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Research Article

Investigation of Smart City Components by AHP-BWM-FUCOM and DEMATEL Methods

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ABSTRACT

The concept of a smart city has emerged with the development of technology in the 21st century, based on the ideal city concept introduced in the 19th century. Increasing number of people move from rural to urban cities with the rapid increase in the world population. As a result of this, smart city concept become more important all over the world. Smart city components which makes a city turn out to a smart city is investigated in the literature very widely. Although over forty smart city components can be counted in the literature, the main six elements which are smart economy, smart people, smart governance, smart mobility, smart environment and smart living are mostly included in the studies. In this study, these six main smart city components is weighted by one of the most widely used MCDM techniques AHP, DEMATEL and more recently developed techniques BWM and FUCOM. According to the results of analysis, Smart Governance is the most important criteria according to the AHP, BWM and FUCOM methods, while Smart Economy is the most important criteria according to the DEMATEL method. At the same time, Smart people are the least important factor according to the AHP, BWM and FUCOM methods, while Smart Governance is the least important factor according to the DEMATEL.

Keywords: Smart City, Smart City Components, Criteria Weighting, AHP, DEMATEL, BWM, FUCOM

1. Introduction

With the rapid increase in the world population, resource consumption has increased and various searches have been made to solve many problems, such as high carbon emissions, environmental pollution, and solid waste problems. The aim of smart city concept is to provide happier people efficient use of resources, sustainable development and more peaceful societies. The need for smart cities has emerged as one result of the Fourth Industrial Revolution, which we frequently hear about today. This revolution, which emerged under the leadership of Germany, is more comprehensive than the rationalization of industry and production. This revolution emerges as a broad revolution that includes production, economy, socio-cultural life, and states. The Fourth Industrial Revolution, whose effects we see in every aspect of life, is a revolution that facilitates people's lives by integrating the physical world and the virtual world, is based on efficiency, and enriches the physical world and presents it to people. In this revolution, which foresees efficiency in all areas of life, smarter and more efficient management of cities by integrating with technology and the virtual world constitutes the agenda of many countries. As a result, the fourth industrial revolution is a development that paves the way for the emergence of smart cities (Örselli & Akbay, 2019). Today, about 55% of the world's population lives in urban areas. With rapid population growth and technology, there is a migration from rural to urban areas. With the development of industrialization and technology, the urban population is increasing rapidly with the effect of globalization and it is not possible to prevent population growth in cities in the light of developing conditions. It is possible to develop urbanization in a healthier way and to prevent irregular urbanization with smart and scientific urban planning practices. In this context, smart cities can be interpreted as the control of global-scale cities through technology in an environmentally friendly manner. In Turkiye, smart cities, which are a concept based on sustainable development and handled with a technology-based approach, are a new perspective for our urbanization. In this context, healthy progress will be achieved with the joint efforts of all segments of society, from public institutions and organizations to private companies working on technology, from municipalities to citizens, on the way to smart cities, which started with e-municipal services and made significant progress (Elvan, 2017).

With the increasing population, problems arise in cities such as energy, water, education, service, health, infrastructure, and security. As an example of these problems; unplanned urbanization, non-management of waste, air and water pollution, heavy traffic and accidents, increase in poverty among citizens, increase in crime rate, shortage of access to resources, disruptions in the supply chain, etc. can be given. The smart city approach has emerged in order to bring "smart" solutions to these emerging problems. The smart city approach aims to make cities more sustainable and livable. The concept of a smart city has emerged with the active use of technology in the solution to urban problems. When the literature is examined, there is no complete definition of the concept of a smart city. The smart city can be explained as integrating information and automation technologies into the private and public areas of the city, resulting in higher energy efficiency, and more productive, greener, environment and human-friendly cities. In the research, the activities that need to be implemented in order for a city to be smart are listed as follows; smart transportation systems, smart grids and energy systems, smart health services, smart environment, and pollution reduction are efficient public administration systems (Çerçi, 2015).

The most important condition for the full implementation of these practices is that the residents of the city cooperate and act together with the city administrators. Smart cities, which create cities that can respond quickly to changing conditions and environmental changes, increase the performance of services, and ensure more efficient use of resources, provide very important socio-economic benefits. Cities need to become smart cities in order to manage the infrastructure and resources of the cities, live in a livable environment, and meet their needs effectively in the future. An innovative approach is required in the transition to smart cities, and the top management has primary duties within smart cities. Innovative studies should be carried out in order to determine what is lacking in the city, what can be done, and what problems can be solved. Municipalities have to equip cities with technological infrastructure and use technology to provide the best service to the people of the region (Varol, 2017).

When evaluated in general, it can be said that mobility/transportation, clean energy, water, and food production, distribution, health, life, and public participation are among the problems that smart cities focus on the development of technology, the emergence of the information age, and the fourth industrial revolution have led to the birth of smart cities, and in the solution of urban problems that arise with the effect of urbanization, a solution has been provided as a result of the integration of technology infrastructure with the smart city approach.

2. Literature Review

There is a wide literature on smart city concept in the literature. It is possible to say that the literature can be investigated in two parts. One side of the research is evaluation of the smartness of the city, the other side of the research is the evaluation of the components of the smart city concept. Hayek et. al.(2022) evaluated recent developments in smart city assessments. In their work, 164 articles published in 2010 to 2020 analyzed deal with smart city. The analysis reveals that one of the most research address is that multiple-criteria decision-based performance measurement framework and characteristics of indicators of smart city. Rani, S. and Kumar, R.(2022) also made the bibliometric assessment of the actuators in smart cities in Scopus database in 2011 to 2021. The dispersion of the actuators in smart city framework represented an increasing trend, with a maximum of 25 articles published in 2021. Adali et. al. (2022) evaluated 17 European cities from a smartness perspective. Six main criteria weigthed with grey MCDM technique to rank the cities. Koca et. al. (2021) evaluated smart city components with DEMATEL method. In their work “Smart People” has emerged as the most important predictor while “Smart Governance” was the least. Avcıoğlu and Tanrıöven (2020), evaluated smart country performance scores and connected main component scores for Switzerland, Bosnia, and Herzegovina, and Turkiye are compared and presented. Turkiye’s smart country performance is also examined, and they presented development areas to improve the current situation. In the study of Orselli and Akbay (2019), smart city application examples in the world and smart city applications in Turkiye are discussed comparatively. The study was created with a qualitative method. First of all, the concept of the smart city is evaluated. Then, the elements and technologies of smart cities is examined, and then the example applications in the world and smart city applications in Turkiye is evaluated. In the study of Boz and Çay (2019), revealed ten factors to rank smart city governments as points, because of considering how city governments follow to prepare smart city strategies. These factors are vision, leadership, budget, financial incentives, support programs, capability readiness, people orientation, innovation ecosystems, smart policies, and past performance. In the study, the first ten smart cities identified because of a joint study carried out by Eden Strategy Institute and OXD Consulting Firm were examined. Aksoğan and Duman (2018), aimed to show the applications and services of Malatya in order to become a smart city and to contribute to the economic and social development of the city of Malatya by suggesting solutions and improvements on what can be done. The concept of a smart city, which is a new solution for better management against globalization, was defined and smart city projects in Konya were discussed thoroughly In Mangır's study (2016).

In this study the main six components accepted in the literature are weighted with widely used MCDM tecqhniques, which are AHP, DEMATEL, BWM and FUCOM. The results are compared.

3. Smart City and Smart City Approach

Today, the share of cities all over the world in resource and energy consumption is approximately 80%, and its share in carbon emissions and natural resource consumption is 75%. The impact of cities on the country's economy is increasing and as the demands increase, it is difficult to meet the needs of citizens, such as energy, water, transportation, and other services. In addition, cities play an important role in socioeconomic development. However, most cities also face the challenge of overcoming problems such as unemployment, lack of permanent place to live, social inequality, traffic congestion, pollution, diseases, and violence. The smart city approach is based on meeting these needs and solving problems (Deloitte, 2016).

The concept of a smart city was used for the first time in 1998. When the literature is examined, besides the concept of a smart city, concepts such as digital city, virtual city, sustainable city, green city, environmentally friendly city, hybrid city, learning city, information city or smart society are used. A smart city is defined as a new concept in which new generation information communication technologies such as the internet of things, cloud computing, big data, and integrated geographic information systems are applied that will facilitate the planning, management, and smart services of the city (Harrison & Donnelly, 2011).

A smart city is a city created by using information technologies in order to increase the quality of life of city residents and the efficiency of city infrastructures and to provide better service to citizens (Akıllı Kentler Nedir, 2015).

Smart cities can intelligently respond to different needs, such as daily life, environmental protection, public safety and city services, and industrial and commercial activities. Smart cities use information technologies to increase the performance of urban services, reduce resource consumption and cost, and use this technology for public services, traffic management, energy, health services, and reducing air-water pollution (Uçar, Şemşit, & Negiz, 2017).

The smart city is a model that deals with the environmental, social, and economic problems of the city and tries to find multidimensional solutions. Sustainability has four main dimensions: quality of life, urbanization, and smartness. Infrastructure and governance, pollution and waste, energy and climate change, social issues, economy, and health are the underlying attributes of sustainability.

The emotional and financial well-being of citizens indicates an improved quality of life. The urbanization feature focuses on the technological, economic, infrastructure and management aspects of the transformation from the rural environment to the urban environment. Finally, smartness is defined as the desire to improve the social, environmental, and economic criteria of the city and its inhabitants. The smart city vision depends on the sustainable city vision. With its digital networks, and efficient and integrated infrastructure, the smart city emerges as a facilitator of sustainable development by harmonizing the objectives of environmental protection, social equality, and economic development (Mangır, 2016).

Smart city applications stand before us as a phenomenon that constantly transforms urban life and that we will encounter frequently in the future. In order for these transformations to contribute positively to the development of our cities and people and not to lag behind the developments in the world, studies are carried out by considering all the necessary factors. In this context, it is important that the transformation process is adopted by the residents and administrations and that it can be prepared with a participatory approach. In reaching this level of awareness, both central and local governments have important responsibilities (Shapiro, 2006).

The smart city approach offers technological solutions to problems. They are solutions for water management, clean and renewable energy, smart traffic control, e-government, urban mobility, wireless internet accessibility and waste management. The establishment of the technological infrastructure, data collection, purposeful processing of the data and the development of the services offered are the most basic steps for the smart city process. A smart city comprises systems integrated with technology to offer its citizens a sustainable, prosperous and participatory future. Smart cities are cities that use information and communication technologies to ensure the livability and sustainability of the city. However, although it offers many solutions with the help of technology, its focus is on people, not technology. Using technology as a tool to increase the quality of life of citizens is of key importance for the success of smart city applications. As a result, smart cities are the efficient use of limited resources by making smart combinations with the support of information and communication technologies and the participation of citizens in order to meet many problems and demands because of rapid population growth (Giffinger & Gudrun, Smart Cities Ranking: An Effective Instrument For The Positioning Of The Cities, 2010).

Smart cities have emerged and become more popular in the last two decades, although they date back to the visions of the urban future of the previous century. Visions of the future, technology, and the means of production of the current period shaped and developed under its influence. The majority of smart strategies can be achieved in a short time. However, it may be possible to implement it with a long-term study and determination. Therefore, the vision for the cities of the future and the city administration is an important phenomenon of the smart city discourse. The understanding and acceptance of this vision, especially by administrators and citizens, is very important for the success of the smart city approach.(https://www.akillikentler.org/akilli-kentler-nedir-7.html)

Although the concept of smart city, which is the equivalent of the English term "Smart Cities", is preferably used in the literature, the concepts of digital, informatics and information cities are also encountered in the literature. Smart city concept; It emerges as a concept that includes "high intellectual or human capital, significantly improved quality of life and economic development, lifelong learning and optimal management of natural resources, which are needed to support continuous innovation and solve problems or difficulties"

Since the concept of smart cities and related applications are still developing in Turkiye, they also contain some risks due to their nature. All institutions and organizations that are responsible for smart cities are aware of the existing risks during the development of smart cities, such as the increase in urbanization, the decrease in natural energy resources, excessively polluting sources, and subsequently global climate change, and the difficulty of local governments in providing the necessary service supply in the face of the increase in service demand. problems; In order to create economically, socially, and environmentally sustainable cities, smart approaches have to be put forward. The factors necessary for the success of the smart city approach are explained below(Bıçakçı,2014);

Providing city residents with access to information and communication technologies and providing them with the necessary skills to use these technologies,

Assigning a committee or committees related to smart city development and managing this process within city administrations,

Supporting small and medium-sized enterprises conducting research on smart cities, benefiting from the work of these enterprises,

Ensuring the participation of citizens in the activities carried out, making use of the facilities provided by information and communication technologies at this point,

Exchange of experience with different smart city examples,

While developing smart city projects, city administration, citizens, private companies, academic environment etc. Ensuring that institutions or communities that can contribute to work together (Armağan M. V., 2018).

3.1. Smart City Components

Smart city components form the characteristic features of a smart city and there are six of them. These; are smart people, smart governance, smart economy, smart mobility, smart environment, and smart life. These components aim to improve the socio-economic, ecological, logistical and competitive performance of the city and to create a long-term sustainable performance. Contributing to the development of smart cities; There are six main elements such as "smart people, smart governance, smart economy, smart mobility, smart environment, and smart life (Giffinger, 2007).

Smart People: As the most important actor of the smart city, citizens should have smart, conscious, and high-quality social capital. Not only the level of education or qualification of citizens; is also explained by the quality of social interactions related to openness to the outside world, social life, and integration. Intelligent people are a necessity for smart cities (Ateş, 2018).

Smart Governance: The city with smart citizens; The state and municipalities should also adopt smart governance, which includes the institutional capacities and awareness levels of smart cities, the plans, policies, and e-management practices they develop, the participation of the city residents in the decision-making processes, the mobile applications and online systems developed within this scope. In order for a smart city initiative to achieve the desired results and appeal to a wide segment of the society, it should develop smart governance channels based on principles and standards such as cooperation and participation in decision-making processes. Besides cooperation and participation in the decision-making process, data sharing, integration of public and social services and practices, accountability, transparency, political strategies and perspectives add depth to smart governance. In summary, participation in the decision-making process, public and social services, transparent management, policy strategies and perspectives reflecting the understanding of e-democracy constitute the essence of smart governance (Armağan M. V., 2018).

Smart Economy: In addition to integration with local and global economic networks, smart economy also includes entrepreneurship, innovation, economic image, branding, productivity, flexibility of labor market and flexibility of job markets within the scope of economic competitiveness. In order for the city that adopts a smart economy to be described as smart, its economy must also be managed intelligently (Deloitte, 2016).

Smart Mobility: The concept of smart mobility includes logistics services supported by information and communication Technologies. Smart Mobility (transport, information, and communication technologies infrastructures): Availability of information and communication technologies and modern, sustainable transportation systems as well as local and international accessibility are the most important aspects of smart mobility (Giffinger, 2007). In this direction, it is aimed to make transportation better and to benefit people with the help of technology.

Intelligent Environments: It is very important that it is arranged and regularly controlled so that its environment is not overlooked while providing intelligent mobility. Within the scope of a smart environment; There are applications such as infrastructure automation, water and sewerage systems monitoring, solid waste collection/separation systems, environmental quality measurement, and energy consumption reduction. Ensuring development and sustainability in the fields of pollution, environmental protection, sustainable resource management the control of green areas and water resources becomes easier with the help of technology. It is aimed to enhance the natural beauties of the city by reducing the pollution rates and protecting the environment Renewable energy sources (wind and solar energy, geothermal energy, biomass energy, and hydrogen energy) can be given as examples of the effective and efficient use of natural resources. It aims to provide a clean, safe and sustainable environment (Canlı, 2019).

Smart Life: Smart Life (culture and quality of life): Smart life, on the other hand, includes culture, health, security, housing, tourism, etc. It includes various aspects of quality of life such as (Giffinger, et al., 2007). It aims to make individuals interact more effectively by connecting with each other and their environment by using the Internet of things technology and social platforms, thus increasing the quality of life of individuals. It is another feature of this dimension that they contribute to the economy by providing better education, health services, and various cultural activities (Aksoğan & Duman, 2018).

Urban technologies constitute the basic infrastructure of smart cities. Geographical information systems, virtual reality, and simulation technologies have a significant share in the real-time analysis and evaluation of the city. Technologies such as "mobile devices, digital platforms, internet of things, big data, cloud computing" are now used in order to qualify cities as smart and measure the level of smartness. These technologies can be summarized as follows: (Alkan, 2015)

• Mobile Devices: Devices and platforms such as personal computers, tablet computers, smartphones, kiosks, smart meters, and internet centers are of great importance for the use of smart city services by the citizens of the city

• Digital Platforms: Shelter, work, transportation, and safe distribution of potable water are among the main problems that require urgent solutions in many cities. New-generation infrastructures seek solutions by focusing on electrification, automation, and digitalization.

• Internet of Things: The transformation of the urban elements covered by smart city applications into smart vehicles with integrated sensors and the collection and sharing of information by communicating with each other is considered the Internet of Things. In other words, it is the use of sensors and wireless internet connection in goods (Akgül, 2013).

• Big Data: Big data enriches experiences on how cities work and provides insights on how best to interact in cities by providing more informed decision-making opportunities for social interaction. The way smart systems produce smart solutions is to transform the "Big Data" collected from thousands of sensors every day into value-added information for the people and managers of the city through smart processes (İSBAK, 2017).

• Cloud Computing Technology: More variety and size of data is produced day by day. Especially in today's technology, the storage capacity causes big problems as users want to store more and more personal data and data day by day. Cloud Technology, which emerged as a solution to these problems, is defined as software applications, data storage services,s and processing capacities that are accessed over the internet (Bulut, 2018).

3.2. Smart City Applications

Various difficulties are also encountered in smart city applications. One of them is financial insufficiency. Technological infrastructure and equipment are costly. Another challenge is the lack of inter-agency cooperation. Collaboration with non-governmental organizations (NGOs), universities, and municipalities is of great importance in order to achieve success in smart city applications. Following innovative approaches in smart city applications is an important factor in achieving success. Consideration should be given to the institutions' ability to closely follow and internalize the developments in smart city technologies, to use them in line with the needs of the city, and to adapt them. Specialization in information and communication technologies is one of the critical success factors in smart city applications (Bilici & Babahanoğlu, 2018).

When this situation is considered together with the lack of knowledge and experience in smart cities, the importance of competent human resources in applications emerges. Cloud computing and big data analytics are not used sufficiently in smart city applications, while mobile applications are widely used. The most common smart applications in the field of transportation; are traffic monitoring systems, electronic payment systems, and smart stops. The most common smart applications in the energy field; are smart street lighting systems, electricity distribution, smart grids, and smart electricity meters. Smart applications in the field of water are electronic payment systems, smart water meters, and automatic water quality monitoring systems (ASÜD, 2016).

3.3. Reflections of Smart City Approach on Turkiye Applications

It is the Informatics Valley Project, which is accepted as Turkiye's first smart city application. After this implementation, the Informatics Valley Projects started to be put on the agenda by other cities, especially Bursa, Kocaeli and Ankara. In addition, it is possible to come across municipality-based projects such as three-dimensional street imaging that works in harmony with the GoogleEart program of Fatih and Beyoğlu municipalities. A data analysis center at international standards was established by the Istanbul Metropolitan Municipality in order to provide faster and uninterrupted service within the scope of smart city projects (İstanbul Büyükşehir Belediye Başkanlığı, 2017). Environmental Control Center combining on-vehicle IoT, where the waste management is done, Traffic Control Center where Istanbul is monitored with 610 cameras, IMM NAVI, where mobile traffic data is shared and online navigation, common use radio services (OKTH), communication with smart urban furniture. . Plans for the preparation and commissioning of infrastructures for many smart transportation applications, smart parking systems, smart lighting systems, smart garbage collection systems, applications for the disabled, home care and remote health applications continue (Fortune, 2017). Another smart city project is the Canal Istanbul Project, which is planned to be built with a length of 45 km and a width of 400 m, which will connect the Marmara Sea and the Black Sea. With the Istanbul Fatih Municipality web-based GIS project, for the first time in the world, floor sections and independent sections can be interrogated and analyzed in three dimensions with a sketch-based field study and compared with existing projects. Fatih Municipality has also included the Augmented Reality application in Smart City projects. It is seen that traffic density measurements are made at certain points throughout Ankara and smart intersection applications are started at a few points. Some of the district municipalities regarding garbage collection have separation and tracking systems. Although it does not have advanced tracking capabilities, the Automatic Fire Brigade Command Center system has been established (Gürsoy, 2019).

4. Methods

In this study, one of the most widely used techniques AHP and DEMATEL with recently developed techniques, BWM and FUCOM applies to weighting the smart city components. These methods used in this research are subjective criteria weighting methods widely used in the literature. However, to the best of our knowledge, there is no such comprehensive comparative research on the indicators. In this part, first, these methods are briefly explained.

4.1. DEMATEL (Decision Making Trial and Evaluation Laboratory)

DEMATEL is a technique which was developed by Fontela and Gabus in 1971 for the research report, Geneva Research Center of the Battelle Memorial Institute to visualise the cause-and-effect relations, which is the strength side of this method, among elements of a system. DEMATEL is used in various researches in the literature. Si et al., 2018 has a review work on DEMATEL for ten years between 2006 to 2016. Also, Kabak M. and Çınar, Y.,2020 have quite wide review in their work. It is a subjective method based on the expert's opinion. Application method starts with the getting expert's opinion for the criteria based on the scale ranging from "0" to "4" (0= no influence, 1=weak direct influence, 2=moderate direct influence, 3= strong direct influence, 4=very strong direct influence). for the DEMATEL is given below orderly.

Step 1: Calculate the initial average matrix by scores.

In this step, $n \times n$ matrix is constructed for each expert. The diagonal elements of the matrix are zero because any criteria have no influence on the same criteria. Each element of this matrix, x_{ij}, defines that criteria i's effect on criteria j.

$$X = \begin{bmatrix} 0 & \cdots & X_{1n} \\ \vdots & \ddots & \vdots \\ X_{n1} & \cdots & 0 \end{bmatrix}, \text{for n criteria} \quad (1)$$

In the situation of there is over one expert, the final matrix is obtained by arithmetic mean of each element of the matrix's.

$$z_{i'} = \frac{1}{m}\sum_{i=1}^{m} x_{ij}, \text{for m experts} \quad (2)$$

Step 2: Calculate the normalized initial influence matrix

$Z = [z_{ij}]_{n\times n}$ average matrix is normalized in this step.

$$\lambda = \min\left(\frac{1}{\max\limits_{1\le i\le n}\sum_{j=1}^{n} z_{ij}}, \frac{1}{\max\limits_{1\le j\le n}\sum_{i=1}^{n} z_{ij}}\right) \quad (3)$$

Direct relation matrix is obtained by using $D = \lambda * Z$ formula.

Step 3: Derive the total-influence matrix

Total influence matrix, combine direct and indirect effects, is obtained by using $T = D(1-D)^{-1}$ formula.

$$T = [t_{ij}]_{n\times n} \quad (4)$$

t_{ij} represent the direct or indirect impact on criteria C_i over criteria C_j.

Step 4: Setting the threshold value

Threshold value provides to eliminate criteria which have a minor effect in T matrix. It is calculated by using $\alpha = \frac{\sum_{i=1}^{n} t_{ij} \sum_{j=1}^{n} t_{ij}}{N}$, N is the total number of components in T.

Step 5: Getting the impact relation-map (IRM).

In this step, R-C and R+C vectors is obtained using raw vector R and column vector C to represent the net effects on the system. R+C is the prominence vector, which expresses the strength of the criteria on the system, while R-C is the relation vector, which represents criterion's net effect' on the system. The positive $r_j - c_j$ value shows the Criterion j has a net influence on the other criteria, while the negative $r_j - c_j$ value demonstrates the Criterion j influenced by the other criteria.

Step 6: Getting criteria weight

$$w_i = \sqrt{(r_j + c_j)^2 + (r_j - c_j)^2} \quad (5)$$

$$W_i = \frac{w_i}{\sum_{i=1}^{n} w_i} \quad (6)$$

Criteria weights represent the priorities of each criterion.

4.2. AHP (Analytical Hierarchy Proses)

AHP is one of the most widely used techniques in the literature based on pair-wise comparisons. It is an eigenvalue approach developed by Thomas Saaty in 1977 and developed in proceeding years (Saaty, 1980, 2004, 2008). The most important specialty of this method makes the researcher to choose is its easiness to apply and flexibility to integrate to other methods. The application process starts with defining the problem and continues with the specifying the objectives and criteria. In the next step, the experts make pair-wise comparisons at the hierarchical level between 1 to 9 according to their importance. In this step, "1" defines that criteria are of the same importance while "9" defines that the criteria are of absolutely more important than the other criteria. Each entry in that matrix has to be transitivity properties, then the matrix can be said as consistent. Inconsistency level can be measured by the Table 2 provided by Saaty (Saaty,1980). Consistency level less than 0.1 is acceptable. Application method for the AHP is given below orderly.

Step1: Defining problem

Step2: Defining criteria and sub-criteria

Step3: Structuring hierarchical matrix using pair-wise comparisons

In this step, A judgmental matrix (A) is set by using pair-wise comparisons according to the expert's opinion based on relative importance scale given in**Error! Reference source not found.**. A quantified judgment is presented by

$$A = [a_{ij}], \quad i, j = 1,2, \dots, n \tag{7}$$

The quantified judgment matrix elements represent the comparison of any two criteria C_i and C_j which is presented by a_{ij} ;

$$a_{ij} > 0, \quad a_{ji} = \frac{1}{a_{ij}}, \quad a_{ii} = 1 \text{ for all } i \tag{8}$$

Priority of Criteria	Definition
1	Equal importance both elements
3	Weak importance one element over another
5	Essential or strong importance over another
7	Demonstrated importance one element over another
9	Absolute importance one element over another
2,4,6,8	Intermediate values between two contiguous priorities

Table 1. The pair-wise comparison scale (Saaty,1980)

Group decision making is an important issue for AHP. When we provide the pair-wise comparisons from over one expert's opinion, we need to combine that values for the entire group. As commonly used arithmetic mean will cause high inconsistency level while geometric mean will provide acceptable results (Saaty, 2008). Providing pair-wise comparisons with over one expert, final outcomes is obtained by geometric mean instead of arithmetic mean.

Step 4: Normalization pair-wised comparison matrix

Pair wised comparison matrix is normalized by dividing each matrix elements by the sum of each criteria value.

$$a_{ij} = \frac{a_{ij}}{\sum_{j=1}^{n} a_j} \tag{9}$$

Step 5: Calculation priority values, which is estimating the local weights of each criterion or alternative.

Step 6: Calculation total priority values λ.

Pair-wised comparison matrix is multiplied by the local weights column to get total priority values.

$$\lambda_i = (\lambda_1, \lambda_2, \dots, \lambda_n)^T$$

Step 7: Calculation consistency index.

Consistency Index is calculated by using formula (10) based on the eigenvalue of weights of criteria and the number of criteria.

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{10}$$

λ_{max} is the average of weighted sum and criteria weights of each criterion is calculated by using equation(11) given below.

$$\lambda_{max} = \frac{\sum_{i=1}^{n} \lambda_i}{n}, i \text{ number of criteria} \quad (11)$$

Step6: Calculation consistency ratio.

Consistency ratio is calculated by using equation(12), which is combination of Consistency Index and Random inconsistency ratio (RI). RI is the fixed values based on number of criteria(n) in Table 2.

$$CR = \frac{CI}{RI} \quad (12)$$

Because the RI is the fixed values, CI value is the decisive. Lesser the value of CI, better is the CR. Less than 0.1 values are accepted as compatible.

Number of Criterion	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Random Inconsistency	0.00	0.00	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 2: The random inconsistency ratio (Saaty,1980)

4.3. BWM (Best-Worst Method)

BWM (Best Worst Method) developed by Rezaei in 2015, the criteria are defined as the best criterion and the worst criterion according to the decision maker's preference. The most preferred or the most important criteria is defined as the "best criterion" while the least preferred or least important criteria defined as the "worst criterion" by making binary comparisons between the criteria according to a scale or the decision maker.

BWM is based on expert opinions and its most important advantage is; It is the method in which the weights are found by comparing the importance of the best criterion regarding all other criteria and the worst criterion regarding all other criteria. In the BWM method, no pair-wise comparison is made between all criteria. Only after the best and worst criteria are determined by the decision maker(s) pairwise comparisons are made based on the best and worst criteria separately according to these criteria. In the method, criterion weights are provided through the established mathematical model (Rezaei, 2015).

BWM (Best Worst Method) is a subjective method used to reveal the weights of the criteria. Although BWM is a method that has similarities with the AHP method, it is a more useful and advantageous method compared to the AHP method. Namely, AHP provides a solution by establishing a large number of pair-wise comparison matrices. Too many matrices cause the problem of inconsistency. The BWM method requires fewer pair-wise comparisons, and this reduces the problem of inconsistency (Arsu, 2021).

The BWM method offers decision-makers a solution in six steps. The process steps of the BWM method are explained below (Bilgiç, Torğul, & Paksoy, 2021).

Step 1: Determining the Criteria

In the first step, the examined criteria (C_1, C_2, ...,C_n) and, if any, sub-criteria(C_{11}, C_{12}, ...,C_{nj}) are determined.

Step 2: Identifying the Best and Worst Criteria

The best (most important-best) and worst (least important-worst) criteria are determined by the decision maker. This should be done for both criteria and sub-criteria.

Step 3: Prioritizing the best criterion over other criteria

Determining the best criterion by using a number between 1 and 9 is the stage where the preference rate is determined according to all other criteria.

Step 4: Prioritizing the worst criterion over other criteria

In this step, just as in the previous step, the decision makers are asked to determine their preference levels according to the 1-9 evaluation scale. Determining the best criterion by using a number between 1 and 9 is the stage where the preference rate is determined according to all other criteria.

Step 5: Calculation of optimal criterion weights.

$$\min \max_{j} \left\{ \left| \frac{w_B}{w_j} - a_{Bj} \right|, \left| \frac{w_j}{w_w} - a_{jw} \right| \right\} \tag{13}$$

s.t.

$$\sum_j w_j = 1$$

$w_j \geq 0$, for all j

Step 6: Calculation of the consistency ratio (Rezaei, 2016).

It is calculated to check the consistency of the comparisons and to see if the results are reliable.

a_{BW}	1	2	3	4	5	6	7	8	9
Consistency Index	0,00	0,44	1,00	1,63	2,3	3,00	3,73	4,47	5,23

Table 3. Consistency Index using BWM

The Consistency Ratio of BWM can be calculated as follows, based on the obtained ξL and the corresponding consistency index.

Consistency Ratio= ξL / (Consistency index)

A consistency Ratio ≤ 0.1 indicates that the resulting vector is acceptable.

4.4. FUCOM

FUCOM (Full Consistency Method), literature Pamucar et al. (2018) is a new subjective weighting method. The model established in the method is based on linear programming (LP). There are two conditions for determining the importance weights of the criteria with LP: The first condition is that the relations between the weighting coefficients of the criteria and the comparative priorities of the criteria are equal. The second condition is mathematical transitivity (Pamucar, Stevic, & Sremac, 2018).

FUCOM has some advantages compared to other weighting methods (AHP, ANP, SAW, BWM etc.). The FUCOM method offers decision-makers a solution in three steps. The operation steps of the FUCOM method are shown below (Ecer, 2021).

Step 1. The criteria to be considered in the problem are defined by making use of the opinions of experts in their fields.

$$c(j) : \text{Criterion } j \; ; \; j = 1,2,3, \ldots n \tag{14}$$

Step 2. Decision makers first rank the criteria according to their own value judgments. This ranking is done from the most important criterion to the least important criterion. It is as seen in Equation (1).

$$C_{j(1)} > C_{j(2)} > \cdots > C_{j(k)} \tag{15}$$

Step 3. The comparative priorities ($\varphi k/(k+1)$) of the criteria whose ranks are formed as a result of the subjective evaluation of the decision maker are determined. The comparative priority vector of the criteria is also reached.

$\varphi_{\mathrm{k}/(\mathrm{k}+1)}$ indicates the advantage of the ranking of the criterion $C_{j(k)}$ over the ranking of the criterion of $C_{j(k+1)}$. As seen in Equation (2), the vectors of the comparative priorities of the criteria are obtained.

$$\Phi = (\varphi_{1/2}, \varphi_{2/3}, \varphi_{3/4}, \ldots, \varphi_{k/(k+1)}) \tag{16}$$

Step 4. A linear programming model is created through the values given during the steps above. In the model, the objective function is established in the form of minimizing the deviation value. The more consistent the superiority values stated by the expert, the smaller the deviation value will be.

χ : deviation value

The objective function of the linear programming model is shown in (17).

$$z_{\min} = \chi \tag{17}$$

Step 5. Constraints are created after the objective function. Constraints in the method are examined in three ways. The first type of constraint expresses the superiority of each criterion over the next criterion. In the first type of constraint, -1 constraint is created from the number of criteria. The first type of constraint is indicated in notation(18).

$W_{j(k)}$: k. weight of criterion

$$\left| \frac{w_k}{w_{k+1}} - \varphi_{k/k+1} \right| \leq \chi, \forall j \tag{18}$$

The second type of constraints are formed from superiority values. In the second type of constraint, -2 constraints are created from the number of criteria. The second type of constraint is indicated in notation (19).

$$\left|\frac{w_k}{w_{k+2}} - \varphi_{k/k+1} \otimes \varphi_{k+1/k+2}\right| \leq \chi, \forall j \tag{19}$$

Step 6: The last constraint is the constraint stating that the sum of the weights must be equal to 1. This constraint is shown in equation (20) below.

$$\sum_{j=1}^{n} w(j) = 1 \tag{20}$$

Step 7: In the last step, according to the positivity condition of linear programming, criterion weights are required to be greater than 0. The positivity condition is specified in notation (21).

$$w_j \geq 0, \text{ for } \forall j \tag{21}$$

By solving the linear programming model created for the problem, the criterion weights are reached (Ecer, 2021).

5. Application

In determining the weights of the six universal criteria that make up the smart city, as a result of the evaluations taken from three expert personnel working in the City and Regional Planning department of the Istanbul Metropolitan Municipality, weighting coefficients are obtained with AHP-DEMATEL -BWM-FUCOM, which are one of the subjective criteria weighting methods.

These six universal smart city criteria for a city to be defined as smart; Smart Economy(C1), Smart People(C2), Smart Governance(C3), Smart Mobility(C4), Smart Environment(C5), Smart Living(C6) is weighted to see criteria order. The criteria and sub criteria which is generally accepted in the literature is given in Table 4. The weight coefficients of these criteria is obtained with the Excel for all methods. And also Excel-Solver is used to get weight coefficients of BWM and FUCOM.

Code	Criteria	Sub Criteria
C1	Smart Economy	Economic competition
		Technological developments
		Production activities and commercial enterprises
		Branding of the city
		International harmony and unity
C2	Smart People	The education level of individuals
		The social and ethnic diversity of individuals
		The lifelong learning levels of individuals
C3	Smart Governance	Effective usage of information processing technologies
		Effective usage of information processing technologies in the public services
		Efficient and transparent management
C4	Smart Mobility	Advanced IT infrastructure and active usage
		Providing transportation services and easy access to local municipal services to disabled individuals
		Well structured transportation network

Code	Criteria	Sub Criteria
C5	Smart Environment	The air quality level of the city
		The awareness of individuals living in the city towards ecological and natural resources
		ICT integration of the city's water and sewer systems
		ICT integration in the city's solid waste collection systems
C6	Smart Living	Life quality levels
		The educational opportunities
		The city's health facilities
		Ensuring public safety
		The cultural and tourism opportunities of the city
		Disaster and Emergency management
		Social solidarity and cooperation

Table 4. Criteria and sub-criteria for the Smart cities

5.1. DEMATEL Application

In the first step, the initial influence matrix is obtained by getting the average mean of the three expert's opinion in Table 5 as explained in 0.

	S. Economy	S. People	S.Governance	S.Mobility	S.Environment	S.Living
Smart Economy	0.000	2.333	1.000	0.667	0.667	2.000
Smart People	0.333	0.000	0.333	0.000	0.000	0.667
Smart Governance	1.667	2.333	0.000	0.333	0.667	1.667
Smart Mobility	2.000	3.000	2.000	0.000	0.667	2.333
Smart Environment	2.667	3.333	2.000	2.000	0.000	2.667
Smart Living	1.000	1.333	0.000	0.000	0.000	0.000

Table 5. The initial influence matrix(X)

In the next table normalized initial influence matrix is obtained by using $\boldsymbol{D} = \boldsymbol{\lambda} * \boldsymbol{Z}$ formula. $\boldsymbol{\lambda}$ is calculated by equation(3) in 0.

	S.Economy	S. People	S.Governance	S.Mobility	S.Environment	S.Living
Smart Economy	0.000	0.184	0.079	0.053	0.053	0.158
Smart People	0.026	0.000	0.026	0.000	0.000	0.053
Smart Governance	0.132	0.184	0.000	0.026	0.053	0.132
Smart Mobility	0.158	0.237	0.158	0.000	0.053	0.184
Smart Environment	0.211	0.263	0.158	0.158	0.000	0.211
Smart Living	0.079	0.105	0.000	0.000	0.000	0.000

Table 6. Normalized initial influence matrix

In the next table, it is seen that the total-influence matrix T by using $T = D(1 - D)^{-1}$ formula given in the Step3 in 0.

	S.Economy	S. People	S.Governance	S.Mobility	S.Environment	S.Living
Smart Economy	0.000	0.184	0.079	0.053	0.053	0.158
Smart People	0.026	0.000	0.026	0.000	0.000	0.053
Smart Governance	0.132	0.184	0.000	0.026	0.053	0.132
Smart Mobility	0.158	0.237	0.158	0.000	0.053	0.184
Smart Environment	0.211	0.263	0.158	0.158	0.000	0.211
Smart Living	0.079	0.105	0.000	0.000	0.000	0.000

Table 6. The total- influence matrix(T)

Elements of the total influence matrix(T) represent the direct or indirect impact among criteria. Threshold value is calculated as 0.135 which is the average value of the total influence matrix elements. The values greater than the threshold value is shown in bold in the total influence matrix(T). The diagram is shown in Figure 1, represents this direct and indirect relation between criteria.

Dimensions	R+C	R-C	Wi
Smart Economy(C1)	1.74	-0.12	0.157
Smart People(C2)	1.69	-1.37	0.196
Smart Governance(C3)	1.44	**0.18**	0.131
Smart Mobility(C4)	1.56	**0.87**	0.161
Smart Environment(C5)	1.85	**1.33**	0.205
Smart Living(C6)	1.43	-0.90	0.152

Table 7. The Sum of influences given and received on dimensions

Smart Governance(C3), Smart Mobility(C4) and Smart Environment(C5) have positive values of R-C matrix, which represent the highest dominance over on the other factors. On the other hand, Smart Economy(C1), Smart People(C2), Smart Living(C6) has negative values of R-C, which means these criteria are effected from the other criteria.

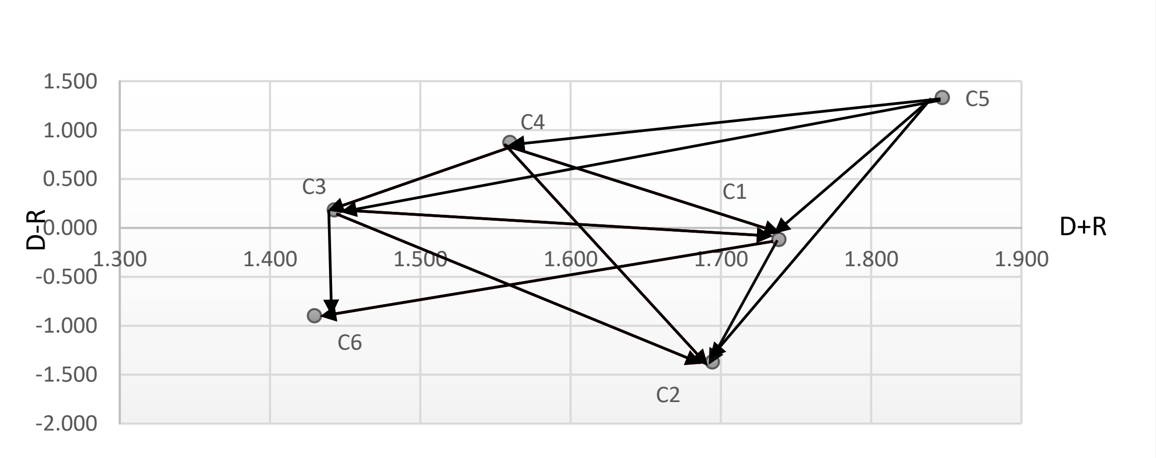

Figure 1. Cause and effect relationship diagram

5.2. AHP Application

Pair-wise comparison matrix given below is obtained by getting geometric mean of three experts' evaluation values.

	S.Economy	S. People	S.Governance	S.Mobility	S.Environment	S.Living
Smart Economy	1.00	1.59	0.44	1.06	0.58	0.75
Smart People	0.63	1.00	0.44	0.64	0.38	0.35
Smart Governance	2.29	2.29	1.00	1.59	1.31	1.49
Smart Mobility	0.94	1.55	0.63	1.00	0.71	1.06
Smart Environment	1.71	2.62	0.76	1.41	1.00	1.44
Smart Living	1.34	2.88	0.67	0.94	0.69	1.00

Table 8. Pair-wise comparison matrix

Normalized pair-wise comparison matrix is obtained by using equation (9) in 0.

	S.Economy	S. People	S.Governance	S.Mobility	S.Environment	S.Living
Smart Economy	0.13	0.13	0.11	0.16	0.12	0.12
Smart People	0.08	0.08	0.11	0.10	0.08	0.06
Smart Governance	0.29	0.19	0.25	0.24	0.28	0.25
Smart Mobility	0.12	0.13	0.16	0.15	0.15	0.17
Smart Environment	0.22	0.22	0.19	0.21	0.21	0.24
Smart Living	0.17	0.24	0.17	0.14	0.15	0.16

Table 9. Normalized pair-wise comparison matrix

Priority values given in Table 10 which also named as the local weights is the average value of each row of normalized pair-wise comparison matrix.

Criteria	Priority Values
Smart Economy	0.13
Smart People	0.08
Smart Governance	0.25
Smart Mobility	0.15
Smart Environment	0.22
Smart Living	0.17

Table 10. Priority Values

According to the Table 11 and Equation(11) $\lambda_{max} = 6.06$ is obtained.

Priority Values	Overall Priority Values	Lambda
0.13	0.79	6.06
0.08	0.51	6.04
0.25	1.52	6.06
0.15	0.90	6.06
0.22	1.31	6.07
0.17	1.05	6.07

Table 11. Calculation of consistency index

Consistency Index(CI= 0,013) and Consistency Ratio(CR=0,01) is calculated by using Equation (10) and (12). Because CI is less than 0.1, it is accepted that pair-wised comparison values are compatible and priority values can be used for interpretation.

5.3. BWM Application

The comparative priorities of the criteria were determined according to the 1-9 scale (1: Equal; 9: Highest). All of the evaluations were created with the logic of determining the priority of the most important criterion over other criteria.

Criteria Number = 6	Criterion 1	Criterion 2	Criterion 3	Criterion 4	Criterion 5	Criterion 6
Names of Criteria	C1	C2	C3	C4	C5	C6
Select the Best	C3					
Select the Worst	C2					
Best to Others	C1	C2	C3	C4	C5	C6
C3	3	9	1	5	4	8
Others to the Worst	C2					
C1	6					
C2	1					
C3	8					
C4	4					
C5	5					
C6	2					
Weights	C1	C2	C3	C4	C5	C6
	0.183	0.046	0.457	0.110	0.137	0.068
Ksi*	0.091					

Table 12. Calculation of criterion weights

In line with the opinions of experts, calculations were made separately for each criterion and opinion via the Excel-Solver program. While calculating the weights, the deviation values from full consistency in the mathematical model were obtained as "0" in all model solutions. Deviation from full consistency is the deviation of the calculated weighting coefficients from the estimated comparative priorities of the criteria. The weights are given in the table below. The arithmetic averages of the three decision makers were finally taken.

BWM							
Experts	**Criteria**	**Criteria**	**Ranking**	**Comparative priority best**	**Comparative priority best**	**Weights**	**Ksi***
EXPERT1	Smart Economy	C1	5	7	2	0.070	0.071
EXPERT1	Smart People	C2	6	9	1	0.039	0.071
EXPERT1	Smart Governance	C3	2	2	7	0.247	0.071
EXPERT1	Smart Mobility	C4	1	1	9	0.422	0.071
EXPERT1	Smart Environment	C5	4	5	4	0.099	0.071
EXPERT1	Smart Living	C6	3	4	5	0.123	0.071
EXPERT2	Smart Economy	C1	5	7	2	0.070	0.071
EXPERT2	Smart People	C2	3	4	5	0.123	0.071
EXPERT2	Smart Governance	C3	4	5	4	0.099	0.071
EXPERT2	Smart Mobility	C4	6	9	1	0.039	0.071
EXPERT2	Smart Environment	C5	1	1	9	0.422	0.071
EXPERT2	Smart Living	C6	2	2	7	0.247	0.071
EXPERT3	Smart Economy	C1	2	3	6	0.183	0.091
EXPERT3	Smart People	C2	6	9	1	0.046	0.091
EXPERT3	Smart Governance	C3	1	1	8	0.457	0.091
EXPERT3	Smart Mobility	C4	4	5	4	0.110	0.091
EXPERT3	Smart Environment	C5	3	4	5	0.137	0.091
EXPERT3	Smart Living	C6	5	8	2	0.068	0.091

Table 13. Calculation of criterion weights

5.4. FUCOM Application

In this section, the criteria for smart city criteria selection with the FUCOM method will be weighted. In line with the opinions received by three experts, calculations will be made separately for each criterion. The ranking and comparative priorities of three decision maker for the main criteria are given in the table below.

Criteria Number= 6	Criterion1	Criterion2	Criterion3	Criterion4	Criterion5	Criterion6
Names of Criteria	C1	C2	C3	C4	C5	C6
Ranking	2	6	1	4	3	5
Criteria(Ranking of Importance)	C3	C1	C5	C4	C6	C2
Comparative Priority	1	3	4	5	8	9
Weights	C3	C1	C5	C4	C6	C2
	0.495	0.165	0.124	0.099	0.062	0.055
TTS (χ)	0.000					

Table 14. Calculation of criterion weights

The following weights were calculated with the Excel–Solver solution made for each expert.

FUCOM						
Experts	Criteria	Criteria	Ranking	Comparative priority	Weights	Ksi*
EXPERT1	Smart Economy	C1	5	7	0.065	0
EXPERT1	Smart People	C2	6	9	0.050	0
EXPERT1	Smart Governance	C3	2	2	0.227	0
EXPERT1	Smart Mobility	C4	1	1	0.454	0
EXPERT1	Smart Environment	C5	4	5	0.091	0
EXPERT1	Smart Living	C6	3	4	0.113	0
EXPERT2	Smart Economy	C1	5	7	0.065	0
EXPERT2	Smart People	C2	3	4	0.113	0
EXPERT2	Smart Governance	C3	4	5	0.091	0
EXPERT2	Smart Mobility	C4	6	9	0.050	0
EXPERT2	Smart Environment	C5	1	1	0.454	0
EXPERT2	Smart Living	C6	2	2	0.227	0
EXPERT3	Smart Economy	C1	2	3	0.165	0
EXPERT3	Smart People	C2	6	9	0.055	0
EXPERT3	Smart Governance	C3	1	1	0.495	0
EXPERT3	Smart Mobility	C4	4	5	0.099	0
EXPERT3	Smart Environment	C5	3	4	0.124	0
EXPERT3	Smart Living	C6	5	8	0.062	0

Table 15. Calculation of criterion weights

5.5. Compare

All methods applied in this study are widely used techniques in the literature, has some advantages and also disadvantages. Among these methods, FUCOM is required minimum pair-wise comparisons with n-1 for a decision problem with n criteria. 2n-3 pair-wise comparisons are made for BWM, while n(n-1)/2 pair-wise comparisons are made in AHP method. These all methods are widely used since they are easy to apply. However, the number of criteria are getting larger, it will be complicated to solve non-linear model for BWM. On the other hand, it is possible to calculate measurement of inconsistency for pair-wise comparisons in AHP, BWM and FUCOM while DEMATEL method has no measurement of inconsistency(Saha,Roy,2021). However, the strong side of DEMATEL is that representing the relation among criteria.

When the outcomes are investigated, it is seen that the results BWM and FUCOM are exactly the same and also AHP results are very similar as well. The ranking of the smart city criteria which are Smart Economy (C1), Smart People (C2), Smart Governance (C3), Smart Mobility (C4), Smart Environment (C5), Smart Living (C6) based on final results shown inTable 16

AHP	DEMATEL	BWM	FUCOM
C3	C5	C3	C3
C5	C2	C5	C5
C6	C4	C4	C4
C4	C1	C6	C6
C1	C6	C1	C1
C2	C3	C2	C2

Table 16. Comparison of applied models

Figure **2** represents the comparison of the criteria based on importance levels. The figure shows that Smart Governance is the most important criteria according to the AHP,BWM and FUCOM methods, while Smart Economy is the most important criteria according to the DEMATEL method. At the same time, Smart people are the least important factor according to the AHP, BWM and FUCOM methods, while Smart Governance is the least important factor according to the DEMATEL.

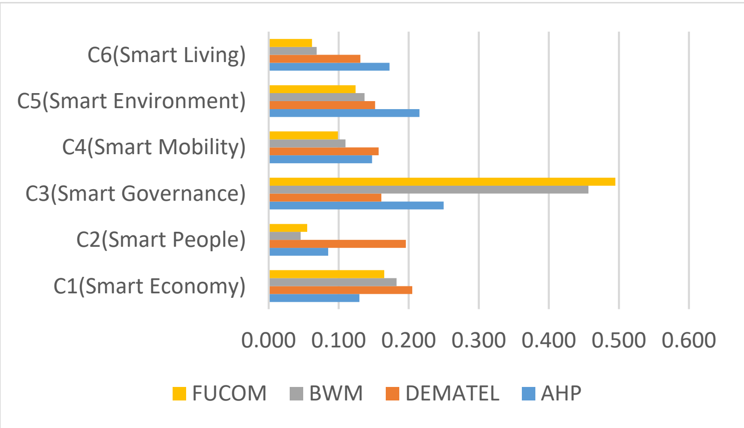

Figure 2. Comparison of the Criteria based on importance levels

6. Conclusion and Evaluation

The desire to live in cities, which was felt more after the 1980s, and especially the alternative lifestyles and changing habits offered by the technologies produced after the 2000s, increase the speed of urbanization day by day. By 2025, it is estimated that approximately 58% of the world's population will live in cities, and this rate will exceed 81% in many developed regions and cities (Amarnath et al., 2018). This will lead to difficulties in providing basic urban services to citizens sustainably. Therefore, it is almost a necessity to establish smart city systems in order to meet the increasing and complex needs with limited resources. Today's cities contain all kinds of imbalances. For this reason, if urban spaces cannot be managed appropriately, undesirable results may occur with the domino effect, considering that most of the population lives in cities. Many authors in the literature have limited the framework of the smart city as a “solution to urban challenges”.

Therefore, it has been argued that the way to put into effect a good smart city model is through good urban planning that takes advantage of the opportunities of technology. In this context, for a city to be considered a smart city; It is necessary to establish a system comprising a smart economy, smart governance, smart mobility, smart environment, smart life, smart technology, smart infrastructure, and most importantly, smart citizens who will accept and use all these smart solutions. In this study, the weights of the smart city components, which are important in qualifying a city as smart, are examined with different criterion weighting methods. Smart cities require a very serious cost and a strong infrastructure in information and communication technologies. When the reflections of these global developments on Turkiye are evaluated; It is seen that cities in Turkiye are affected by these developments and almost every city includes smart city applications, though very few.

It can be said that especially cities with high-income levels are one step ahead and many smart city applications have been implemented. It is seen that these applications are generally smart traffic, smart parking systems, information services, map drawing with unmanned aerial vehicles, applications for the disabled, and electricity generation in partly solar energy panels. In this context, it can be said that smart city applications in Turkiye are limited, but the fact that they have started is promising for the future. As a result, the future of human beings will be shaped in smart cities, new generation cities will focus more on the internet and user-oriented services, and information communication technologies and infrastructures will make the biggest contribution to smart cities. It is not difficult to predict that the countries/cities that invest in smart urban solutions will be very profitable in the future and that there will be huge differences in development and change between them and the countries that do not invest. Because smart cities necessitate economic and social change and transformation for both citizens and society.

In this study, these six main smart city components is weighted by one of the most widely used MCDM techniques AHP, DEMATEL and more recently developed techniques BWM and FUCOM.

The fact that the results are the same according to two different subjective criteria weighting methods, BWM and FUCOM, that the smart city criteria weights are in the same order of importance, show that the results are consistent and reliable, but also show that the expert opinions are correct and consistent according to the result of BWM and FUCOM methods. AHP results is also very similar to these methods results as well. DEMATEL method provides the direct and indirect relations among the criteria.

Smart governance is the most important criteria according to the AHP, BWM and FUCOM methods. Smart people is the least important factor according to the AHP, BWM and FUCOM methods. On the other hand, Smart Governance(C3), Smart Mobility(C4) and Smart Environment(C5) represent the highest dominance over on the other factors while Smart Economy(C1), Smart People(C2), Smart Living(C6) are effected from the other criteria based on DEMATEL method.

References

Adali, E.A.(2022), Assessment of European cities from a smartness perspective: An integrated grey MCDM approach, Sustainable Cities and Society ,84, 104021

Akgül, M. K. (2013). "Kentlerin e-Dönüşümü Akıllı Kentler S.291, http://anahtar.sanayi.gov.tr /tr/news/kentlerin-e-donusumu-akillikentler/416 (Access date: 15.12.2017). Verimlilik Dergisi.

Akıllı Kentler Nedir(Online). https://www.akillikentler.org/akilli-kentler-nedir-7.html

Akıllı Kent Yonetim Sistemleri(Online) https://www.akillikentler.org/akilli-kent-yonetim-sistemleri-202.html

Aksoğan, M., & Duman, M. Ç. (2018). Akıllı Şehir Uygulamaları; Malatya Örneği. 1. Uluslararası Battalgazi Multi Disipliner Çalışmalar Kongresi Tam Metin Kitabı Cilt I (s. 183-202). Malatya: İktisadi Kalkınma ve Sosyal Araştırmalar Enstitüsü. 1. Uluslararası Battalgazi Multi Disipliner Çalışmalar Kongresi Tam Metin Kitabı Cilt I (s. 183-202). Malatya: İktisadi Kalkınma ve Sosyal Araştırmalar Enstitüsü.

Alkan, T. (2015). "Akıllı Kentler ya da 21. Yüzyıl Şehirleri". Bilişim Dergisi(182), s. 70-77.

Armağan, M. V. (2018, Eylül). Bilgi Toplumunda Akıllı Şehirler ve Katılımcı Yurttaşlık. Yüksek Lisans Tezi.

Arsu, T. &. (2021). Personel Seçim Sürecinde Kullanılan Kriterlerin Best-Worst Metodu (Bwm) İle Değerlendirilmesi. Üçüncü Sektör Sosyal Ekonomi Dergisi, s. 1949-1967.

ASÜD. (2016). E-Haber, https://www.asuder.org.tr /akilli-sehir-nedir-turkiyede-akilli-se"Akıllı Şehir Nedir? Türkiye'de Akıllı Şehir Uygulamaları". adresinden alındı

Ateş, M. (2018). Akıllı Şehir Kavramı: Kentsel ve Mekansal Boyutu Burdur Mehmet AKif Ersoy Üniversitesi. 7. Türkiye Lisansüstü Çalışmalar Bildiriler Kitabı-III (s. 117-130). Burdur: Burdur Mehmet AKif Ersoy Üniversitesi.

Biçakcı, H. (2014). Yeni Kent Tasarımı ve Akıllı Kentler: Karşılaştırmalı Bir Analiz ve Samsun İçin Model Önerisi. Yüksek Lisans Tezi Ondokuzmayıs Üniversitesi Sosyal Bilimler Enstitüsü.

Bilgiç, S., Torğul, B., & Paksoy, T. (2021). Sürdürülebilir Enerji Yönetimi İçin BWM Yöntemi İle Yenilenebilir Enerji Kaynaklarının Değerlendirilmesi. Verimlilik Dergisi, 95-110.

Bilici, Z., & Babahanoğlu, V. (2018). "Akıllı Kent Uygulamaları ve Konya Örneği". Akademik Yaklaşımlar Dergisi, 9(2), s. 124-139.

Bulut, C. (2018). Bulut Bilişim (Cloud Computing) Nedir? E-Makale, https://www.endustri40.com/bulut-bilisim-cloud-computing-nedir/, (Access date : 19.03.2019).

Canlı, E. (2019). Dijital Çağın Dönüşen Kentleri Akıllı Kentler: Londra Örneği.

Cerci, İ. N. (2015). Akıllı kentler, Bir İhtiyaç ve Geleceğe Dönük Bir Yaşam Modelidir. Bilişim Dergisi, s. 196-201.

Chang, C.W. et. al.(2007), An application of AHP and sensitivity analysis for selecting the best slicing machine, Computers & Industrial Engineering, vol.52 pp. 296–307

Deloitte. (2016). Akıllı Şehir Yol Haritası. E-Makale, https://www.sehirsizin.com/Documents/ DeloitteVodafone-Akilli-Sehir-Yol-Haritasi.pdf.

Demirci, E., Kılıç. H.S.(2019), Personnel Selection based on integrated Multi-Criteria Decision Making Techniques, Int.Adv.Eng. Pure Sci., 2:163-178

Ecer, F. (2021). FUCOM sübjektif ağırlıklandırma yöntemi ile rüzgâr çiftliği yer seçimini etkileyen faktörlerin analizi. Pamukkale Üniversitesi Mühendislik Bilim Dergisi, 24-34.

Elvan, L. (2017). Akıllı Şehirler: Lüks Değil İhtiyaç. İTÜ Vakfı Dergisi, s. 6-9.

Fortune. (2017). "Yol Açın! Akıllı Şehirler Geliyor". http://www.fortuneTurkiye.com/yol-acin-akilli sehirler-geliyor-45878, (Erişim Tarihi: 28.12.2017).

Giffinger, R. (2007). "Smart Cities Ranking Of European Medium-Sized Cities". Vienna: Vienna University of Technology Research Report.

Giffinger, R., & Gudrun, H. (2010). Smart Cities Ranking: An Effective Instrument For The Positioning Of The Cities. ACE: Architecture, City and Environment(12), s. 7-26.

Gürsoy, O. (2019). Akıllı Kent Yaklaşımı ve Türkiye'deki Büyükşehirler İçin Uygulama İmkanları. Yüksek Lisans Tezi.

Harrison, C., & Donnelly, I. A. (2011). A Theory of Smart Cities. Proceedings of the 55th Annual Meeting of the ISSS, (s. 1-15). Hull, UK.

Hayek, P.(2022), Recent developments in smart city assessment: A bibliometric and content analysis-based literature review, Cities 126, 103709

ISBAK. (2017, 12 28). Akıllı Şehrin Mimarı: İSBAK . E-Makale, http://isbak.istanbul/akilli-sehirler-3/, (ErişimTarihi: 28/12/2017).

İstanbul Büyükşehir Belediye Başkanlığı. (2017). İBB Türkiye'nin İlk Uluslararası Standartta Veri Merkezini Kurdu. E-Haber, https://www.ibb.istanbul/News/Detail/34231, (Access date: 30.12.2017).

Kabak, M., Çınar, Y.(2020), Çok Kriterli Karar Verme Yöntemleri, MS Excel Uygulamalar, Nobel yay., Ankara

Koca et.al. (2021), Evaluation of the smart city: Applying the dematel technique, Telematics and Informatics 62, 10162

Lai, S.L. et.al.(2002), Group Decision Making in a multiple criteria environment: A case using the AHP in software selection, European Journal of Operational Research 137(2002),134-144

Mangır, F. (2016). "Smart City: Strategies For Local Governments: The Case Of Konya In Turkiye". Selçuk Üniversitesi Sosyal Bilimler Meslek Yüksekokulu Dergisi(41.Yıl Özel Sayısı), s. 17-36.

Orselli, E., & Akbay, C. (2019). Teknoloji ve Kent Yaşamında Dönüşüm: Akıllı Kentler. Uluslararası Yönetim Akademisi Dergisi, 2(1), s. 228-241.

Ozkaya,G., Erdin,C.(2020), Evaluation of smart and sustainable cities through a hybrid MCDM approach based on ANP and TOPSIS technique, Heliyon6, Volume 6, Issue 10, October 2020, e05052, https://doi.org/10.1016/j.heliyon.2020.e05052

Pamucar, D., & Ecer, F. (2020). Prioritizing the weights of the evaluation criteria under fuzziness: The fuzzy full consistency method–FUCOM. Facta Universitatis Series : Mechanical Engineering, 419-437.

Pamucar, Stevic, D., & Sremac, S. (2018). A new model for determining weight coefficients of criteria in MCDM models: Full consistency method (FUCOM), Symmetry, 1-22.

Podvezko, V.(2019), Application of AHP technique, Journal of Business Economics and Management, 10(2): 181–189

Rani, S., Kumar, R.(2022), Bibliometric review of actuators: Key automation technology in a smart city framework, Materials Today: Proceedings 60, pp. 1800–1807.

Rezaei, J. (2015). Best-Worst Multi-Criteria Decision-Making Method. Omega, 49-50.

Rezaei, J. (2016). Best-Worst Multi-Criteria Decision-Making Method: Some Properties And A Linear Model. Omega, s. 126-130.

Saaty, T.L. (1980), The Analytic Hierarchy Process: Planning, Priority Setting, and Resources Allocation, McGraw-Hill, New York, NY.

Saaty, T.L. (2008), "Decision making with the analytic hierarchy process", International Journal of Services Sciences, Vol. 1 No. 1, pp. 83-98.

Saha, A., Roy, R.(2021), An Integrated approach to identify suitable areas for buit-up development using GIS-based multicriteria analysis and AHP in Siliguri planning area, India, SN Applied Sciences, Springer Nature Journal 3:395 | https://doi.org/10.1007/s42452-021-04354-5

Singhal, D. et. al.(2018), DEMATEL approach for analyzing the critical factors in remanufacturing process, Materials Today: Proceedings 5 (2018) 18568–18573

Shapiro, J. M. (2006). Smart Cities: Quality Of Life, Productivity, And The Growth Effects Of Human Capital. The Review of Economics And Statistics(2), s. 324-335.

Si, S.L. et. al. (2018), DEMATEL Technique: A Systematic Review of the State-of-Art Literature on Methodologies and Applications, Hindawi Mathematical Problems in Engineering, vol. 2018, Article ID 3696457 | https://doi.org/10.1155/2018/3696457

Uçar, A., Şemşit, S., & Negiz, N. (2017). Avrupa Birliği Akıllı Kent Uygulamaları ve ve Türkiye'deki Yansımaları. SDÜ İktisadi ve İdari Bilimler Fakültesi Dergisi(Kayfor15 Özel Sayısı), s. 1785-1798.

Varol, Ç. (2017). Sürdürülebilir Gelişme de Akıllı Kent Yaklaşımı : Ankara'daki Belediyelerin Uygulamaları. Çağdaş Yerel Yönetimler(1), s. 43-58.

Yenkar, P.P., Sawarkar, S.D., A novel ensemble approach based on MCC and MCDM methods for prioritizing tweets mentioning urban issues in smart city, Kybernetes , Emerald Publishing Limited 0368-492X DOI 10.1108/K-08-2021-0785. https://doi.org/10.1108/K-08-2021-0785