheshti University. Performing this project gave us a great opportunity to have access to different resources (like different documents and regulations) and a wide range of stakeholders. Multiple meetings with related stakeholders, employees and city management experts gave us a thorough view of different aspects of Tehran city management.

The main questions of this research are as follows:

1- What are the general characteristics of the smart city concept, which can be considered for all the cities in the world?

2- How can we derive customized characteristics for a target city, using these general characteristics?

3- How can we validate and prioritize the derived characteristics?

4- How can we use these characteristics to prioritize the smart city projects in a particular city?

The rest of this paper is organized as the following: in section 2 we review the research literature. In Section 3 we present the methodology of our approach. Sections 4 and 5 introduce the details and results of each phase of the proposed approach. Section 5 demonstrates the applicability of the approach as well. Finally, Section 6 is devoted to the conclusion and some directions for future work.

2. LITERATURE REVIEW

Among all the researches obtained from our systematic search about smart cities, we could not find any work with exactly the same research questions as ours. However, there are researches which have performed some kind of investigation and analysis on the existing definitions. In this manner, they can be somehow related to our work.

The most related work is the research carried out by ITU-T Focus Group on Smart Sustainable Cities . This research was aimed at finding a comprehensive definition for "Smart Sustainable Cities" based on an analysis on existing definitions in the literature. In this work, over a hundred definitions were analyzed and a definition for smart sustainable city was presented using the top keywords extracted from the definitions of the smart sustainable city.

There is a fundamental difference between the work in source and the presented work in this paper. Authors in source are seeking out only a common and comprehensive definition for all smart sustainable cities across the globe, while this paper proposes an approach to formulate a specific and customized definition for each smart city separately (while common features for all smart cities are considered as well). Although there are similarities between the method of source and the first phase of our approach, two important differences exist:

- In source, only the syntax or wording of the keywords has been taken into consideration. If a keyword has appeared with exactly the same wording in "n" different definitions, the approach of source counts this word "n" times; if another word or phrase with different wording but with the same meaning appears in a document, it will not be counted. Our approach uses phrases instead of words, and considers the meaning and the context rather than the wording. In other words, the ITU-T approach has a syntactic approach, but our proposed approach is semantical. For instance, the words "urban" and "city" are sometimes used interchangeably. In the approach of source, these two words are ranked separately, while in the proposed approach, the two words are considered the same from the beginning.

- The approach in source considered the number of keywords in the definitions as the only factor in ranking them while our proposed approach considers

the credibility of the sources of definitions (in addition to the frequency) as a more important factor. This means that, in our approach, a phrase with less frequency but more creditable sources can have a higher rank compared to that of a word with higher frequency but less creditable sources [4].

In 2014, Cocchia proposed a literature review on the smart and digital city concepts source. It is claimed that depending on what is understood from word "smart", a different opinion about smart cities may exist source. In this work, the literature review was performed for smart and digital city concepts from 1993 to 2012, investigating how these words were emerged, and developed and what their similarities and differences were Afterwards, a literature review is proposed by performing five types of analysis: 1) Time analysis, 2) Terminology analysis, 3) Definition analysis, 4) Typology analysis, and 5) Geographic analysis [5].

Albino et al. proposed a literature review on smart cities by exploiting the definitions, dimensions, and initiatives of smart cities. Effort was made in order to clarify the meaning of the smart city concept, and identify the main aspects and dimensions of this concept through an in-depth literature review. Different metrics for smartness of a city were proposed so as to show the need for a globally approved definition for smart cities. Although identification of the main aspects of the smart city concept in this work has a similar goal to the first phase of our work, our proposed approach is not limited to this subject, and the second phase of our work has a considerable contribution to our main objective. In addition, the process of analysis in source has notable differences with the first phase of our approach [6].

Papa et al. proposed a literature review for providing urban planners with a perspective on smart cities. The authors consider some assumptions about what a smart city is, and then, based on those assumptions, provide a literature review on relations between ICT and city planning in eighties and nineties. Afterwards, they shift their focus on investigating the debates on smart cities in EU since 2000. Finally, this paper clarifies that, despite these efforts, a shared and common definition for smart cities is still missing and the authors believe that urban planning should play the key-role in coordination among these different meanings and definitions. Our work can be considered a support to solve the problem concluded in [7].

Zygiaris proposed a smart city reference model for assisting urban planners to plan for a specific smart city based on special characteristics of the city. Using this model, planners can define a conceptual layout for a smart city and describe its characteristics in various urban layers. It was assumed that urban planners know the special characteristics of their smart city and plan for such a city based on these characteristics. In contrast, our approach tries to help urban planners to determine a suitable set of characteristics of their smart city. In other words, the result of applying our approach to a specific city can be considered as the input for the approach of [8].

Chourabi et al. proposed an integrative framework for smart cities. Also, eight critical factors for smart cities that

shape the base of their framework were presented. These factors are "management and organization, technology, governance, policy context, people and communities, economy, built infrastructure, and natural environment". This framework can be used by city governors and planners for having a better vision of what they want as a smart city [9].

The problem statement in source is that, despite abundant literature on smart city theories and practices, there is no general and comprehensive understanding on what really connects the complex and multidimensional nature of smart city to desired results. Therefore, the authors try to intertwine the enablers and drivers into a multidimensional framework for smart cities. The paper provides a methodological approach to establish this connection. This approach is the same as ours in the way of including a systematic review of the literature on smart cities. After performing the literature review, the authors put smart city drivers into three groups: community, technology and policy; and then, link them to six outcomes of smart cities: productivity, sustainability, accessibility, well-being, livability and governance. All the drivers and outcomes shape the mentioned framework. The smart city framework presented in source can provide a conceptual understanding of the smart city notion [10].

Valdez et al. Show that the proposed roadmaps and frameworks for smart cities are mostly unrealistic and non-identical. They have studied a big smart city project in Milton Keynes, UK. The results show that the final outcomes of the project are very different from what roadmaps and frameworks have drawn up. Their conclusion and emphasis on having a specific roadmap for each city is a proof for our idea in this paper. Silva et al. in source consider smart cities as an application of the IoT notion. They believed that integration of ICT into cities brought up the concepts like telicity, information city, and digital city, and now, IoT is realizing smart cities. This paper also states that there is not a common understanding of smart cities and that is because it is an evolving concept [11-12].

Kummitha and Grutzen believe that approaches presented for planning smart cities are not thorough and do not cover all aspects. This defect in the field has been presented by a review of researches on smart cities, showing that the ideas of smart cities are very different and conflicting. It shows that understandings of smart cities are not very realistic to date. The method used in source aims to show that how smart cities differ in their meanings, intentions and offerings, which is another reason for having a specific definition for each individual smart city [13].

Wall and Stavropoulos state the need of considering city network characteristics of a smart city into its planning phase [14]. This is done through exploring the crossover between the smart city and the world city network literature. The emphasis on considering a set of characteristics in smart city planning is close to our idea.

Shokouhi et al. Tried to extract the most important factors of a smart city, studying on Ahvaz, a city in southern west of Iran. Their method was also based on reviewing the related literature. The authors have collected all criteria by using different resources based on descriptive-analytical methods. For the next step, they have asked about 40 urban planning experts to rank those criteria and sub-criteria with respect to Ahvaz and based on the Fuzzy TOPSIS technique. The focus of source was just on one city, Ahvaz [15].

3. THE METHODOLOGY OF THE PROPOSED APPROACH

In this section, we illustrate the overall methodology of the proposed approach. The details and results of each phase are presented in the subsequent sections. Fig. 4 shows the methodology of our approach performed in two phases.
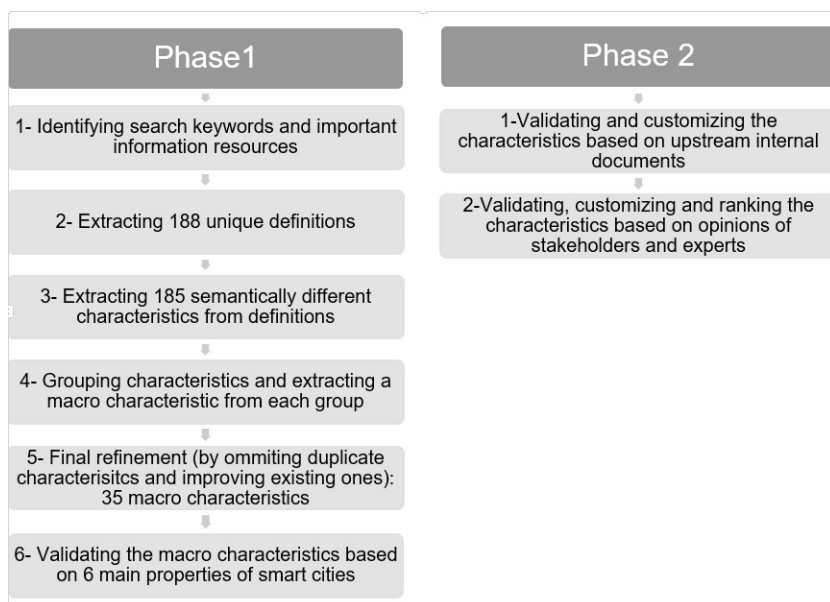

Fig. 4 The overall methodology

In phase 1, an initial list of characteristics (which are common across the globe) was extracted according to the following steps:

1. A set of search keywords Table 2 and a collection of creditable resources were selected.
2. The result of search on the selected resources was 188 unique definitions related to the smart city concept.
3. Smart city characteristics were extracted from these definitions based on a manual method.
4. The characteristics were grouped, and a macro-characteristic was assigned to each group. The main reason for this step was to reduce the number of characteristics and thus to decrease the time for the customization and prioritization in the second phase.

- IBM
- ITU
- FG-SSC
- Science direct
- Oracle
- Wiley online library
- Business dictionary
- Schneider electric
- Springer
- IEEExplore
- Toshiba
- The climate group
- Navigant research
- IDC
- Center for smart sustainable city innovation-Ernst & young
- PwC
- Deloitte services LP
- Think innovation
- Smart cities industry summit
- ResearchGate
- IEEE computer society

Table 2 shows the keywords used to search on the above mentioned resources

Table 2 Keywords for searching in the documents and resources

Smart Governance	Intelligent City
Smart Economy	Knowledge City
Smart Mobility	Sustainable City
Smart Environment	Talented City
Smart People	Wired City
Smart Living	Digital City
Urban	Eco-City
Metropolitan	Enhanced City
Town	Governance and growth
Municipal	Society and community
Citified	Environment and natural resources
Civic	Urban development and infrastructure
Mega-metropolitan	Smart Governance
Interurban	Civil

5. In the fifth step, we refined the macro-characteristics (by merging the overlapping ones and improving titles for better inclusion).
6. Finally, as the first validation step, each extracted main characteristic was mapped to at least one of the six main components of smart cities.

In order to perform the first step of phase 1, a considerable number of information sources, a portion of which is listed below, were identified so as to extract the existing definitions. The information sources included different resources, ranging from academic researches to available documents related to smart city projects or international prominent companies. These various sources were used for creating an acceptable collection of different viewpoints:

- Huawei Ltd
- Capgemini
- ABB, Fujitsu
- European investment bank
- Ericsson, European commission
- European energy award-Energie schweiz
- World bank blogs-Sustainable cities
- HBR blog network
- Fiberhome technologies group
- University of genoa
- Government of Italy
- FG-SSC-0014
- ITU focus group on smart sustainable cities
- International telecommunication union
- Fast company, Business standard
- Council for innovative research
- The online platform for Taylor & Francis group content

Each of the 188 unique definitions found as the result of this search was given weight according to the credibility of the information source in order to rank the extracted characteristics. Table 3 shows the basis of giving weights to the documents.

Table 3 Assigning credibility degree to each document[2]

Credibility Degree	Criterion
A	Documents after 2012 and from a creditable reference (journal, conference or even reliable company and project)
B	Documents before 2012 and from a creditable reference, and documents after 2012 and from a reference with less credibility
C	Documents before 2012 and from a reference with low credibility
B+	Creditable documents in 2012 or any documents that has a credibility between A and B for some reason
C+	Documents before 2012 and from a reference with medium credibility

Unlike the first phase, the second one should be separately carried out in each city. This phase helps city managers plan for smart city based on global trends, while satisfying local suggestions and limitations. The steps of this phase are:

1. The final characteristics from phase 1 must be validated and customized based on upstream documents of the target city.
2. The opinions of city stakeholders and experts should be applied to the result of the previous step in order to perform a further validation and customization step and also to prioritize the resulting characteristics.

Since the upstream documents (about the city management and planning, IT governance, etc.) of a city or country enforce and/or suggest some specific standards, policies, constraints and limitations for any plan in that city, the first step of phase two is performed through investigating the characteristics extracted from phase one in terms of upstream documents and policies of the target city. This investigation performs a step of validation and customization of the extracted characteristics; while a number of these characteristics will be supported by the upstream documents (and policies) and thus should be preserved, some of them may be removed or changed (to be more relevant in terms of the city goals and policies); also, regarding and analyzing the upstream documents, some new characteristics which are not reflected in the international resources and probably imply special concerns of the city may be added.

In the second step, the characteristics resulted from the first step will be validated, customized (by removing or updating some of the existing characteristics and adding some new ones) and ranked by city stakeholders and city experts. This step is done through distributing a suitable and clear questionnaire among stakeholders and experts and ask their opinion about the characteristics resulted from the previous step.

4. DETAILS AND RESULTS OF PHASE 1: COMMON CHARACTERISTICS

In step 3 of phase one, we investigated each obtained definition manually by the aim of extracting the main characteristic(s) of the smart city notion, stressed by that definition. Since our investigation was performed manually, we did not take just the syntax or wording of the keywords into consideration. Our approach used phrases instead of words, and considered the meaning and the context rather than the wording. Based on this investigation, 185 unique characteristics were extracted from the resulted definitions. This rather large number of characteristics forced us to group them in order to decrease the overwhelming process of customization and prioritization in the second phase for a target city.

We applied the fourth and the fifth steps of phase one in order to group the characteristics and to consider only one representative macro-characteristic per group. The result was 35 macro characteristics. Table 4 shows only a portion of grouping due to lack of space[3]. We put the logically related characteristics in one group so that each group would be presented as an understandable macro-characteristic. The first column of Table 4 shows these macro-characteristics, for each, we have shown the number of occurrences and the degree of credibility of its references. With this information, the degree of credibility was calculated for each group/macro-characteristic. It was revealed that each macro-characteristic was involved in at most three definitions.

Table 4 Characteristics grouping

Name of group	Candidate Characteristic	Number of occurrences	Credibility of reference		
			Ref 1	Ref 2	Ref 3
Information Integration & Technology Integration	Information integration	2	A	B	
	Combine diverse technologies	1	A		
	Optimized SOS	1	A		
Provide Inclusive, Diverse and Sustainable Urban Environment	Improve urban environment performance	1	B		
	High productivity of the urban environment	1	B+		
	Provide inclusive, diverse and sustainable urban environment	1	C		
	Improve Urban space quality	1	C		

The resulting macro-characteristics are illustrated in Table 5. In this table, in addition to the number of occurrences of each characteristic in definitions, the weight of the related resources Table 3 was also considered as the basis of ranking. The column of "Weight Formula" shows how to calculate the weight of a macro-characteristic. For instance, formula 5b1a5c+5c in the first row means that the corresponding characteristic has been found in five definitions with credibility degree of B, 1 definition with credibility degree of A, five definitions with credibility degree of C+, and five definitions with credibility degree of C.

Table 5 The resulted characteristics from step five of phase 1, Ranked by weight

Char code	Characteristic	Number of occurrences	Weight formula	Weight
CH1	Holistic & efficient services	16	5b1a5c+5c	11.5
CH2	Better & sustainable quality of life	13	8c3c+1a1b	8.7
CH3	Participatory governance	11	4c+4c3b	7.6
CH4	Develop IoT paradigm	11	5c+4c2b	7.5
CH5	Data integration & wired infrastructure	9	2a4c2b1c+	6.7
CH6	People participation	8	1a3c+2c2b	5.9
CH7	Investment in human & social capital	8	3b+1c+4c	5.8
CH8	Knowledge creation & sharing	7	5b1b+1c	5.5
CH9	Public learning & education	7	2b+3c2b	5.2
CH10	Maintain and improve natural & physical resources	7	6c1c+	4.3
CH11	Open data & services	6	2b2c+2c	4.2
CH12	Sustainable economic growth	6	1b3c+2c	4.1
CH13	Advanced logistics and transportation	6	5c1b	3.8
CH14	Quick & effective decision making	5	3c1a1b	3.6
CH15	Safe & secure life	5	1c+2c2b	3.5
CH16	Real-time monitoring & analysis	5	2b2c1c+	3.5
CH17	Innovative business models	4	3b1b+	3.3
CH18	Healthier & happy community	5	1b4c	3.2
CH19	Diverse and sustainable urban environment	4	1b1b+2c	2.9
CH20	Intelligent personalized (customized) services	4	4c	2.4
CH21	Reduce CO_2 emission	3	1b2c	2
CH22	Apply modern technologies	3	1b2c	2
CH23	Standardization	3	2c+1c	2
CH24	Improve urban & real-estate construction	3	3c	1.8
CH25	Reduce poverty & inequality	3	3c	1.8
CH26	Innovative strategic planning	3	3c	1.8
CH27	Collaborative services (interoperability among policy makers)	2	1a1c	1.6
CH28	Produce VAS & information	2	1b1c+	1.5
CH29	Smart citizens & communities	2	1c+1b	1.5
CH30	Democracy	2	1c1b	1.4
CH31	Managed reproducible energies	2	2c	1.2
CH32	Reduce bureaucratic processes	2	2c	1.2
CH33	People attraction	2	2c	1.2
CH34	Integrate & monitor critical infrastructures	1	1b	0.8
CH35	Improve all physical, IT, Social, Business infrastructures	1	1b	0.8

An initial validation of macro-characteristics was performed in the sixth step of this phase through mapping these characteristics to the six main components of smart cities. This mapping has also another important application: since each city will rank the resulting characteristics in the second phase, an estimated ranking of the six main components for the target city will be indirectly obtained. Based on this ranking, urban managers and planners can prioritize city projects more effectively. Part of this mapping is presented in Table 6[4]. Since some of the characteristics may be mapped to more than one component, we used percentage of relativity to each related component. In most cases, the percentages are specified approximately since they will not affect the final results considerably. Furthermore, it is not possible to determine the accurate values of percentages at all.

Table 6 Mapping characteristics to the six main components of smart cities

Char code	Component (percentage of relativity)
CH1	Smart governance (18 percent)
	Smart economy (18 percent)
	Smart mobility (18 percent)
	Smart environment (18 percent)
	Smart living (10 percent)
	Smart people (18 percent)
CH2	Smart living (25 percent)
	Smart governance (15 percent)
	Smart economy (15 percent)
	Smart mobility (15 percent)

Char code	Component (percentage of relativity)
CH3	Smart environment (15 percent)
	Smart people (15 percent)
	Smart governance (80 percent)
	Smart people (20 percent)
CH4	Smart mobility (30 percent)
	Smart governance (15 percent)
	Smart economy (15 percent)
	Smart environment (15 percent)
	Smart living (15 percent)
	Smart people (10 percent)

It should be noted that the resulting 35 characteristics may change during time and as a result of changes in technologies and standards on one hand, and issues of cities on the other hand. These changes will be accordingly reflected in international resources and can be considered by the same approach again.

5. DETAILS AND RESULTS OF PHASE 2 THROUGH A CASE STUDY

In order to present the details of the second phase, and also, so as to show the applicability of the proposed approach, the application of our approach to the city of Tehran is illustrated in this section.

Based on the article 128 of the "Second Five-Year Plan of Tehran municipality (2014-2018)" [16], the development of the "ICT master plan for Tehran city management" is required. Underway preparing this plan, we as the executive team, responsible for the ICT master plan, were able to apply the second phase of our proposed approach to the city of Tehran. This enabled us to have a wide access to upstream documents of Tehran (to perform step one of the second phase) and to participate in multiple meetings with stakeholders and experts (to perform step two of the second phase).

In the rest of this section, we demonstrate the results of application of our approach to extract the main characteristics desired by Tehran municipality and other stakeholders.

5.1. Validation and customization of the extracted characteristics based on the local upstream documents of Tehran and Iran

This step of validation and customization was to map the extracted characteristics to the internal upstream documents. We performed this step to assure that the extracted characteristics were completely compatible and in line with the upstream documents (for I.R. Iran and Tehran). Also, this step helped us add new characteristics which are not reflected in the international resources and thus have not been resulted during our systematic review, but are emphasized in the national upstream documents. This mapping was done to 18 important upstream documents like Iran 20-year vision, the fifth five-year plan of Iran, the ICT master plan of Iran, the ICT master plan of

Tehran, the e-government master plan of Iran and the second five-year plan of Tehran Municipality. Due to lack of space, we only present a part of the mapping to the second five-year plan of Tehran Municipality Table 7 Also, shows relation between top level goals of Tehran IT Master Plan and some of the extracted characteristics. It should be noted that this table is not used to validate all characteristics, but to show that the main goals of Tehran IT Master Plan are covered by the extracted characteristics [16-20].

Fortunately, only two characteristics, i.e., Develop IoT Paradigm and Managed Reproducible Energies, are not explicitly covered in the mentioned upstream documents. However, both of them are among the characteristics of smart cities. The IoT concept is the most important technological difference between smart city and other related concepts (especially, digital city). Fig. 5 shows this difference in a schematic way. In the view of smart cities based on digital cities, a digital city provides infrastructures like GPS, GIS and similar technologies, connects and digitalizes all economic, social, cultural, and other aspects of a city. In the next step, a smart city uses these results and creates a visual, quantitative and smart city management.
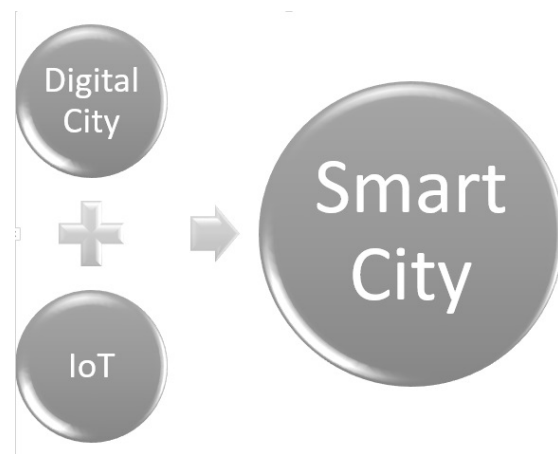

Fig. 5 Difference between smart and digital cities

The lack of the IoT technology in the upstream documents is understandable because IoT is a relatively new technology. On the other hand, reproducible energies

have also an important role in green and smart cities (especially, in the smart environment component). In developing countries like Iran, issues like CO_2 reduction, greenhouse gasses, and environment protection are recently trending. Therefore, it is also natural that this characteristic is also missing in the upstream documents.

Interesting points are found when trying to validate some of the characteristics, individually, for Tehran. The first characteristic in Table. 5 had been used as the title of the first issue in the IT Charter of Tehran Municipality (in the title of "presenting appropriate information and services to citizens and passengers in anytime and any location with proper methods"). The point is that this charter has been extracted from Iran 20-year Vision and confirmed by the former informatics council of Tehran municipality. The second characteristic, "Better & Sustainable Quality of Life", is the issue that should be considered in the vision of all cities in world, according to the recommendation of European Union [1]. The third characteristic, Participatory Governance, is recommended in paragraph D of article 122 and paragraph B of article 123 in the second five-year plan of Tehran municipality.

The eighth characteristic, "Knowledge Creation & Sharing", is validated by the document "Tehran 2025" (related to the Tehran 20-year vision) that states creating knowledge-based processes is considered the basis of transition from digital city to smart city. Furthermore, turning Tehran to a knowledge-based, smart and global city, is explicitly mentioned in Tehran 2025 and article 125 of the second five-year plan of Tehran municipality.

As another example, the fourteenth characteristic, "Quick & Effective Decision Making", is stressed on in paragraph 4 of Tehran Municipality IT Charter. Paragraphs H and K of article 129 of the second five-year plan of Tehran municipality emphasize on the fifteenth characteristic, "Safe & Secure Life". Characteristic number 23, "Standardization", is important because standardization of methods in all activity areas and using new technologies and executive methods are emphasized in the second five-year plan of Tehran municipality. As another example, characteristic 27, "Collaborative Services" (interoperability among Policy Makers), is mentioned in article 127 of the second five-year plan of Tehran municipality. Characteristic number 33, "People Attraction", is also one of five values in the IT Master Plan of Tehran Municipality [22]. As the final example, it should be noted that the eleventh characteristic, Open Data & Services, is supported by different articles of "Data Publication and Open Access" law of Iran.

Table 7 Mapping the characteristics to the second five-year plan of Tehran municipality

Char code	Spot in the plan	Equivalent term in the plan
CH1	Page 32	Organizing city services of Tehran
CH7	Page 182	Promoting human capital of city management regarding knowledge, specialty, skill, potentiality and qualifications
CH9	Page 52	Enabling citizens
CH15	Page 27	Providing security for Tehran as the capital of country
	Page 20	Tehran; safe and resistant city against accidents
CH16	Page 190	Software development of Tehran observatory center in order to city management level monitoring, analysis and decision making and content development of this center in GIS context
CH18	Page 20	Tehran; joyful, happy and lively city
	Page 52	Paying attention to city calm and health
CH20	Page 124	Suitable (customized) answer to citizens' requirements of city services
CH21	Page 96	Compatibility of transportation systems with the environment cleanness
CH23	Page 182	Standardizing all methods in all activity areas and emphasizing on using new executive methods and technologies
CH24	Page 30	Promoting city environment quality and efficiency by zoning lands and organizing constructions with different applications
	Page 33	Improving, modernization and reconstruction of Tehran distressed areas
CH34	Page 241	Smart monitoring and control of Tehran borders
CH35	Page 20	Tehran; a city with appropriate infrastructure
	Page 109	Using smart systems and infrastructure in transportation management

Table 8 Relation between top level goals of Tehran IT master plan and some of the extracted characteristics

Characteristic	Spot in the plan	Equivalent term in the plan
Holistic & Efficient services	Page 32	Organizing city services of Tehran
Investment in Human & Social Capital	Page 182	Promoting human capital of city management regarding knowledge, specialty, skill, potentiality and qualifications
Public Learning & Education	Page 52	Enabling citizens
Safe & Secure Life	Page 27	Providing security for Tehran as the capital of country
	Page 20	Tehran; safe and resistant city against accidents
Real-time Monitoring & Analysis	Page 190	Software development of Tehran observatory center in order to city management level monitoring, analysis and decision making and content development of this center in GIS context
Intelligent Personalized & Customized Services	Page 124	Suitable (customized) answer to citizens' requirements of city services
Reduce CO2 Emission	Page 96	Compatibility of transportation systems with the environment cleanness

Characteristic	Spot in the plan	Equivalent term in the plan
Healthier & Happy Community	Page 20	Tehran; joyful, happy and lively city
	Page 52	Paying attention to city calm and health
Improve Urban & Real estate Construction	Page 30	Promoting city environment quality and efficiency by zoning lands and organizing constructions with different applications
	Page 33	Improving, modernization and reconstruction of Tehran distressed areas
Standardization	Page 182	Standardizing all methods in all activity areas and emphasizing on using new executive methods and technologies
Integrate & Monitor Critical Infrastructures	Page 241	Smart monitoring and control of Tehran borders
Improve all Physical, IT, Social, Business infrastructures	Page 20	Tehran; a city with appropriate infrastructure
	Page 109	Using smart systems and infrastructure in transportation management

During the investigation of the local upstream documents, it was known that 7 related characteristics were emphasized in the local documents while they have not been covered in the characteristics extracted through phase 1. Thus, they were added to the characteristics list. This step ensured that the local and specific characteristics and issues of Tehran were included. The new 7 characteristics were namely:

1- CH36: Development based on Iranian/Islamic identity & culture,
2- CH37: Considering principles and moral aspects of people, organizations and society,
3- CH38: Legitimacy and respecting laws,
4- CH39: Development based on sublime art and architecture,
5- CH40: Changeability and adaptability,
6- CH41: Introducing Tehran as an international city
7- CH42: Improving the tourism industry

5.2. Validation, customization and prioritization of the extracted characteristics by applying stakeholders and experts' opinions

For gathering the opinions of city experts and stakeholders for further validation and customization of the extracted characteristics, and also, for ranking them in terms of Tehran goals and priorities, some meetings were held with people mentioned in Table 9.

Table 9 Participants in the meetings

Number of Participants	Role	Row
9	Management board members and deputy directors of Tehran Municipality ICT Organization	1
3	Delegates from Tehran municipality deputies (deputy for technical and development, planning and development, economy and finance, transportation and traffic, etc.)	2
2	Strategic consultants of the Tehran mayor	3
8	IT directors of municipality areas	4
10	Delegates from municipalities of Tehran 22 districts	5
25	Delegates from Tehran municipality organizations (sports, Urban Renewal, Waste Management, etc.) and delegates from subsidiary companies (Tehran Traffic Control Company, Milad Tower Company, Office Services Company, etc.)	6

The selection of stakeholders and experts was based on the set of potential stakeholders introduced in [23]. In the meetings, a questionnaire dispensed among the stakeholders and experts in order to acquire their opinions. For the individuals who could participate in our meetings, a briefing was presented including smart city concepts, and the method for characteristics' extraction and validation. For the others who could not attend to the meetings, we prepared a detailed document, consisting of the above briefing sent through the municipality automation system. We put each characteristic in one row of the questionnaire and asked each person to assign qualitative degrees of A through E to those characteristics. The definition of these degrees is as follows:

- A (vital): Based on Tehran issues and priorities, considering the characteristic is vital. In other words, disregarding the characteristic, Tehran smart city plan would face certain shortcomings.
- B (high priority): Based on Tehran issues and priorities, ignoring the characteristic would introduce some risks when designing Tehran smart city action plan.

- C (mediocre priority): Tehran smart city action plan is valid without considering the characteristic and there is no risk in using this plan. However, the quality of the plan may be decreased.
- D (low priority): Tehran smart city action plan is still valid without the characteristic, there will be no risk in using this plan, and the quality is not affected; but it is better to consider it.
- E (no priority): There is no need to consider the characteristic.

In accordance to this questionnaire, points -1, 1, 2, 3 and 4 were assigned to E, D, C, B and A choices, respectively. Furthermore, a specific weight was assigned to choices of each category of stakeholders. For instance, choices of management board members of Tehran Municipality ICT Organization, strategic consultants of the Tehran mayor, and deputy mayors had the most weight. Average score (from 1) and rank of each characteristic from the viewpoint of experts and stakeholders are presented in Table 10 Characteristics are ranked according

to the weight gained from the process of phase 1.

Finally, Tehran municipality decided to take the main goals and characteristics of the Tehran smart city plan as characteristics that got a score above 3 in the process of phase 1 and ranked lower than 10 from questionnaires dispensed among experts and stakeholders:

1. Providing Holistic & Efficient services: Providing software and business services for different layers including city, citizenship, organizational, economic, cultural, etc. with public and private access allowance.
2. Data Integration & Wired Infrastructure: Providing integrated and standard data and information space and providing integrated and reference-model-based ICT infrastructure.
3. Better and sustainable quality of life: Increasing life quality through sustainable improvement of aspects like economy, cooperative governance, advanced urban services, etc.
4. Quick & Effective Decision Making: Making fast, correct and effective decisions based on data analysis (in daily decisions and in decisions made when disasters like earthquakes, floods, etc. occur)

5. Advanced logistics and transportation: Using new technologies for continues improvement of transportation infrastructure and related processes.
6. People Participation: Engagement of people in city and citizen services.
7. Safe & Secure Life: Building safe, healthy and continually monitored city and lifestyle.
8. Real-time Monitoring & Analysis: Creating infrastructures for real-time analysis and monitoring of flowing data among city and citizen systems.
9. Investment in Human & Social Capital: Extracting more knowledge, providing more services, getting feedback and better navigation of city management through citizens, themselves.

Since number 8 (real-time monitoring & analysis) is a prerequisite for number 4 (quick & effective decision making) and is thus anyway required to realize number 4, Tehran municipality removed number 8 and added two new characteristics (to have 10 main characteristics): "Collaborative Services (interoperability among policy makers)" (ranked 4 by experts and stakeholders) and "Reduce CO2 Emission" to the list of main goals.

Table 10 Weights and ranks of characteristics based on stakeholders' point of view

Rank from stakeholders' point of view	Score from stakeholders' point of view	Weight from systematic review	Char Code
1	1	11.5	CH1
3	0.93	8.7	CH2
14	0.76	7.6	CH3
16	0.74	7.5	CH4
2	0.98	6.7	CH5
8	0.82	5.9	CH6
10	0.8	5.8	CH7
17	0.73	5.5	CH8
13	0.77	5.2	CH9
13	0.77	4.3	CH10
27	0.57	4.2	CH11
18	0.71	4.1	CH12
6	0.85	3.8	CH13
5	0.86	3.6	CH14
8	0.82	3.5	CH15
9	0.81	3.5	CH16
26	0.58	3.3	CH17
17	0.73	3.2	CH18
24	0.6	2.9	CH19
24	0.6	2.4	CH20
7	0.83	2	CH21
12	0.78	2	CH22
20	0.68	2	CH23
23	0.61	1.8	CH24
25	0.59	1.8	CH25
11	0.79	1.8	CH26
4	0.88	1.6	CH27
15	0.75	1.5	CH28
10	0.8	1.5	CH29

Rank from stakeholders' point of view	Score from stakeholders' point of view	Weight from systematic review	Char Code
25	0.59	1.4	CH30
18	0.71	1.2	CH31
17	0.73	1.2	CH32
17	0.73	1.2	CH33
7	0.83	0.8	CH34
10	0.8	0.8	CH35
21	0.64	-	CH36
22	0.63	-	CH37
15	0.75	-	CH38
29	0.41	-	CH39
19	0.69	-	CH40
20	0.68	-	CH41
28	0.55	-	CH42

6. CONCLUSIONS AND FUTURE WORK

In this paper, we proposed a new approach for extracting smart city characteristics for each particular city, applicable for any city willing to become smart. Some of applications of these characteristics are as follows:

- The characteristics can be considered a main input for the strategic planning of a city. Especially, the vision, mission, goals, policies and values of a smart city are mainly affected by its special characteristics derived based on the proposed two-phase approach.
- These characteristics help aligning the main goals of the city management based on the smart city concept.
- These characteristics may be used for prioritizing the six main components of smart cities for a specific city. Based on this, city managers and city planners can prioritize city projects more effectively.

In the first phase of the proposed approach, 35 general characteristics of smart cities were extracted Table 5. Also, an initial validation of these characteristics was performed in this phase via mapping these characteristics to the six main components of smart cities. In order to illustrate the second phase as well as showing the usability of our approach, we applied this approach to Tehran. The first result of this study has been 10 customized, validated and ranked characteristics for future Smart Tehran. These characteristics are considered the main inputs to align Tehran urban management goals and to define ICT projects and other smart city related projects in Tehran. In addition, these characteristics had two other applications:

1. As mentioned in Section 4, the extracted characteristics were mapped to the six components of smart cities Figure. 3 through step 6 of the first phase Table 6. Regarding the ranking of characteristics conducted in the second phase, city planners can have an estimated ranking of the six main components (and therefore, the related city projects) for the under study city. Following a same approach, we prioritized the six main components of smart cities for Tehran as follows:
   a) Smart economy

   b) Smart mobility
   c) Smart living
   d) Smart governance
   e) Smart people
   f) Smart environment

2. The resulting characteristics have been considered one of the main inputs for ICT strategic planning of Tehran. Due to the lack of space and in order to preserve the focus of the paper, the details of this strategic planning were not presented. But it should be noted that the main components of the strategic plan, i.e., mission, vision and values, involve the highly ranked characteristics as follows:

- Mission: Changing Tehran urban management approach based on engagement of people and providing integrated and adaptive technological solutions for all urban services with the aim of increasing the quality of life and gaining values for all stakeholders through providing efficient and ubiquitous access to services and facilities in all operational domains of Tehran.
- Vision: Tehran, a sustainable, ubiquitous and citizen-centric global city.
- Values
- Providing holistic, integrated and efficient services for citizens.
- Providing open and transparent data.
- Sustainable development.
- Quick and efficient decision making.
- Realizing knowledge-based society based on social capital.
- Better and sustainable quality of life.
- Safe and secure life.
- Citizen-centricity.

Having the proposed approach in hand, we can mention the following items as our future works:

- Integrating our approach with the existing known methods for city strategic planning.
- Proposing a framework for smart cities, based on the extracted characteristics.

- Proposing a method for identifying main infrastructure requirements of a smart city, based on the extracted characteristics.

NOTE

1. https://www.worldatlas.com/citypops.htm
2. Our method for this ranking has been adopted from the method presented in https://www.college.columbia.edu/academics/integrity-sourcecredibility
3. The full table of grouping is provided at http://ticksoft.sbu.ac.ir/upload/PDF/Characteristics.pdf
4. The full table of mapping is provided at http://ticksoft.sbu.ac.ir/upload/PDF/Characteristics.pdf

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

REFERENCES

1. Nam T, Pardo TA. Conceptualizing smart city with dimensions of technology, people, and institutions, in Proceedings of the 12th Annual International Digital government Research Conference: Digital Government Innovation in Challenging Times, ACM, 2011.
2. Cohen B. The smart city wheel. 2013 [cited 2018 September 9, 2018]; Available from: https://www.smart-circle.org/smartcity/blog/boyd-cohen-the-smart-city-wheel/.
3. Giffinger R, Fertner Ch, Kramar H, Meijers E. City-ranking of European medium-sized cities. Cent. Reg. Sci. Vienna UT, 2007, pp. 1-12.
4. Technical report on smart sustainable cities: An analysis of definitions, International Telecommunication Union (ITU-T), Focus Group on Smart Sustainable Cities (FG-SSC), United Nations, 2014.
5. Cocchia A. Smart and Digital City: A Systematic Literature Review, in Smart City, Springer, 2014, pp. 13-43.
6. Albino V, Berardi U, Dangelico RM. Smart cities: Definitions, dimensions, performance, and initiatives, Journal of Urban Technology, 2015, Vol. 22, No. 1, pp. 3-21.
7. Papa R, Gargiulo C, Galderisi A. Towards an urban planners' perspective on smart city, TeMA Journal of Land Use, Mobility and Environment, 2013, Vol. 6, No. 01, pp. 5-17.
8. Zygiaris S. Smart city reference model: Assisting planners to conceptualize the building of smart city innovation ecosystems, Journal of the Knowledge Economy, 2013, Vol. 4, No. 2, pp. 217-231.
9. Chourabi H, Nam T, Walker Sh, Gil-Garcia JR, Mellouli S, Nahon K, Pardo TA, Jochen Scholl H. Understanding smart cities: An integrative framework. in System Science (HICSS), 2012 45th Hawaii International Conference on IEEE, 2012.
10. Yigitcanlar T, Kamruzzaman Md, Buys L, Ioppolo G, Sabatini-Marques J, Costa EM, Joseph Yun J. Understanding 'Smart cities': Intertwining development drivers with desired outcomes in a multidimensional framework, Cities, 2018.
11. Valdez AM, Cook M, Potter S. Roadmaps to utopia: Tales of the smart city, Urban Studies, 2018: p. 0042098017747857.
12. Silva BN, Khan M, Han K. Towards sustainable smart cities: A review of trends, architectures, components, and open challenges in smart cities, Sustainable Cities and Society, 2018, Vol. 38, pp. 697-713.
13. Kummitha RKR, Crutzen N. How do we understand smart cities? An evolutionary perspective, Cities, 2017, Vol. 67, pp. 43-52.
14. Wall R, Stavropoulos S. Smart cities within world city networks, Applied Economics Letters, 2016, Vol. 23, No. 12, pp. 875-879.
15. Shokouhi MA, Naghibirokni SN, Alizadeh H, Ahmadi A. Evaluation of smart city criteria in ahvaz city, Iran, International Journal of Architectural Engineering and Urban Planning, 2016, Vol. 26.
16. Second Five-Year Plan of Tehran Municipality (in Farsi), Tehran Municipality, 2014.
17. Final Document for 20-Year Vision I.R.Iran (in Farsi), Government of Iran, 2005.
18. General Policies of Fifth Five-Year Development Plan of I.R.Iran (in Farsi), Government of Iran, 2010.
19. Iran ICT Master Plan (In Farsi), Government of Iran, 2007.
20. Management Summery of IT Master Plan of Tehran as a Global City, with an Informational Approach (Tehran 2025) (in Farsi), Tehran City Council, Think Tank for Industry and Technology, 2007.
21. Document for Master Plan of E-government in I.R.Iran (2011 to 2015) (in Farsi), Government of Iran, 2010.
22. Kargari MZ. Tehran Municipality ICT Master Plan, Iran Science and Technology University, 2005.
23. Setting the stage for stakeholders' engagement in smart sustainable cities, ITU-T Focus Group on Smart Sustainable Cities, 2015.

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