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Evaluation of the smart city: Applying the dematel technique

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ABSTRACT

The smart city is a growing multi-dimensional and systematic urban model that offers smart, technological, and sustainable solutions for urban challenges and is separated into various conceptual main and sub-dimensions. In this paper, the smart city concept is addressed by developing a hybrid methodology consisting of two phases. In the first phase, a qualitative analysis is established to determine the smart city concept. In the second phase, the DEMATEL (Decision Making Trial and Evaluation Laboratory) technique is used to examine smart city focusing on the dimensions derived from the literature in the form of six main and 33 sub-dimensions. Data is collected by contacting ten academia experts through a questionnaire specifically designed; open-ended questions and DEMATEL technique assessments. Results indicated that both phases had different outputs. While technology was highlighted and possible managerial issues emerged in the qualitative section, on the contrary, in the quantitative section, 'smart people' has emerged as the most important predictor of the smart city while 'smart governance' was the least. By the DEMATEL, not only the most and the least important dimensions within each group revealed but also the causer and receiver effects of each dimension. Further, the results and implications of the study are discussed.

1. Introduction

More than half of the world population lives in cities today (UN, 2019). Increasing population growth, particularly in the urban area, causes many challenges towards urban sustainability (Abdullah and Rahim, 2020; Rana, 2011; Rosenzweig et al., 2010). Correspondingly, like smart city, some new urban approaches, which have promoted alternative models for creating sustainable human settlements, have emerged in recent years (Cugurullo, 2018; Hollands, 2008). The smart city is a conceptual urban development approach depending on the employment of human, collective, and technological capital to enhance urban development and prosperity (Angelidou, 2014). In other words, being smarter increases the capabilities of cities in response to potential future urban challenges.

Consequently, the concept of a smart city has gained increasing attention worldwide, particularly in cities in which a large population of people living (Al-Nasrawi et al., 2015). It is a matter of exploration, such as the urban population lives in medium-sized cities, while most research focuses on the metropolises. Respectively, there is competitiveness and sustainable development in medium-sized cities (e.g., European cities) and global smart cities. However, the challenges and drivers for being smart needed to be identified in terms of strengths and weaknesses for better comparison between cities and adapting eligible strategies to become smarter.

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Although smart city concept has become a popular term, there is no consensus about what smartness means or how to identify its key characteristics in the literature. Besides the popularity of the term, awareness and applicability issue still remains in question. Some studies focus on technology and data, while others are interested in sustainability, innovation, resiliency, and openness (Gil-Garcia et al., 2016). From a general perspective, there exist a number of studies intended for identifying key dimensions of smart city, such as Fusco Girad et al. (2009), Giffinger et al. (2007), Lombardi et al. (2012), Nam and Pardo (2011a), Washburn et al. (2010). Some researchers measure the level of urban smartness within the dimensions of the smart city (Giffinger et al., 2007; Giffinger and Gudrun, 2010; Shen et al., 2018). Although there is a growing number of literature focusing dimensions of smart city, a rare number of studies tend to determine the importance ranking of dimensions as well as reveal the relationships between them.

In terms of dimensional perspective, criteria or sub-criteria (or domains/sub-domains) are assumed to be important and influencing each other. Also, the degree of influence for each of them may differ. In other saying, each domain is presented that has its own degree of influence or weight (Abdullah and Rahim, 2020). However, the importance of dimensions and sub-dimensions is generally neglected in studies of smart cities. In this sense, the authors observe a gap in the smart city's present literature and address it empirically. Additional to awareness and applicability of what is smartness, it is imperative and significant to contribute to the current literature answering two following questions, too:

(1) What is the importance ranking of smart city dimensions/sub-dimensions?
(2) What are the relationships between the dimensions/sub-dimensions?

The answers to the above questions allow us to understand the importance of dimensions and realize the relations in between. To bring more rational and realistic approaches to smart city evaluation can be regarded as a contribution. In that regard, a hybrid approach containing qualitative and quantitative phases was developed. The data required was collected by semi-structural questions to reveal expert perceptions to check the significance. In the qualitative phase, the questions about the awareness and applicability of the concept of smart city have been prepared. These questions were asked to a group of 10 academicians with expertise in urbanization. The reason that to have chosen medium-sized cities is due to the preferences of Giffinger et al. (2007) in their original work. In the quantitative phase, Center of Regional Science, Vienna UT, in the October 2007 report of the smart city dimensions were chosen to evaluate (Giffinger et al., 2007). These dimensions were evaluated by DEMATEL (Decision Making Trial and Evaluation Laboratory) method. The relationships between the main dimensions and sub-dimensions were revealed, and their weights were calculated. By highlighting the priority of the dimensions, it also helps to analyze the cause and effect associations. From this point of view, one of the most important features of the DEMATEL method is that it is able to establish an explanatory model of relationships by determining the level of interaction and the degree of interaction between the criteria. The outline of the paper is as follows: Section 2 revises the relevant literature on smart cities and focuses on the definition, scope, and dimensions of the concept. The case illustration as Section 3 performs a literature review regarding dimensional perspective of the term sequencing to form a pattern for the DEMATEL. Section 4 outlines the methodology, the research design and describes questionnaire preparation and data collection. Section 5 presents the results of the study. Finally, Section 6 discusses, concludes, and provides the contributions of this paper.

2. Literature review

2.1. The concept of smart city

Cities have to compete in a new economic environment today. Growth, economic value, and competitive differentiation of urban areas depend on the skills of citizens, creativity, knowledge, and the creative and innovative capacity of the economy. A more citizen-centric approach for reaching the services, cities need to apply better-advanced information technology, analytics, and systems thinking. To improve their current and future service delivery capacities, they need to make their core systems (public safety, transport, government services, and health) 'smarter' (Dirks et al., 2010). Therefore, smart cities are getting more attention day by day from both policymakers and academics concerning urban studies. Many western cities have been increasingly influenced by discussions about smart cities as an 'urban labeling phenomenon'. There is a debate about what a smart city is (Albino et al., 2015; Bakıcı et al., 2013; Meijer and Bolivar, 2016) as there is no widely accepted definition (Tranos and Gertner, 2012; Zanella et al., 2014). On the other hand, the term the smart city is not being used holistically in the literature. Rather than, it is used regarding various aspects and many features of the city in general (Lombardi et al., 2012). To avoid confusion, a conceptualization of the smart city seems to be right. Nam and Pardo (2011a) do exactly that, and they conceptualize smart cities with various dimensions such as technology, people, and institutions. They customize three concepts as following, respectively: integration of infrastructures and technology-mediated services, social learning for strengthening human infrastructure, and governance.

Although many existing studies are defining the smart city, there is a range of conceptual variants that have been adopted by replacing 'smart' (for instance, intelligent or digital) (Alawadhi et al., 2012; Albino et al., 2015). For this reason, the domains proposed by Nam and Pardo (2011a), Nam and Pardo (2011b) can be utilized to take a systematic approach. In this sense, the first perspective of the smart city is related to the term 'technology'. Because of its power to transform life and work within an urban area in significant and fundamental manners, technology has a key role in being a smart city (Albino et al., 2015). Another technology-oriented definition is made by Washburn et al. (2010). According to them, the smart city is a city that uses smart computing technologies to make critical infrastructure components and services more efficient, intelligent, and interconnected. A further technology-driven and sustainability-driven definition belong to Barrionuevo et al. (2012). They define the smart city as a human settlement utilizing all available technology and resources in a smart and coordinated way to develop integrated, habitable, and sustainable. Hall (2000) also focuses on the

sustainability aspect of the smart city; the vision of a smart city is the urban approach of the future. It is secure, environmentally green, technologic, and efficient all urban structures.

Another perspective of the identification of a smart city is to focus on the 'human' dimension. The publications with a human dimension do not ignore technology but put the smart people in the center of the smart city. From the human resource perspective, human capital or human resources is the key feature of the smart city (Meijer and Bolivar, 2016). For instance, Hollands (2008) made a definition connected with the dimension of human resources, and he emphasizes human capital while defining the concept. According to him, the smart city has a complex structure and contains many features on-site. First of all, smart cities are settlements based on great learning and innovation capacity. They use these capacities in favor of the creativity of their populations, institutions of knowledge production, and their digital infrastructure for communication.

The dimension of governance is a further manner of defining a smart city, and it focuses on the interactions between stakeholders/shareholders in the 'community' (Meijer and Bolivar, 2016). For instance, Lindskog (2004) views the concept of the smart community holistically and defines it as a city which *"tries to incorporate all the possible aspects and parts involved outgoing from a geographically limited area such as a town, city or region and their citizens. This concept sets the community and citizens' needs in focus"*. As can be seen from this definition, the smart city activates the urban governance under the needs and demands of the stakeholders/shareholders in the urban area.

In addition to the categorization of Nam and Pardo (2011a) (the domains of technology, people, and institutions), a further tendency exists that defines the smart city over multiple dimensions. For instance, Giffinger et al. (2007) require identifying certain characteristics of a smart city for a further definition and propose six smart city domains: smart economy, smart people, smart governance, smart mobility, smart environment, and smart living. Within these domains, they define the smart city as "*a city well performing in a forward-looking way in these six characteristics, built on the 'smart' combination of endowments and activities of self-decisive, independent and aware citizens*". There are other definitions of the smart city. Table 1 shows some definitions of the concept:

With the enlightenment of the above discussions, it can be defined that the concept of a smart city is; human, technology, and institution oriented as well as multi-dimensional perspective in the literature. In this sense, to make a definition, the smart city may be defined as a governmental city that promotes creativity, social learning, and innovation to generate sustainable, technological, and smart solutions for the needs of urban stakeholders.

2.2. Dimensions of the smart city

Generally, the label of 'smart' is not attributed to a city entirely. It is separated in many characteristics of the city, which are singularly considered 'smart' (Albino et al., 2015; Lombardi et al., 2012). Moreover, the concept of a smart city varies according to actors and perspectives across the literature. These different perspectives are valid for cities because they have different objectives, focus, and variable contexts related to smart cities (Al-Nasrawi et al., 2015).

A respected volume of studies aims to identify the dimensions of the smart city across the literature (Giffinger et al., 2007; Lombardi et al., 2012; Nam and Pardo, 2011a; Washburn et al., 2010). For instance, Giffinger et al. (2007) identify the components of the smart city as follows: industry, education, participation, and technical infrastructure. According to them, a smart city is a multi-dimensional concept, and a definition requires identifying specific characteristics. They identify six domains of a smart city as a smart economy, smart people, smart governance, smart mobility, smart environment, and smart living.

Lombardi et al. (2012) have associated the six characteristics of the smart city with the regional and neoclassical theories of urban development and particularly based on theories of regional competitiveness, transport and ICT economics, natural resources, human and social capital, quality of life, and participation of citizens. In that context, each domain of smart city refers to a different urban activity, as can be seen in Table 2.

A further multi-dimensional study is carried out by Nam and Pardo (2011a), proposing three key components of the smart city: technology, people, and institutions. The technology dimension depends on the integration of infrastructures and technology-mediated services. It consists of some concepts from the literature: digital city, intelligent city, ubiquitous city, wired city, hybrid city, and

Table 1
Definitions of the smart city.

"A city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rail/subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens."	(Hall, 2000)
"A city well performing in a forward-looking way in these six characteristics, built on the 'smart' combination of endowments and activities of self-decisive, independent, and aware citizens."	(Giffinger et al., 2007)
"Territories with a high capacity for learning and innovation, which is built into the creativity of their population, their institutions of knowledge production, and their digital infrastructure for communication."	(Hollands, 2008)
"Smart city is a city that uses smart computing technologies to make critical infrastructure components and services more efficient, intelligent, and interconnected."	(Washburn et al., 2010)
"Smart cities will take advantage of communications, and sensor capabilities are sewn into the cities' infrastructures to optimize electrical, transportation, and other logistical operations supporting daily life, thereby improving the quality of life for everyone."	(Chen, 2010)
"Being a smart city means using all available technology and resources in an intelligent and coordinated manner to develop urban centers that are at once integrated, habitable and sustainable"	(Barrionuevo et al., 2012)
"A conceptual urban development model based on the utilization of human, collective, and technological capital for the enhancement of development and prosperity in urban agglomerations."	(Angelidou, 2014)

information city. On the other hand, the human dimension is relevant to social learning for strengthening human infrastructure. Besides, some concepts, like creativity, social learning, humane city, and knowledge city, have been associated with the human dimension. The last institutional dimension is related to governance for institutional improvement and citizen engagement, based on the smart community and stakeholders of the city.

Washburn et al. (2010) described the smart city as a collection of smart computing technologies applied to the seven critical infrastructure components and public services: city administration, education, healthcare, public safety, real estate, transportation, utilities. In that context, the main components of the smart city can be summarized as follows: an efficient and streamline urban management; a quality and low-cost education system; a rapid and available healthcare system; a real-time, rapid and secure public safety; a smarter real estate reduces operating costs, but increases the value and improves occupancy rates; a transportation system reducing traffic and encouraging public transportation; a utility of saving energy and water use as well as reduction of wastes.

3. Case illustration

There is a widespread acceptance in the literature that the smart city is multi-dimensional (Fusco Girad et al., 2009; Giffinger et al., 2007; Giffinger and Gudrun, 2010; Lombardi et al., 2012; Nam and Pardo, 2011a; Washburn et al., 2010). Other than those counted, there are many studies related to performance measurement in the smart cities (Al-Nasrawi et al., 2015). In comparison, the smart city's dimensions (or sub-dimensions) may not be of equal importance. So, one or more of them may be much more important than the others. Besides, the dimensions may be mutually affecting one another. For this reason, it is significantly essential to order the importance of dimensions/sub-dimensions and to reveal relationships between them.

Considering the smart city's multi-dimensional structure and the evaluation of smart performance at different dimensions, the need for multi-dimensional models emerges (Al-Nasrawi et al., 2015). As a multi-criteria decision-making method, DEMATEL is used to reveal the complex inter-relationships and address influences between the criteria (Chen and Chen, 2010). Therefore, it has been used in many studies, such as marketing strategies, control systems, safety problems, developing global managers' competencies, and group decision-making (Lee et al., 2013). On the other hand, it is utilized in selecting and as well as determining the relationships between the criteria. For instance, Chen and Chen (2010) have used DEMATEL to model complex interdependent relationships and establish a relationship structure using performance criteria for innovation evaluation.

On the other hand, it has been used in some studies in combination with the other methods. Büyüközkan and Güleryüz (2016) combined DEMATEL with ANP (Analytic Network Process) to select the most appropriate renewable energy resources. In a further study, Wu (2008) has used DEMATEL to choose knowledge management strategies by combining it with ANP. Furthermore, it is applied to make a selection between criteria related to dimensions of the smart city. To give an example, Wu and Chen (2021) proposed a structured method for project selection in smart cities. Research aiming to develop a selection mechanism of context-aware radio access technology for smart urban settlements is carried out by Habbal et al. (2019). Rad et al. (2018) used a hybrid method, including in DEMATEL, to assess ubiquitous cities with a methodological framework. In this paper, DEMATEL approach is used to determine the weights of the dimensions of smart city to reveal the internal relationship between the dimensions/subdimensions that affect each other and been affected by each other mutually. Identifying these unknowns allows us to highlight the relative importance of predictors of each dimension, leading the current knowledge and understanding of smart city as an emerging concept. The dimensions of the smart city were adapted from the Center of Regional Science, Vienna UT, in the October 2007 report are given in Table 3.

4. Solution methodology

This study's methodology has two folds: (1) qualitative phase and (2) quantitative phase based on MCDM. The hybrid methodology applied in the study is given in Fig. 1.

The participants are chosen from academics as a purposive sampling as the smart city is a novel issue and has great popularity in the related academic field. To reveal the awareness and the applicability issues, the authors purposively selected the participants from the academy as with the intention of they have detailed knowledge in theoretical and practical terms.

4.1. Qualitative phase

A hybrid approach is a research approach that includes integrating qualitative and quantitative data, allowing for a more comprehensive understanding of the research problem.

If smart cities' constructivism is qualified as a social problem, an approach to discover and understand the meanings attributed to

Table 2
Matching the domains of the smart city and urban activity.

Smart Governance	Participation
Smart People	Smart Human Capital
Smart Environment	Natural Resources
Smart Living	Quality of Life
Smart Economy	Competitiveness
Smart Mobility	Transport and ICT

adapted from Lombardi et al., 2012

Table 3
The dimensions of the smart city.

Smart City	Smart Environment	Attractivity of natural conditions
		Pollution
		Environmental protection
		Sustainable resource management
	Smart Economy	Innovative spirit
		Entrepreneurship
		Economic image and trademarks
		Productivity
		Flexibility of labor market
		International embeddedness
		Ability to transform
	Smart Governance	Participation in decision-making
		Public and social services
		Transparent governance
		Political strategies and perspectives
	Smart People	Level of qualification
		Affinity to life long learning
		Social and ethnic plurality
		Flexibility
		Creativity
		Cosmopolitanism/Openmindedness
		Participation in public life
	Smart Living	Cultural facilities
		Health conditions
		Individual safety
		Housing quality
		Education facilities
		Touristic attractivity
		Social cohesion
	Smart Mobility	Local accessibility
		National/International accessibility
		Availability of ICT-infrastructure
		Sustainable, innovative and safe transport systems

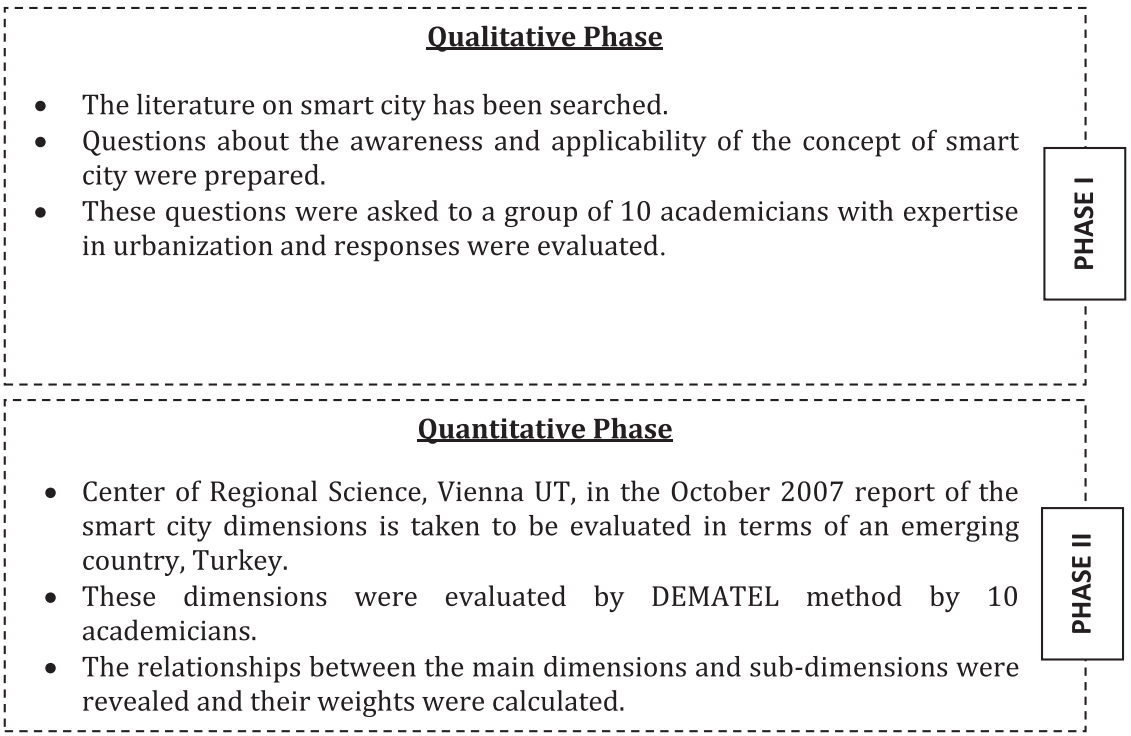


Fig. 1. Hybrid Methodology.

individuals and groups would be more appropriate. The qualitative approach is used in studies that emphasize the inductive style, focusing on individual understanding and interpreting its complexity.

The qualitative method facilitates the contextual linking of implicit and real thinking. By doing so, the researchers designed semi-structural interviews for a field and data-driven transformation. Adopting this technique, the researchers developed the questions and the process steps acquiring data from participants' own environments, making inductive data analysis by reaching themes from particular situations, and interpreting the data's meanings.

Hence, to corroborate the conceptual framework derived from the literature, six questions were asked to reveal expert perceptions to check the significance through the semi-structural interviews (lasting 20 to 30 min). During interviewees' selection, researchers aimed at experts to be with an urbanization background and interested in the subject smart city to be able to interpret the criteria in the later phase. During the interviews, in an open manner, each interviewee was asked to speak briefly about what they think about a smart city and the first thing that comes into their mind. By doing so, authors could check any difference between the smart city in the minds and the smart city identified with the factors according to the theoretical background. Determining the concept's awareness depending on the novelty would also help determine the social logic that enlightens the future adoption strategies to overcome the possible bias and plan the spread of definition more accurately. Strategically, this would also help practitioners and policymakers in resource allocation before implementing the strategy.

According to the study's main research questions, one researcher has interpreted responses to form a conventional interpretation, dividing responses into thematic categories. The main interest was finding out the meaning and awareness of smart city as a novel concept. The questions consisted of the following main subjects: (1) smart city as a concept, (2) differentiation of smart city from other smart approaches, (3) possible factors/criteria for smart city, (4) smart city as a solution, (5) the efficacy of smart city implementations around the world and the country-specific.

4.2. Quantitative phase

The DEMATEL (The Decision Making Experiment and Evaluation Laboratory) is the approach that creates a structural model to analyze the effects between complex factors in Geneva in 1973 (Muhammad and Cavus, 2017; Shieh et al., 2010).

The DEMATEL methodology is summarized below (Fontela and Gabus, 1976; Wu, 2008):

Step1: Creating the Direct Relationship Matrix

x_{ij}^{k} integer score k. given by an expert. This score shows the effect level of criterion i on the criterion j. The nxn matrix A, as shown in Eq. (1), is calculated by taking the average of the individual scores of the experts. The DEMATEL binary comparison scale used is given in Table 4.

$$a_{ij} = \frac{1}{H}\sum_{k=1}^{H} x_{ij}^{k} \tag{1}$$

H: Total number of experts

Step2: Creating the Normalized Direct Relationship Matrix

Normalized direct relationship matrix (X) is obtained by using direct relationship matrix (A) with the help of Eq. (2).

$$X = k \cdot A \tag{2}$$

$$k = \frac{1}{max\sum_{\substack{j=1 \\ 1\leqslant i\leqslant n}}^{n} a_{ij}}, \quad i,j = 1,2,\ldots,n \tag{3}$$

Step 3: Creating the total effect matrix

The total effect matrix (T_C) is obtained using the direct relation matrix (X), which is normalized with the help of Eq. (4). I refer to the unit matrix.

$$T_C = X(I - X)^{-1} \tag{4}$$

Step 4: Obtaining the causal diagram

The sum of rows and columns Eq. (5) is calculated separately using vector R and vector C as Eqs. (6) and (7).

The horizontal axis (C + R), then called "significance," is made by adding R to C, which reveals how important the criterion is. Similarly, the vertical axis (C-R) named "relation" is made by subtracting C from R.

Table 4
DEMATEL pairwise comparison scale.

Numerical Value	Definition
0	Ineffective
1	Low Impact
2	Moderate Impact
3	High Impact

$$T = \left[t_{ij}\right]_{nxn},\ i,j = 1,2,\ldots,n \tag{5}$$

$$R = \left[\sum_{j=1}^{n} t_{ij}\right]_{nx1} = \left[t_i\right]_{nx1} \tag{6}$$

$$C = \left[\sum_{i=1}^{n} t_{ij}\right]_{1xn} = \left[t_j\right]_{1xn} \tag{7}$$

Step 5: Creating the network relationship map

A threshold value has to be determined to create the network structure using the total effect matrix. After the threshold value is determined, in the total effect matrix, cell values equal to or above this threshold value show the relationships between criteria and the direction of these relationships. Various methods can determine the threshold value. This study determined it by taking the average of the elements in the total effect matrix.

Step 6: Determining the weights of the factors

While determining each factor's weight (wi), Eq. (8) is used below, and Eq. (9) is used for normalizing these weights.

$$w_i = \sqrt{(R_i + C_i)^2 + (R_i - C_i)^2} \tag{8}$$

$$W_i = \frac{w_i}{\sum_i^n w_i} \tag{9}$$

5. Results

5.1. Qualitative results

As it is aimed to elicit the interviewees' rationales for smart city concepts according to the interviews, the qualitative results shed light on the term's controversial structure. The thematic categorization addressed perceptions a priori to choice and decision mechanisms to foresee that what is currently in mind differs from reality.

(1) (2) *How can you describe the term smart city and differentiate it from other smart approaches for cities?*

According to interviewees, when describing the term smart city, the use of technology has burst as the most emphasized and repeated theme. Table 5 summarizes the thematic categories, from most prominent to least; technology, sustainability, participation, innovation, people-friendliness, ecology.

Before the quantitative phase, evaluating the criteria about smart city derived from literature, the current picture as the *technology* itself is a significant theme among the others. Except for ID6, 9 out of 10 interviewees have described smart city under the technology umbrella. Some of the statements are;

… *a city that solves environmental problems using knowledge and technology* (ID1).
… *use of technology to match efficiently and effectively for sustainable living and the city* (ID3).
… *cities that can adopt technology to everyday life* (ID8).
… *use of Geographical information systems, technology-based transportation systems* (ID9).
… *the concept that focuses on developing computing technologies and based on the efficient and sustainable use of resources* (ID10).

On the other hand, to clarify and frame the rationale of the term, a second question was asked if a smart city would differ from the other city approaches. As researchers have observed, all responses had included 'technology' whether in the term itself or such as; IT, ICT, SmartSolutions, etc.

(3) *Thinking of Smart city, what could you think of in terms of comprehensiveness? Do we need any more factors?*

We have observed a few patterns cleared from the interviewees' responses supporting our selection of Smart city criteria in the quantitative phase. As ID3 and ID4 agreed on, the current factors are relatively enough; on the other hand, ID1 and ID4 have come up

Table 5
Summary of thematic categories in smart city descriptions among the interviewees.

	Technological	Sustainable	Participative	Innovative	People-Friendly	Ecological
ID1	x	x	x	x		
ID2	x			x	x	
ID3	x					
ID4	x					x
ID5	x	x				
ID6		x	x			
ID7	x	x				
ID8	x					
ID9	x					
ID10	x	x				

with 'governance' and 'digital governance' factors leading us to think wise in terms of stakeholder approach (human as a benchmark in the creation and also end-user of technology). Human factor or as it has been used as Smart People set forth according to below statements:

> *… educational and technological differences between countries distinguish the occurrence adventure of smart cities. Therefore, the decrease in the use of technology in the upper age groups necessitates the development of new strategies, especially in the studies to be conducted in our country. Therefore, new dimensions can be considered, especially in reaching individuals* (ID6).
>
> *… urban development processes are not unilateral. The mental transformation of users must be taken into account* (ID10).

Further, ID9 stated that smart city was quite thriving and sufficient in terms of traffic and public transportation and inadequate in solid waste management, concluded with ID8′s Smart health factors to create in need of consciousness emerged, which might also indirectly related with Smart People criteria.

(4) *Do you think the smart city approach is effective in solving urban problems?*

In terms of questioning efficacy, six out of ten interviewees' statements were as toward definitely to nearly 'efficient' but only in given Europe, USA, and Canada examples. Additionally, ID7 stated to be efficient; the detection of problems was to be technology-intensive, and so was their solution, referring to the adequacy of determination that would lead to adequate smart city solutions. Another interviewee highlighted the theoretical importance of participation, the time taken in getting public opinion in practice by stressing the cybersecurity of decision-making mechanisms can affect the decisions of today's applications (ID6). Conversely, ID10 mentioned, causal deepening of socio-economic development differences in society when solving urban problems as problems arising from technology was not to be ignored.

(5) *What is the level of competence of smart city applications in the world and your country?*

Aiming to converge the state of mind -the rationale- of the interviewees, the researchers have indicated given responses as attitudes and expectations. By doing this, it helped to canalize the current to the future through normalized decision making. Hence, the responses showed that even worldwide implications support hopes (six out of ten interviewees were neutral or positive), in the country-specific points of view, remains negative (eight out of ten were all negative). Experts are aware of the developments and positive outcomes; however, the picture is still very blurred when it comes to country-specific. These results led the authors to the need for a better understanding of the smart city (or other new consequences for changes) and how to change the status quo of minds for full consciousness.

Furthermore, findings supported that interviewees' minds are archived with highly correlated few structures such as *digitalisation_technology_big cities_big economies*, etc. Although the smart city concept has aroused in terms of the high rising population, it is not a solely big city concept.

5.2. Quantitative results

In this study, the DEMATEL technique was used to reveal the reasons for the relations between the main and sub-dimensions of the smart city concept. The stage of determining relationships is essential as it can help explain the relative importance of each dimension. By designing a specific questionnaire, data were collected through expert opinions of five male, five female academicians whose expertise is in urbanization. The respondents' profile consists of the majority has over three years of working experience, while one-half of the total having more than five.

Eq. (1) is utilized to define relations between dimensions, and the results are in below Table 6 average direct relation matrix of main dimensions. Following, the normalized direct relation matrix is presented in Table 7 using Eqs. (2) and (3). Table 8 shows the total relation matrix was calculated by using Eq. (4). Further, with Eqs. (5)-(6)-(7)-(8)-(9), the main dimensions relation matrix was obtained to identify the relative importance of the dimensions by calculating the vector R and C. Table 9 determines the Relations Between Main Dimensions. Ri + Ci values correspond to the factors showing the significance levels of the dimensions. These significance levels are also presented with calculated wi and Wi values, revealing that the most important dimension is Smart People followed by Smart Living, Smart Environment, Smart Economy, Smart Mobility, and Smart Governance, respectively. In addition, Ri-Ci values are used to determine the effect states of the dimensions. If (Ri-Ci) < 0 for one dimension, it is said to be affected by other dimensions; on the contrary, affecting the other criteria if (Ri-Ci) > 0 for one dimension. Smart Living, Smart Mobility, and Smart Environment have emerged as influenced (receiver) criteria, Smart People, Smart Economy, and Smart Governance are the influencing (causer) criteria.

The average value of the elements of the total effect matrix is calculated to define the threshold value as in Tamura et al. (2002), and the threshold was determined as 1.0575. The relationship between the main dimensions given in Fig. 2 is drawn by identifying the elements of the total effect matrix table that are greater than the threshold value.

Table 6
Average Direct Relation Matrix of Main Dimensions.

Dimensions	Smart Environment	Smart Economy	Smart Governance	Smart People	Smart Living	Smart Mobility
Smart Environment	0,0000	2,0909	1,3636	2,1818	2,7273	2,2727
Smart Economy	2,1818	0,0000	2,0000	2,3636	2,2727	2,3636
Smart Governance	2,3636	2,1818	0,0000	2,2727	2,2727	1,9091
Smart People	2,7273	2,5455	2,5455	0,0000	2,5455	2,2727
Smart Living	2,2727	1,8182	1,8182	2,0909	0,0000	2,3636
Smart Mobility	2,1818	2,1818	1,2727	1,7273	2,4545	0,0000

Table 7
Normalized Direct Relation Matrix.

Dimensions	Smart Environment	Smart Economy	Smart Governance	Smart People	Smart Living	Smart Mobility
Smart Environment	0,0000	0,1655	0,1079	0,1727	0,2158	0,1799
Smart Economy	0,1727	0,0000	0,1583	0,1871	0,1799	0,1871
Smart Governance	0,1871	0,1727	0,0000	0,1799	0,1799	0,1511
Smart People	0,2158	0,2014	0,2014	0,0000	0,2014	0,1799
Smart Living	0,1799	0,1439	0,1439	0,1655	0,0000	0,1871
Smart Mobility	0,1727	0,1727	0,1007	0,1367	0,1942	0,0000

Table 8
Total Effect Matrix.

Dimensions	Smart Environment	Smart Economy	Smart Governance	Smart People	Smart Living	Smart Mobility
Smart Environment	0,9673	1,0427	0,8666	1,0359	1,1881	1,0883
Smart Economy	1,1601	0,9437	0,9405	1,0884	1,2091	1,1362
Smart Governance	1,1583	1,0793	0,7946	1,0727	1,1963	1,0980
Smart People	1,3014	1,2144	1,0597	1,0333	1,3399	1,2376
Smart Living	1,0988	1,0079	0,8758	1,0113	0,9879	1,0722
Smart Mobility	1,0480	0,9861	0,8077	0,9492	1,1037	0,8721

Threshold value: 1.0575.

Table 9
Relations Between Main Dimensions.

Dimensions	Ri	Ci	Ri + Ci	Ri-Ci	w	W
Smart Environment	6,1888	6,7338	12,9226	−0,5450	12,9341	0,1695
Smart Economy	6,4780	6,2741	12,7521	0,2039	12,7538	0,1671
Smart Governance	6,3992	5,3449	11,7441	1,0543	11,7913	0,1545
Smart People	7,1864	6,1908	13,3771	0,9956	13,4141	0,1758
Smart Living	6,0539	7,0249	13,0787	−0,9710	13,1147	0,1719
Smart Mobility	5,7668	6,5045	12,2713	−0,7377	12,2935	0,1611

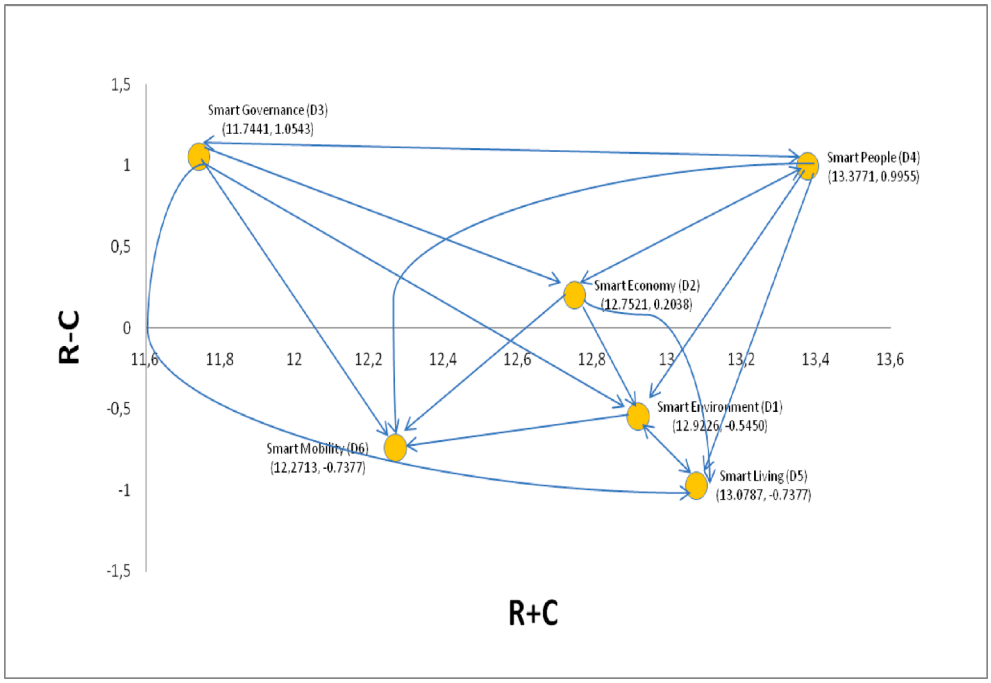


Fig. 2. Diagram of the main dimensions of smart city.

This procedure was repeated for all dimensions. All results are presented in Table 10 as causer and receiver dimensions. Besides, Ri + Ci values and Ri-Ci values were calculated for all sub-dimensions in the very same table. Based on this table, relationship diagrams are drawn between the sub-dimensions under each main dimension. The significant relationships between the predictors of smart city are shown in Fig. 3(1) for Smart Environment, 3(2) for Smart People, 3(3) for Smart Economy, 3(4) for Smart Governance, 3(5) for Smart Mobility, and 3(6) for Smart Living.

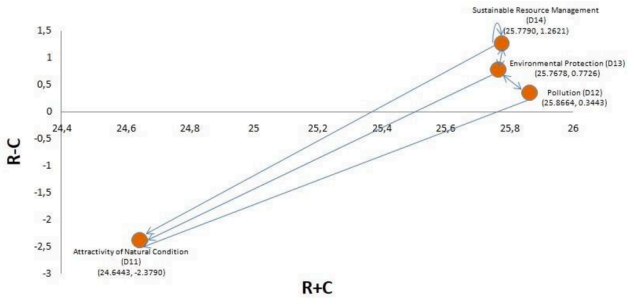
Fig. 2 helps to interpret the general picture of relations of the main dimensions of the smart city concept. Smart governance is the main influencer affecting five other dimensions, while smart living and smart environment are both affected by the other four dimensions.

Table 10 further reveals that Attractivity of natural conditions, Economic image and trademarks Flexibility of labor market, Public and social services, Social and ethnic plurality, Flexibility, Creativity, Participation in public life, Cultural facilities, Individual safety, Touristic attractivity, Local accessibility, and National/International accessibility and Sustainable, innovative and safe transport systems are explicitly receiver factors in terms of negative Ri-Ci. On the other hand, Pollution, Environmental protection, Sustainable resource management, Innovative spirit, Entrepreneurship, Productivity, International embeddedness, Ability to transform, Participation in decision-making, Transparent governance, Political strategies and perspectives, Level of qualification, Affinity to life-long learning, Cosmopolitanism/Open-mindedness, Health conditions, Housing quality, Education facilities, Social cohesion, and Availability of ICT-infrastructure are explicitly causer factors, indicating these factors influence on the other factors of the smart city.

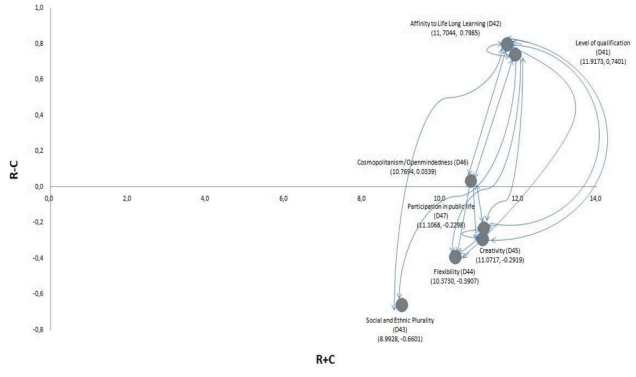
The significant relations are also presented in plots of Fig. 3 in terms of a better understanding of specific sub-dimensions on others. In Fig. 3(1), Attractivity of natural conditions is affected by all other dimensions of the smart environment's main dimension of smart city, meaning as for a smart environment, the focus should be on the attractiveness of natural conditions by paying attention to pollution, environmental protection and managing the resources. In Fig. 3(2) Level of qualification and Affinity to life-long learning are causers and affecting other dimensions as it can be seen that the influence is relatively strong. As smart people being the most important main dimension of smart city, it can be foreseen that an individual having a high level of qualification and affinity to life-long learning; could change the status of social and ethnic parity. Instead, Flexibility, Creativity, and Public life participation are to be

Table 10
Causer and Receiver Dimensions.

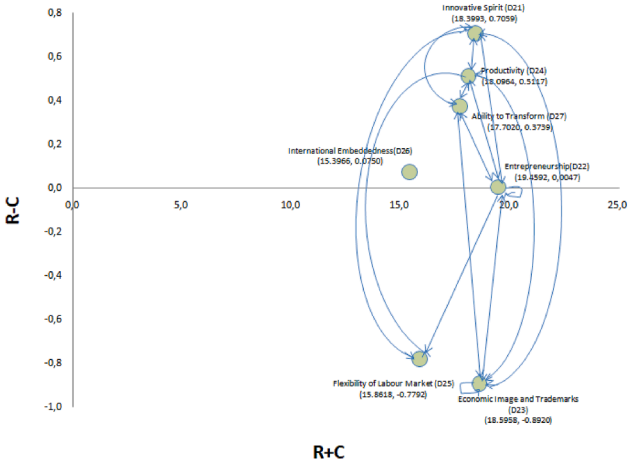
Main Dimensions/Sub-dimensions	Row Sum(Ri)	Column Sum(Ci)	Ri + Ci	Ri-Ci
Smart Environment	6,1888	6,7338	12,9226	−0,5450
Attractivity of natural conditions	11,1326	13,5117	24,6443	−2,3790
Pollution	13,1054	12,7611	25,8664	0,3443
Environmental protection	13,2702	12,4976	25,7679	0,7726
Sustainable resource management	13,5206	12,2585	25,7791	1,2621
Smart Economy	6,4780	6,2741	12,7521	0,2039
Innovative spirit	9,5526	8,8467	18,3993	0,7059
Entrepreneurship	9,7320	9,7273	19,4592	0,0047
Economic image and trademarks	8,8519	9,7439	18,5958	−0,8920
Productivity	9,3040	8,7923	18,0964	0,5117
Flexibility of labor market	7,5413	8,3205	15,8618	−0,7792
International embeddedness	7,7358	7,6608	15,3966	0,0750
Ability to transform	9,0379	8,6641	17,7020	0,3739
Smart Governance	6,3992	5,3449	11,7441	1,0543
Participation in decision-making	8,4223	8,3354	16,7577	0,0869
Public and social services	6,6488	8,6141	15,2629	−1,9652
Transparent governance	8,4616	7,6715	16,1331	0,7901
Political strategies and perspectives	8,8506	7,7623	16,6129	1,0883
Smart People	7,1864	6,1908	13,3771	0,9956
Level of qualification	6,3287	5,5886	11,9173	0,7401
Affinity to life long learning	6,2514	5,4530	11,7044	0,7985
Social and ethnic plurality	4,1664	4,8265	8,9928	−0,6601
Flexibility	4,9912	5,3818	10,3730	−0,3907
Creativity	5,3899	5,6818	11,0717	−0,2919
Cosmopolitanism/Open-mindedness	5,4017	5,3678	10,7694	0,0339
Participation in public life	5,4385	5,6683	11,1068	−0,2298
Smart Living	6,0539	7,0249	13,0787	−0,9710
Cultural facilities	3,3026	4,2551	7,5577	−0,9525
Health conditions	4,2280	3,4227	7,6507	0,8052
Individual safety	3,6010	4,0774	7,6784	−0,4763
Housing quality	3,1008	2,9459	6,0467	0,1549
Education facilities	4,7099	3,9023	8,6122	0,8075
Touristic attractivity	3,7851	4,5570	8,3421	−0,7719
Social cohesion	4,0095	3,5764	7,5859	0,4331
Smart Mobility	5,7668	6,5045	12,2713	−0,7377
Local accessibility	7,8909	8,6828	16,5737	−0,7919
National/International accessibility	8,6270	8,7651	17,3921	−0,1380
Availability of ICT-infrastructure	9,2777	8,0120	17,2897	1,2658
Sustainable, innovative and safe transport systems	8,2727	8,6086	16,8813	−0,3359



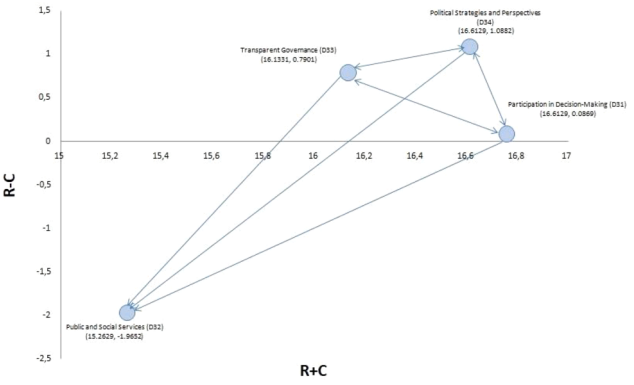
(1) Smart Environment Dimensions



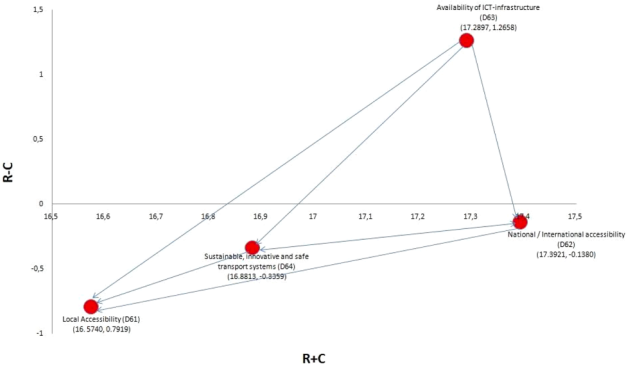
(2) Smart People Dimensions



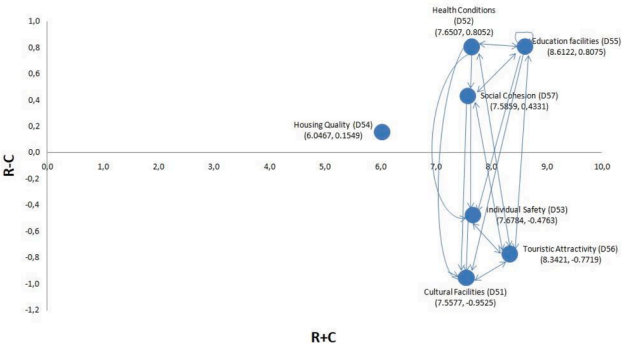
(3) Smart Economy Dimensions



(4) Smart Governance Dimensions



(5) Smart Mobility Dimensions



(6) Smart Living Dimensions

Fig. 3. The significant relationships between the predictors of smart city.

affected, as they are one of the most desired characteristics of 21st-century people. Following Fig. 3(3) shows that in terms of the smart economy, Economic image and trademarks were profoundly affected by other dimensions; on the contrary, International embeddedness was not affected by any different dimensions. In Fig. 3(4), Public and social services were affected by the other three sub-dimensions; hence, in smart governance, Decision marking participation, Transparency, and Political strategies and perspectives are the cornerstones in terms of public and social services. Following in Fig. 3(5), it can be seen that Local accessibility was affected by all the other three dimensions. In comparison, the Availability of ICT-infrastructure was the net causer, affecting all other three dimensions, showing the importance of ICT technologies as discussed in the literature and in the qualitative findings of this study.

6. Discussion and conclusion

In this paper, a smart city assessment of six main dimensions is addressed based on the previous literature. A hybrid methodology of two phases, which consists of expert judgments, a qualitative descriptive method, and a quantitative phase including DEMATEL, is utilized to reveal smart city awareness and the applicability in general and evaluation of its dimensions by DEMATEL. The results will be discussed within each related methodology for the consistency of the research questions accordingly.

In association with the information and communication technologies, the responses from experts which are tested in the qualitative phase of the study revealed that smart city needs a broader definition. A definition is required to be including a full scope of social structural factors such as; cultural and education facilities or participation in public or even housing quality, etc. The qualitative phase findings lie on crucial importance as there is no universal definition of the term smart city in association with the factors and indicators analyzed. The overview of statements can be covered within the smart factors but not the city. These findings might have been related to the concurrent focus on Industry 4.0 and digitalization in an emerging country causing distraction from a detailed elaboration of the smart city. Further, results from the Web of Science Collection are also supporting the foregone conclusion. At least 2/3 of the Smart City related research (see Appendix A) has been published in computer technology or engineering science publications contributing knowledge about the term by strengthening the existing perceptions to form stereotypes, distracting from core aspects, and a starting point of the structure.

Another aspect of this study is technology as a cognitive component of the interviewees' rationale, mediating other themes (sustainability, participation, innovation, people-friendliness, ecology, etc.) in terms of the relationship with smart city concept. Therefore, cybersecurity and trust issues should become highly invisible in use for people to live in a smart city. This is induced by the demographic structure, becoming the main issue in the creation of smart cities. The qualitative phase has also shown us the strengths and weaknesses as an important aspect. According to statements, weaknesses are more highlighted to strengths in comparison. Hence, via qualitative research, the cognitive rationale and socially embedded values of the novel concept through given statements have been pictured.

In the quantitative phase, six main and 33 sub-dimensions of smart city are considered by ten participants familiar with the field, most of whom have professional experience in urbanization for more than three years. Based on the Center of Regional Science, Vienna UT October 2007 report of the smart city dimensions is taken to be evaluated in terms of an emerging country. To reveal the participants' perspectives on the subject, the DEMATEL method has been applied. The results of the expert judgments indicate that Smart people is the strongest predictor of smart city, especially Level of qualification and Affinity to lifelong learning are the most important sub dimensions, showing that social and individual education matters most when structuring a smart city. This result is also consistent with education facilities becoming the most important factor in terms of smart living. The other predictors are smart living, smart environment, smart economy, smart mobility, and smart governance, main dimensions, from the strongest to the weakest importance in predicting the smart city.

As limitations, considering that cyber-security and social rights are main concerns on the current smart cities research, the adapted dimensions do not include those issues. As a result, the people dimension happened to be the main predictor rather than the technology itself or the management of technology such as security issues. Another limitation of the study can be addressed as the participants were academics; however, in further research, governors and all other stakeholders can be selected as participants.

7. Concluding remarks

In this study, social and human capital criteria came into prominence with indicators included as level of qualification, affinity to life long learning, social and ethnic plurality, flexibility, creativity, cosmopolitanism/open-mindedness, participation in public life. Referring to the background mentioned in the literature, in terms of adapting theoretical knowledge with empirical rationale with the interviews, can be concluded as the following:

- Technology as a remark: while all 'the smart' approaches are understandable-since the concept was first invented- the researchers have witnessed a consistent technological improvement, a continuum starting auricular to it is so much stable at the moment. Step by step, there have been approaches from being interactive to green and then to smart. This logic might help people to understand why the definitions are intercorrelated.
- In interviews, what is meant as the meaning of technology is needed to be cleared. Is it IoE or IoT? As data harvested by the internet, IoT may be the first to come into mind. On the same side, 'smart' has a very similar meaning to IoT, although this is also a novel concept for many people worldwide. As the researchers observed in the interviews, the term IoE was not mentioned, but energy delivering technology, waste discharge connections, or even a HVAC system referring to infrastructure were. This result leads us to the broader education and definition of the novel concepts.
- As one of the important contributions of this research, the expert judgment provides significant insights into the smart city concept through the given dimensions. The qualitative phase results were mainly in a technology focus; however, after the evaluation of the specific dimensions via a questionnaire, the results indicated that people matter most rather than the technology itself or the management of the technology such as security issues. Smart mobility and smart governance were the weakest predictors compared to the other six dimensions of the smart city as a controversy. This situation indicates that experts have focused on the general (macro perspective) point of view in the qualitative phase. On the other hand, when they are given a form including specific dimensions, experts' focus was able to prioritize the specific dimensions sufficient enough to initiate significant relation of the subject in question (micro-level assessment).

- Such a hybrid methodology can guide decision-makers to see the general and the specific parts of the smart city concepts.
- This research has also contributed to the emerging field of smart city, in practicality and applicability perspectives of utilizing a hybrid framework not only for decision-makers of the smart city but also all stakeholders in areas with similar problems.
- The authors believe that the same dimensions can be used in a different country sample, as it is believed that a hybrid approach answers the status quo of being smart and want to be done to being smart/er. In addition to that, causer-receiver interactions enlight for decision-makers from any stakeholder group where to start the change first.

It can be stated that instead of just ranking the factors, the causer and receiver relation strengthens the potential activity as a step in creating smart cities. It is crucial for our approach; what is to be done in future lenses is to be considered on the basis of a combination of politics, business, and people, which are mutually connected in terms of building the structure of a smart city.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tele.2021.101625.

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