Chapter 8
Making Opportunities for Developing Smart Cities Using Artificial Intelligence

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Abstract Smart Cities are one of the non-exclusive layers of modern social policy, circular economy, and urban development and the subject of contemporary society and scientific researchers. The significant lifestyle changes have invoked us to think to build more sustainable and Smart Cities, the ones able to withstand the rapid evolution of our surroundings. This chapter aims to explore key indicators as the opportunities for the development of Smart Cities in a pandemic COVID-19 using artificial intelligence. It provides a theoretical overview of scientific insights into the development and application of the Smart City concept, listing possible obstacles. In the identification of key indicators that are important prerequisites for the development of a Smart City, multi-criteria decision-making (MCDM) were applied: analytic hierarchy process *(*AHP), triangular fuzzy analytic hierarchy process (FAHP), triangular interval type-2 fuzzy sets (IT2FS), trapezoidal FAHP, and trapezoidal IT2FS as methods of fuzzy logic. Based on six groups of the criterion, and a large number of sub-criteria, the dominant indicators were singled out as the development of the legislative and strategic framework of the Smart City platform and its application in the COVID-19 pandemic circumstances, as well as the standardization of ICT and ICT management. The presented model could help in the policy-making process as the starting point of discussion between stakeholders, as well as citizens in the final decision of adoption measures and best-evaluated options.

Keywords Smart Cities · Artificial intelligence · Multi-criteria decision-making

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Introduction

Although the centers of culture, science, and education, cities are increasingly mentioned in a negative context compared to rural areas. They are in the public focus, primarily due to the problems that accompany urban environments – from being the biggest environment polluters to being the biggest energy consumers (Moser et al. 2014). The increased needs of contemporary man in the context of comfort, high standard of living, and financial security have significantly contributed to the concentration of population in cities, shifting from rural to urban areas, but also attracting migration to economically developed areas, even outside the borders of the country where people used to live. The consequences caused by the continuous urbanization process, neglect of care for the surroundings, and irrational consumption of resources, some of which endanger the quality of the environment, are just some of the problems that urban areas face (Wang et al. 2020). Rigorous lifestyle changes have prompted us to consider innovative ways in creating a more sustainable society, able to withstand the rapid development of our environment. Qualitative management based on sustainable strategies, accountability, transparency, citizen participation, and reducing emissions, energy efficiency, waste management, and mobility are significant factors in ensuring sustainable progress (Salvioni and Almici 2020).

The Smart City concept is one step toward it. Smart Cities are a subject of contemporary society and scientific researchers since they have become one of the nonexclusive layers in modern social policy conducting, circular economy, and urban development. The Fourth Industrial Revolution and digitalization are a prerequisite for all planned activities in the managing framework of urban environments, their sectors, and infrastructure. In the search for solutions that will accelerate the monitoring of urban processes, improve infrastructure systems, and simplify daily activities, information-communicative technologies (ICT) are becoming an important tool in creating future technical patents and smart grids (Monzon 2015).

The planet has become a global market in which countries compete in innovation and sustainability of created technological products, personnel expertise, scientific achievements, and strong companies. The Smart City model varies from country to country, depending on the different political, social, and economic factors. While developed countries are proud of inventions that use sensors and artificial intelligence, require almost no manual human control, and make extensive use of available resources, many developing countries are still nowhere near strategies that accurately implement the Smart City concept in future urban development.

The whole world is currently actively committed to the fight against the pandemic caused by the COVID-19 virus, and this disorder temporarily reduces development plans in creating smart environments. Simultaneously, the pandemic is increasingly fostering reflections on developing existing digital infrastructure more innovatively and the search for smart solutions that will help, both in the long-term way to eliminate the virus and in the short-term when it comes to treating patients. The pandemic has shifted boundaries in the way we think about sustainable future development and has significantly changed priorities in creating sustainable living environments.

This chapter examines the opportunities for developing Smart Cities using artificial intelligence. It provides a theoretical overview of current scientific insights on the development and implementation of the Smart City concept, providing a discussion of possible barriers. The research tries to identify crucial indicators as significant prerequisites for Smart City development using multi-criteria analysis. Given the complexity of the problem we are investigating and its multidimensionality, we opted for the application of the AHP method, triangular FAHP, triangular IT2FS, trapezoidal FAHP, and trapezoidal IT2FS as the methods of fuzzy logic.

The chapter is structured as follows. In the next section, the Smart City concept from idea to reality, defining indicators for the formation of Smart City, is presented. The third section gives the relation between Smart City and artificial intelligence. The fourth section assesses new COVID challenges for urban areas and COVID as a catalyst for Smart Cities. The fifth chapter deals with the methodology of fuzzy numbers and analysis, a tool of artificial intelligence in the selection of key indicators. The sixth chapter gives numerical results, and the seventh contains discussion and recommendations. The conclusion is in the last section.

Smart City Concept: From Idea to Reality

In response to the growing challenges of urbanization, the Smart City movement connects urban theories with new scientific and technological achievements, offering solutions to contemporary urban problems. Developed in the 1990s in the USA, the concept was first mentioned in the context of "growing cities in a smart way" and promoting the "compact city" model to prevent agglomeration growth of urban spaces and develop an awareness of environmental issues (Wey and Hsu 2014). In that sense, experts dealing with urban planning have recognized important indicators in creating new and remodeling existing urban areas, which are still considered the main postulates of urban development (Kotharkar et al. 2014; Al-Shouk and Al-Khfaji 2018):

- The formation of mixed-use urban centers
- Differentiating motor traffic from a pedestrian in a narrow city center and other public areas promoting pedestrian movement and the use of bicycles as a means of transport, promoting healthy living and reducing emissions
- Socioeconomic diversity of the population with planning that offers all social classes the same urban conditions and facilities, without the possibility of gentrification
- Efficient use of all resources.

Linking the epithet "smart" to the city, as the core from which sustainability must be drawn, happened in 1994 (Dameri and Cocchia 2013). Since the EU started using the "smart" label in 2010 to qualify sustainable urban development projects, the concept has moved to a wider application (Susantia et al. 2016). “Smart” devices, applications, roads, phones, lights, and buildings have become part of our everyday life. Internet search has completely suppressed the importance of libraries as institutions (Koca-Baltić and Momčilović-Petronijević 2020), sensors built into phones inform us about weather-meteorological conditions, applications for free parking space, the arrival time of public transport, and traffic route that is less loaded (Park et al. 2018).

Technological development has pushed the boundaries when thinking about smart sustainable cities. Innovative solutions have become a tool to gather the information that would help detect current urban problems. Besides, they can be a successful tool to improve urban sectors and infrastructure. With the notion of a Smart City, artificial intelligence has developed to justify the innovative solutions, reached with the creativity and knowledge of man, but also with the application of devices and robotics (Voda and Radu 2019). Smart City has materialized in the film industry and seen through the automatization, the application of aircraft, and the replacement of humans with robotic power.

The interpretation of a Smart City in the literature is different – from representing entities completely dependent on modern technologies to a form of sustainable city that has a clearly defined planning strategy, quality management, good communication between government and citizens, and the “intelligent” way for self-improvement and resilience (Stratigea 2012; Milošević et al. 2021a). There is no precise definition of a Smart City. According to Hall (Mosannenzade and Vettorato 2014), “a city that monitors and integrates conditions of all of its critical infrastructure, 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” can be considered as the smart one. Generally accepted (Li et al. 2019), “the city can be considered as smart when investments in human and social capital, and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and high quality of life, with a wise management of natural resources through participatory governance.”

According to different authors and studies, a Smart City represents:

- A global movement developed parallel with the Fourth Industrial Revolution and reflected largely in the scientific field of urbanism and spatial planning (Bibri 2019).
- A city, usually of medium size (100–500 k inhabitants) (Lazaroiu and Roscia 2012), created by various actors: government, public-private partnership, investors, IT and other types of companies, and scientists but also the citizens themselves.
- A sustainable system that improves the quality of life in the city, urban water, energy, transport, construction, and infrastructure management sectors (Talari et al. 2017).

- A product of the Internet of Things (IoT) platform, which uses big data, artificial intelligence platforms, sensors, and applications to improve existing urban environments (Yadav et al. 2019).
- Livable urban area, with a high degree of resistance to current changes (Milošević et al. 2019). Technological innovations within the development of a Smart City in different segments of everyday life can be systematized as follows (Milošević et al. 2020a; Milošević et al. 2017; Milošević et al. 2021b):
- *Technological innovations in education* – the creation of online educational platforms for distance learning, digital book and lecture formats, online knowledge testing.
- *Technological innovations in healthcare* – the creation of an integrated information system, development of telemedicine, providing medical care online, monitoring the patient's condition using GPS bracelets.
- *Technological innovations in housing* – construction of "smart" homes, application of "smart" energy-saving devices, kinetic furniture, control of heating, cooling, air conditioning systems using sensors.
- *Technological innovations in mobility* – GPS applications for tracking traffic jams, available parking spaces, and public transport, automated starting of motor vehicles, "smart" transport logistics, and "smart" services.
- *Technological innovations in architecture* – digitization of cultural heritage, application of augmented reality software to investigate the characteristics of monuments that were previously demolished, application of modern software for detection of endangering the stability of existing structures, application of GIS and BIM systems for preserving and restoring architectural heritage in urban areas.
- *Technological innovations for environmental monitoring* – monitoring of water and energy consumption, innovative systems for the conversion of one form of energy into another.
- *Technological innovations in culture and tourism* – virtual sightseeing, digital presentation of the tourist offer.
- *Technological innovations in governing* – e-government and e-portals for communication with citizens, digital public administration, and services. The development strategy is a precondition for transforming the existing city into a "smart" one. In creating a platform for Smart City development and finding new opportunities to overcome barriers, there are different levels at which "smart" solutions can be implemented. Degree from general to more specific is proposed, starting from the development of the real estate, through the development of basic infrastructure, to improving life services and lifestyle.

Levels represent an attempt to introduce a hierarchical approach to the development of a Smart City concept as follows (Milošević et al. 2019):

- Development of real estate – includes implementation of spatial and urban planning, considers the needs of citizens, geolocation plans, and urban development of the city in terms of basic needs for accommodation and life.

- Development of basic infrastructure – the task is to develop the infrastructure for contemporary life and business, electricity, water, CT infrastructure, gas, sewerage, and road network.
- Development of "smart" infrastructure – the task is to add sensor systems and ICT, so the original infrastructure is transformed into a "smart" infrastructure that is capable to collect and analyze all the data for higher levels of management.
- Improving life service – development of classic and "smart" infrastructure and opportunities that can provide advanced services for citizens and organizations in the urban area.
- Improving lifestyle – a high standard of living provides low levels of pollution, acceptable economic costs, and higher living needs, as well as meeting individual needs with lifestyle, art, and culture

Defining Indicators for the Formation of Smart City

According to Griffing (Giffinger et al. 2007), a Smart City defines six dimensions: "smart" governing (A), "smart" economy (B), "smart" citizens (C), "smart" livability (D), "smart" mobility (E), and "smart" environment (F). Each dimension of a Smart City refers to several indicators that must be taken into account when creating Smart City development strategies.

Smart governing (A) refers to indicators related to planning and the legal framework for the implementation of management procedures. This group of indicators includes various forms of management and coordination of processes and actors in the city, with continuous monitoring of problems, and work on attempts to combat them and overcome them by new plans and strategies. Smart governing implies collaboration between different actors at different levels of the hierarchy, of which the most important is the relationship between government and citizens and the development of governance models that combine centrally defined regulation with actions and citizen participation (Glasmeier and Christopherson 2015; Mellouli et al. 2014).

It also refers to management in the ICT sector and the development of design and implementation of innovative solutions, as well as enabling transparent access to all data and services by citizens. Participatory decision-making within the framework of urban planning is extremely important for the management of smart environments. These factors are introduced as follows:

- Development of a legislative and strategic framework of Smart City platform and its implementation in COVID-19 pandemic circumstances – A_1
- Standardization of ICT and ICT management – A_2
- Public-private stakeholder partnership with active citizen's participation – A_3
- Higher data openness and transparency – A_4

Advances in technology follow the economic progress of the area. Smart economy (B) as one of the drivers of Smart City development in developing countries indicates economic factors related to financial analysis of investments and returns. Market growth, its productivity, and transformation, entrepreneurship, primarily created in the field of innovation and development of the IT sector, as well as various forms of financing from state and private budget funds aimed at designing and implementing new solutions and placing them on the national and international market, are the subject of numerous studies (Anand and Navio-Marco 2018; Sujata et al. 2016). Smart economy obtains:

- Entrepreneurship and innovation – B_1
- ICT sector development and job opportunities within it – B_2
- Higher funding for design and implementation of local and national "smart" solutions and initiatives – B_3
- Higher commercialization of innovative technologies assessment – B_4
- Higher technology competition on the national and international market – B_5
- Higher external funding for the Smart City platforms – B_6
- Development of e-commerce and e-business platforms – B_7
- Flexibility and market transformations – B_8

For the development of *smart governing* and *smart economy*, human capital is recognized through a group of indicators of *smart citizens* (C). Smart Cities need smart citizens who live in harmony with technology. The studies most often emphasize the importance of citizen participation in the activities of the urban area to create some support for current strategies for the development of a Smart City (Batty et al. 2012; Monfaredzadeh and Krueger 2015). The following indicators related to smart citizens were selected:

- Higher awareness level in the community – C_1
- High level of qualification and education – C_2
- Expressed flexibility, creativity, and openness to innovation – C_3
- Public confidence in modern solutions – C_4
- Higher citizen engagement – C_5
- Social and ethnic diversity – C_6

Smart livability in Smart Cities includes improved standards in many segments of everyday life (Lin et al. 2019; Sofeska 2017) and relates to:

- Personal safety – D_1
- Affordable housing – D_2
- Utilities, resource availability, and infrastructure equipment – D_3
- Job opportunities for all – D_4
- Improvement of the health, education, tourism, and culture sectors – D_5
- Regulation of privacy data – D_6
- Social integration – D_7

The smart mobility should include indicators that indicate cooperation and interconnection of all available modes of transport and infrastructure, fast exchange of information and data, and complete user orientation. They include (Cassandras 2017; Stephanedes et al. 2019):

- ICT infrastructure integration – E_1
- An innovative transportation system that favors non-motorized vehicles – E_2
- Local and international accessibility – E_3

Concern for the environment indicates various indicators necessary for sustainable development, as well as environmental imperative in the development of Smart Cities (Chen and Han 2018; Dostal and Ladanyi 2018). Smart environment includes different ways for energy-saving and natural resources protection:

- Sustainability consideration – F_1
- Environment protection and quality monitoring – F_2
- Urban recycling – F_3
- Use of renewable energy sources – F_4
- Construction of energy-efficient and smart facilities – F_5
- The decrease in energy consumption associated with new technologies – F_6
- Management and protection of the natural resource – F_7

Defining the Success for the Development of a Smart City

The successful transformation of cities into smart ones, and the further development of cities that already have the epithet smart, will result if the significant success factors of digital transformation are used, namely, people, processes, and technologies. The concept of a Smart City exists in recent decades, but so far, only a few ideas reach the stage of realization in terms of the public service that the city provides to its citizens. There are many reasons, but the omissions have mainly been attributed to infrastructure mismatches and legal barriers. It is necessary to hold wide-ranging postulates for any initiative, in the concept of a Smart City, to overcome this practice (Milošević et al. 2019):

- It is necessary to continuously engage citizens in creating and establishing a vision, using digital technologies, social networks, media.
- Wishes should not replace the defined project framework, and it is necessary to set measurable goals and choose appropriate indicators.
- The lean methodology should be applied wherever possible, especially if the development of new expansive infrastructure is needed.

Guided by Smart City postulates, it is necessary to harmonize the ambitions of local authorities. The process can be successful if the following conditions are obligatory tasks:

- It is necessary to choose the relevant indicators of Smart City development. This choice determines the quality of the results of the transformation process achieving benefits for citizens.

- In the Smart City establishing process, the responsibility and the ability to make quick decisions are capital to succeed. The initiative must have a powerful political consensus within local authorities.
- It is necessary to define the goals and enable continuous evaluation and quantification.
- The public-private cooperation model, especially of society, universities, and local government, could be a success guarantee when identifying the mutual benefits, and the economic effects are significant.
- In practice, the use of opportunities for Smart City development and long-term sustainability of all planning segments have to be achieved.
- Citizens as service users can provide valuable data, ideas, and comments such they are significant participants in a Smart City.

There are three steps to implementing a Smart City strategy moving forward:

1. They need to have a vision of what they want to deploy.
2. They have to make sure they have a monetization plan as to which areas they want to digitize: schools, universities, hospital.
3. They have to understand how to monetize this.

There is no need to constantly define Smart Cities and continue with the topic if it includes resilience or learning. It is necessary to focus on supporting government business and meet all kinds of economic, environmental, and social goals, using technology in the best way.

Smart City and Artificial Intelligence

Artificial intelligence (AI) is increasingly present in everyday life, which facilitates an accelerated lifestyle. In some routine tasks, AI makes life simpler and can make daily life in the city relieve, while consistent implementation and acceptance by the citizens are necessary. In the age of uncertainty and complexity that lies ahead, the continued adoption of AI is expected to continue and thus its impact on the sustainability of our cities (Yigitcanlar and Cugurullo 2020). The benefits of artificial intelligence are becoming more and more apparent thanks to the development of Smart Cities. The synergy of artificial intelligence and Smart City leads to the improvement of city life and the facilitation of human lives because that is their common goal. People are not even aware of how much artificial intelligence is present in their lives. A large amount of data generated in a Smart City would be useless without the use of AI. AI processes and analyzes data generated from machine-to-machine interaction in the context of Smart Cities, intelligent stores, and city infrastructure. There are countless smart apps in the city where AI can play a significant role: from improving traffic through smart parking management to the secure integration of autonomous vehicles and shuttles. Artificial intelligence is one of the main segments of Smart Cities and raises the city to a whole new level. AI collects a large amount of data to make recommendations, predict future events, and help make decisions. The future of Smart Cities is expected to be closely linked to AI use and will be present in almost all areas of the urban community, from traffic situations to citizen safety. Some research shows that respondents perceive artistic intelligence as a significant aspect influencing Smart City development (Voda and Radu 2018). The technology used has intended for people who use the technology, and the user experience is not universal, but everyone experiences it differently. The goal is for citizens to use the devices regardless of their education and technological knowledge. Significant opportunities are the intersection of AI development with Smart City development in theory and practice (Khan et al. 2018).

Big data as a part of artificial intelligence contributes to making the next decisions, determining the necessary resources, and identifying critical places thanks to the large amount of data it collects. Thanks to using AI in Smart Cities, it makes life easier for people; saves electricity; reduces exhaust fumes, the number of traffic accidents, and the number of thefts; and contributes to the quality of life in various areas. The application of artificial intelligence must be reliable. To safely implement AI respecting ethical principles and law, it is necessary to meet some requirements. The first requirement is human action and supervision, which provides that the system does not compromise human autonomy. It is imperative to provide an opportunity for people to intervene, although it is not always possible and desirable. The systems must be safe, accurate, and reliable, and technical stability and security should ensure safety checks at all times. Privacy and data management have guaranteed at all stages of the AI life cycle, and access to data involves a certain level of control. Transparency allows the user to explain the work of artificial intelligence. The application of artificial intelligence must affect social and environmental well-being in such a way as to promote the sustainability and ecological responsibility of the system and must take into account social performance as a whole.

COVID as a Catalyst for Developing Smart Cities

In 2020 the planet faced a new challenge that affects cities and completely changed our lives. The global pandemic caused by the COVID-19 virus forced us to make changes. Social distance has caused a shift from face-to-face to online communication and affected various aspects of urban life. A huge number of people all over the planet work from the space of their homes, while students continue their education mostly on the principle of distance learning. Living spaces are becoming working. It changes people's daily habits and creates the need for better organization of space and activities. The lack of socialization, as well as the impossibility of intimacy-closeness, significantly disturbed the mental health of people, affecting the personal dissatisfaction of citizens, but also insecurity and increased fear of health and life.

Most countries are in lock-down, closing their borders to visitors and introducing a limited movement of citizens. Restaurants, hotels, malls, spas, gyms, theaters, and museums have been out of order for months. This significantly influenced the economic downturn, causing job losses and the bankruptcy of smaller family businesses. Many states have also limited the number of people who gather outdoors, so city parks, squares, and other public areas are almost empty. The public transport reduces, while a healthy lifestyle, walking, and cycling are increasingly being promoted, raising the question of the future creation of urban solutions for public spaces. The need to create virtual activities that would occupy people's free time is recognized.

Developing Smart Cities are facing economic recovery, considering the huge budgets currently focused on helping citizens, small businesses, and the healthcare system, investing in medical equipment, drugs, and vaccines to immunize the population (Allam and Jones 2020). The reduction of the finance aimed at the technology innovation projects must be overcome by a more precise urban strategy. The question of the real possibilities for implementation of the sustainable "smart" solution in nearly future arise. Table 8.1 gives an overview of COVID challenges for Smart City development.

Firstly, it seemed that the concept of a Smart City threatens to stagnate in a COVID pandemic. Many governments have used the global situation as an advantage. Moving jobs to living spaces, and shifting business meetings, sales, shopping, education, entertainment, information to the online mode, there is a need to improve existing digital technology systems and develop new smart solutions. Paradoxically, social isolation has necessitated digital connectivity. Work and studying from home have caused the need for more online data, fewer system failures, faster networking, secure systems, easily accessible web portals, and high-quality available data (Abusaada and Elshater 2020).

COVID pandemic demonstrates how cities are resilient in crises when the existing database, information, and digital infrastructure enable. An increasing number of ICT companies offer platforms for learning and communication between

Table 8.1 COVID challenges for Smart City development

Governing	**Economy**
Limited access to certain services	Financial crisis
The need for different city management	Job loss/bankruptcy
The need for stronger ICT management	Redirecting funds to healthcare
Mobility	**People**
Reduced public transport	Increased need for ICT professionals
Reduced international transport	The need for health workers
The need for urban solutions that promote pedestrian and bicycle traffic	The need for new scientific advances
Livability	**Environment**
A sense of fear and insecurity	The need to preserve natural environments
The need to reorganize the healthcare and education sectors	Development of smart sustainable solutions
The need to renew culture and tourism	
Lack of social integration	

teachers and students, for business and other meetings, overcoming the barrier set by the lack of social gathering and travel. “Smart” applications are used around the world as a form of sending information to citizens when they may go outside their homes, as a way of communication between citizens and police authorities. Due to the impossibilities or limited possibilities of travel, but also visits to museums, theaters, and other cultural institutions, digitalization has enabled online transmission of numerous performances, film premiers, and virtual tours of museums and famous buildings around the world from the comfort of home.

COVID has become a powerful catalyst for the development of a Smart City. The application of “smart” solutions in the direct suppression of the pandemic is of importance. Artificial intelligence has enabled the production of “smart helmets” equipped with thermal cameras to detect potentially infected in the United Arab Emirates (Smart City Transformation in a post-COVID world 2020). The Australian government has launched the COVIDSafe App to track the contacts of the infected (Smart City Transformation in a post-COVID world 2020). Similar applications have been developed in the United Kingdom (England, NHS Test and Trace; Scotland, Test and Protect; Wales, Test, Trace, Protect; Northern Ireland, contact tracing service) (https://www.adalovelaceinstitute.org/blog/uk-contact-tracing-apps-the-view-from-northern-ireland-and-scotland/ n.d.). These applications use the principle of informing the citizens on a positive test, by asking them to log in to the application, leaving data and names of all persons with whom they had close contact. Many other platforms created by the urban health system management sector enable interactive daily monitoring of cases of infections, making online reports with data streamed on case numbers, age, gender, place of residence, and vaccination system, as well as the number of recovered, dead, and tested.

The pandemic has become a polygon for testing technological possibilities and moving the existing boundaries of digitalization. Due to the citizen’s distrust of governance and new technologies, there is a need to protect personal data. At the same time, we must not neglect the transparency of events and the engagement of citizens in the management of cities. On the other hand, the impossibility of meeting and talking live and discussing current issues may still be detrimental to the development of Smart City strategies, so there is a need for these projects to be fully digitized. Many online urban and architectural competitions encourage citizens to give their vision of post-COVID urban environments and thus offer new urban, architectural, technological, and other types of solutions that nurture partial social distancing, without reducing the quality of life in cities.

The pandemic has provided a new perspective on the way we plan our infrastructure. It depends on our abilities to re-invent and refine Smart City models to adapt to the precarious situation we are facing today. One option is an upgraded Smart City model – Smart^{p} City (p = pandemic ready). Smart City concepts must consider the following ways to resolve an uncertain situation:

- Touchless delivery of goods and food items
- Smart supply chain set up
- Touch-free inspection of patients

- Wireless inspection of civic violations
- Tackling cybercriminals and fake news
- Online education and examination infrastructure
- Touch-free sanitation and waste management
- A blockchain-enabled citizen tracking system
- E-voting infrastructure
- Smart intensive care units and isolation wards

The flexibility of the Smart City model is imperative. If the upgraded models are not synchronized and fail to adapt to new situations, the overall effort will fail further.

Methodology: Fuzzy Numbers and Analysis

In this paper, in addition to the crisp numbers used in the Analytic Hierarchy Process (AHP) method (Saaty 1980; Selimi et al. 2018; Milošević et al. 2016), triangular and trapezoidal fuzzy numbers are used when applying the Fuzzy Analytic Hierarchy Process (FAHP) (Srdjević and Medeiros 2008; Kahraman et al. 2014). The fuzzy number is a special fuzzy set $F = \{(x, \mu_F(x)), x \in R\}$ where $\mu_F(x)$: $R \to [0, 1]$ is a continuous function. The triangular fuzzy number (TFN) is denoted with $\tilde{T} = (l, m, u)$ (Milošević et al. 2020b). The membership function for TFN is:

$$\mu_F(x) = \begin{cases} \dfrac{x-l}{m-l}, & x \in \{l, m\} \\ \dfrac{u-x}{u-m}, & x \in \{m, u\} \\ 0, & otherwise. \end{cases} \tag{8.1}$$

In the trapezoidal FAHP method, trapezoidal fuzzy numbers (TrFN) denoted with $\tilde{M} = (l, m^l, m^h, u)$ are used (Ozkok 2019). The corresponding membership function is now

$$\mu_F(x) = \begin{cases} \dfrac{x-l}{m^l-l}, & x \in (l, m^l) \\ 1, & x \in (m^l, m^h) \\ \dfrac{u-x}{u-m^h}, & x \in (m^h, u) \\ 0, & otherwise. \end{cases} \tag{8.2}$$

If $m^l = m^h$, the trapezoidal fuzzy number is reduced to the triangular fuzzy number.

The laws for operations for an arbitrary two trapezoidal fuzzy numbers $\tilde{M}_1 = \left(l_1, m_1^l, m_1^h, u_1\right)$ and $\tilde{M}_2 = \left(l_2, m_2^l, m_2^h, u_2\right)$ are like in (Oztaysi 2015):

$$\tilde{M}_1 \oplus \tilde{M}_2 = \left(l_1 + l_2, m_1^l + m_2^l, m_1^h + m_2^h, u_1 + u_2\right) \tag{8.3}$$

$$\tilde{M} \Theta \tilde{M}_2 = \left(l_1 - u_2, m_1^l - m_2^h, m_1^h - m_2^l, u_1 - l_2\right) \tag{8.4}$$

$$\tilde{M}_1 \odot \tilde{M}_2 = \left(l_1 \cdot l_2, m_1^l \cdot m_2^l, m_1^h \cdot m_2^h, u_1 \cdot u_2\right) \tag{8.5}$$

$$\tilde{M}_1 \oslash \tilde{M}_2 = \left(l_1/u_2,\ m_1^l/m_2^h,\ m_1^h/m_2^l,\ u_1/l_2\right) \tag{8.6}$$

$$k\tilde{M}_1 = \left(kl_1, km_1^l, km_1^h, ku_1\right) \tag{8.7}$$

$$\sqrt[n]{\tilde{M}_1} = \left(\sqrt[n]{l_1}, \sqrt[n]{m_1^l}, \sqrt[n]{m_1^h}, \sqrt[n]{u_1}\right) \tag{8.8}$$

The operations for triangular fuzzy numbers are similarly defined.

Interval type-2 fuzzy sets (IT2FS) have been introduced in which the required number of computational operations is significantly reduced compared to T2FS while maintaining the good features possessed by T2FS. This chapter presents a comparative study of the FAHP with both independent approaches.

Type-2 fuzzy number (T2FN) is defined as a fuzzy set $G = \{((x, u), \mu_G(x, u)) \,\forall\, x \in X, \forall u \in I_x \in [0, 1], 0 \leq \mu_G(x, u) \leq 1\}$ where I_x denotes an interval in [0,1] (Chen and Lee 2010). Interval type-2 fuzzy number (IT2FN) is a special case of T2FN when the membership function is $\mu_G(x, u) = 1$.

The trapezoidal IT2FN is represented with

$$\tilde{\tilde{M}} = \left(\left(\tilde{M}^U : H_1\left(\tilde{M}^U\right), H_2\left(\tilde{M}^U\right)\right), \left(\tilde{M}^L ;, H_1\left(\tilde{M}^L\right);, H_2\left(\tilde{M}^L\right)\right)\right), \tag{8.9}$$

where $\tilde{M}^U = \left(l^U, \left(m^l\right)^U, \left(m^h\right)^U, u^U\right)$ and $\tilde{M}^L = \left(l^L, \left(m^l\right)^L, \left(m^h\right)^L, u^L\right)$ are TrFNs, while $H_1\left(\tilde{M}^U\right)$, $H_2\left(\tilde{M}^U\right)$, $H_1\left(\tilde{M}^L\right)$ and $H_2\left(\tilde{M}^L\right)$ represent the middle left and middle right vertex heights of the upper and the lower trapeze, respectively (see Fig. 8.1). Heights $H_1\left(\tilde{M}^U\right)$, $H_2\left(\tilde{M}^U\right)$, $H_1\left(\tilde{M}^L\right)$ and $H_2\left(\tilde{M}^L\right)$ belong to the interval [0,1]. For two trapezoidal IT2FNs, $\tilde{\tilde{M}}_1 = \left(\left(\tilde{M}_1^U; H_1\left(\tilde{M}_1^U\right); H_2\left(\tilde{M}_1^U\right)\right), \left(\tilde{M}_1^L; H_1\left(\tilde{M}_1^L\right); H_2\left(\tilde{M}_1^L\right)\right)\right)$ and $\tilde{\tilde{M}}_2 = \left(\left(\tilde{M}_2^U; H_1\left(\tilde{M}_2^U\right); H_2\left(\tilde{M}_2^U\right)\right), \left(\tilde{M}_2^L; H_1\left(\tilde{M}_2^L\right); H_2\left(\tilde{M}_2^L\right)\right)\right)$ arithmetic operations are as follows:

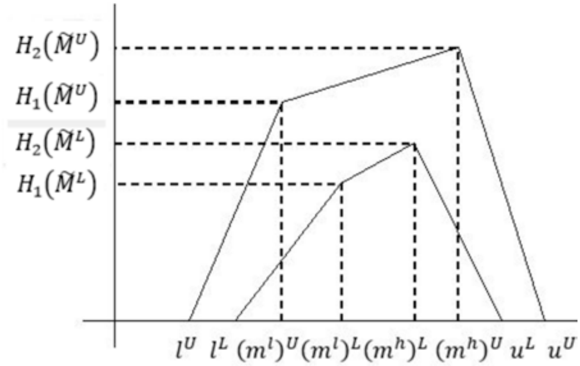

Fig. 8.1 Graphical representation of trapezoidal IT2FN

$$\tilde{\tilde{M}}_1 \oplus \tilde{\tilde{M}}_2 = \begin{pmatrix} \left(\tilde{M}_1^U \oplus \tilde{M}_2^U;, \min\left(H_1\left(\tilde{M}_1^U\right), H_1\left(\tilde{M}_2^U\right)\right);, \min\left(H_2\left(\tilde{M}_1^U\right), H_2\left(\tilde{M}_2^U\right)\right)\right), \\ \left(\tilde{M}_1^L \oplus \tilde{M}_2^L;, \min\left(H_1\left(\tilde{M}_1^L\right), H_1\left(\tilde{M}_2^L\right)\right);, \min\left(H_2\left(\tilde{M}_1^L\right), H_2\left(\tilde{M}_2^L\right)\right)\right) \end{pmatrix} \quad (8.10)$$

$$\tilde{\tilde{M}}_1 \Theta \tilde{\tilde{M}}_2 = \begin{pmatrix} \left(\tilde{M}_1^U \Theta \tilde{M}_2^U;, \min\left(H_1\left(\tilde{M}_1^U\right), H_1\left(\tilde{M}_2^U\right)\right);, \min\left(H_2\left(\tilde{M}_1^U\right), H_2\left(\tilde{M}_2^U\right)\right)\right), \\ \left(\tilde{M}_1^L \Theta \tilde{M}_2^L;, \min\left(H_1\left(\tilde{M}_1^L\right), H_1\left(\tilde{M}_2^L\right)\right);, \min\left(H_2\left(\tilde{M}_1^L\right), H_2\left(\tilde{M}_2^L\right)\right)\right) \end{pmatrix} \quad (8.11)$$

$$\tilde{\tilde{M}}_1 \odot \tilde{\tilde{M}}_2 = \begin{pmatrix} \left(\tilde{M}_1^U \odot \tilde{M}_2^U;, \min\left(H_1\left(\tilde{M}_1^U\right), H_1\left(\tilde{M}_2^U\right)\right);, \min\left(H_2\left(\tilde{M}_1^U\right), H_2\left(\tilde{M}_2^U\right)\right)\right), \\ \left(\tilde{M}_1^L \odot \tilde{M}_2^L;, \min\left(H_1\left(\tilde{M}_1^L\right), H_1\left(\tilde{M}_2^L\right)\right);, \min\left(H_2\left(\tilde{M}_1^L\right), H_2\left(\tilde{M}_2^L\right)\right)\right) \end{pmatrix} \quad (8.12)$$

$$\tilde{\tilde{M}}_1 \oslash \tilde{\tilde{M}}_2 = \begin{pmatrix} \left(\tilde{M}_1^U \oslash \bar{M}_2^U;, \min\left(H_1\left(\tilde{M}_1^U\right), H_1\left(\tilde{M}_2^U\right)\right);, \min\left(H_2\left(\tilde{M}_1^U\right), H_2\left(\tilde{M}_2^U\right)\right)\right), \\ \left(\tilde{M}_1^L \oslash \bar{M}_2^L;, \min\left(H_1\left(\tilde{M}_1^L\right), H_1\left(\tilde{M}_2^L\right)\right);, \min\left(H_2\left(\tilde{M}_1^L\right), H_2\left(\tilde{M}_2^L\right)\right)\right) \end{pmatrix} \quad (8.13)$$

$$\tilde{\tilde{M}}_1 = \left(\left(k\tilde{M}_1^U;, H_1\left(\tilde{M}_1^U\right);, H_2\left(\tilde{M}_1^U\right)\right), \left(k\tilde{M}_1^L;, H_1\left(\tilde{M}_1^L\right);, H_2\left(\tilde{M}_1^L\right)\right)\right) \quad (8.14)$$

$$\sqrt[n]{\tilde{\tilde{M}}_1} = \left(\left(\sqrt[n]{\tilde{M}_1^U}; H_1\left(\tilde{M}_1^U\right); H_2\left(\tilde{M}_1^U\right)\right), \left(\sqrt[n]{\tilde{M}_1^L}; H_1\left(\tilde{M}_1^L\right); H_2\left(\tilde{M}_1^L\right)\right)\right) \quad (8.15)$$

Similarly, the triangular IT2FN can be represented as follows:

$$\tilde{\tilde{T}} = \left(\left(\tilde{T}^U; H\left(\tilde{T}^U\right)\right), \left(\tilde{T}^L; H\left(\tilde{T}^L\right)\right)\right). \quad (8.16)$$

In formula (8.16), $\tilde{T}^U = \left(l^U, m^U, u^U\right)$ and $\tilde{T}^L = \left(l^L, m^L, u^L\right)$ are TFNs, while $H\left(\tilde{T}^U\right)$ and $H\left(\tilde{T}^L\right)$ are triangle heights of the upper and the lower triangle, respectively. Like in the trapezoidal case, heights $H\left(\tilde{T}^U\right)$ and $H\left(\tilde{T}^L\right)$ belong to the interval [0, 1]. Arithmetic operations for the triangular IT2FNs are similar to arithmetic operations for trapezoidal IT2FNs.

Tables 8.2, 8.3 and 8.4 give the linguistic meanings of triangular and trapezoidal fuzzy numbers and triangular and trapezoidal IT2FNs.

Comparison matrices

$$A = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ \frac{1}{a_{12}} & 1 & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{1}{a_{1n}} & \frac{1}{a_{2n}} & \dots & 1 \end{bmatrix} \tag{8.17}$$

are constructed first for all considered preference criteria. In formula (8.17), a_{ij}, $i, j = 1, 2, \dots, n$ is a crisp number in the AHP method or corresponding triangular

Table 8.2 Crisp value, TFN and TrFN with linguistic variables

Crisp Value	TFN	TrFN	Linguistic variables
1	(1,1,3)	(1,1,1,3)	Equally important (EI)
2	(1,2,3)	(1,1.5,2.5,3)	Intermediate value (I_1)
3	(1,3,5)	(1,2,4,5)	Weakly important (WI)
4	(3,4,5)	(3,3.5,4.5,5)	Intermediate value (I_2)
5	(3,5,7)	(3,4,6,7)	Fairly important (FI)
6	(5,6,7)	(5,5.5,6.5,7)	Intermediate value (I_3)
7	(5,7,9)	(5,6,8,9)	Strongly important (SI)
8	(7,8,9)	(7,7.5,8.5,9)	Intermediate value (I_4)
9	(7,9,9)	(7,9,9,9)	Absolutely important (AI)

Table 8.3 Definition of interval type-2 fuzzy scale of the linguistic variables for the triangular IT2FN

Triangular interval type-2 fuzzy scale		Linguistic variables
(1,1,3;1)	(1,1,2;0.9)	Equally important (EI)
(1,2,3;1)	(1.5,2,2.5;0.9)	Intermediate value (I_1)
(1,3,5;1)	(2,3,4;0.9)	Weakly important (WI)
(3,4,5;1)	(3.5,4.4,5;0.9)	Intermediate value (I_2)
(3,5,7;1)	(4,5,6;0.9)	Fairly important (FI)
(5,6,7;1)	(5.5,6,6.5;0.9)	Intermediate value (I_3)
(5,7,9;1)	(6,7,8;0.9)	Strongly important (SI)
(7,8,9;1)	(7.5,8,8.5;0.9)	Intermediate value (I_4)
(7,9,9;1)	(8,9,9;0.9)	Absolutely important (AI)

Table 8.4 Definition of interval type-2 fuzzy scale of the linguistic variables for the trapezoidal IT2FN

Trapezoidal interval type-2 fuzzy scale		Linguistic variables
(1,1,1,3;1,1)	(1,1,1,2;0.9,0.9)	Equally important (EI)
(1,1.5,2.5,3;1,1)	(1.5,1.75,2.25,2.5;0.9,0.9)	Intermediate value (I_1)
(1,2,4,5;1,1)	(2,2.5,3.5,4;0.9,0.9)	Weakly important (WI)
(3,3.5,4.5,5;1,1)	(3.5,3.75,4.25,4.5;0.9,0.9)	Intermediate value (I_2)
(3,4,6,7;1,1)	(4,4.5,5.5,6;0.9,0.9)	Fairly important (FI)
(5,5.5,6.5,7;1,1)	(5.5,5.75,6.25,6.5;0.9,0.9)	Intermediate value (I_3)
(5,6,8,9;1,1)	(6,6.5,7.5,8;0.9,0.9)	Strongly important (SI)
(7,7.5,8.5,9;1,1)	(7.5,7.75,8.25,8.5;0.9,0.9)	Intermediate value (I_4)
(7,9,9,9;1,1)	(8,9,9,9;0.9,0.9)	Absolutely important (AI)

fuzzy number $\tilde{T}$, trapezoidal fuzzy number $\tilde{M}$ triangular IT2FN $\tilde{\tilde{T}}$, and trapezoidal IT2FN $\tilde{\tilde{M}}$ in FAHP.

The aggregation of different experts' opinions is calculated by the averaging method. Based on the linguistic assessments of k experts, for triangular numbers, their fuzzy presentation $e_i = (l_i, m_i, u_i)$, $i = 1, \ldots, k$ are obtained. The corresponding aggregated crisp value has then calculated by the formula

$$c_v = \frac{1}{k}\sum_{i=1}^{k} m_i$$

rounded to the nearest integer. Similarly, in the case of trapezoidal numbers, based on the opinion of experts $e_i = \left(l_i, m_i^l, m_i^h, u_i\right), i = 1, \ldots, k$ crisp value has calculated by the formula

$$c_v = \frac{1}{2k}\sum_{i=1}^{k}\left(m_i^l + m_i^h\right)$$

rounded to the nearest integer. The corresponding linguistic value of the aggregate opinion, in both cases, is obtained from Table 8.2.

After that, the consistency index $CI = \frac{\lambda_{\max} - n}{n-1}$ and consistency ratio $CR = \frac{CI}{RI}$ are calculated. The value λ_{max} represents the maximal eigenvalue of the comparison crisp matrix A, RI is known random index, while n is the dimension of the matrix. If $CR < 0.1$, the comparison matrix is consistent and the estimates of the relative importance of the criteria are counted as acceptable. Otherwise, when $CR \geq 0.1$, experts must correct their assessments.

For assigned a_{ij} the geometric mean of each row is calculated as follows:

$$r = \left[a_{11} \odot a_{12} \odot \ldots \odot a_{1n}\right]^{\frac{1}{n}}, i = \overline{1, n}, \tag{8.18}$$

According to that, fuzzy weights of each criterion are obtained

$$w_j = r \odot \left[r_1 \oplus r_2 \oplus \ldots \oplus r_n\right]^{-1}, j = \overline{1, n}. \tag{8.19}$$

The defuzzified values in the FAHP methods are obtained using the center area method (Do et al. 2015). In the case of triangular fuzzy number $\tilde{T} = (l, m, u)$, the defuzzified value is $\frac{1}{4}(l + 2m + u)$. When $\tilde{M} = (l, m^l, m^h, u)$ is a trapezoidal fuzzy number, the defuzzified value is $\frac{1}{4}(l + m^l + m^h + u)$. For the triangular IT2FN, denoted by $\tilde{\tilde{T}}$ and given by (16), the defuzzified value is $\frac{1}{8}\left(l^U + u^U + l^L + u^L + 2H\left(\tilde{T}^U\right)m^U + 2H\left(\tilde{T}^L\right)m^L\right)$, and for the trapezoidal IT2FN, denoted by $\tilde{\tilde{M}}$ and given by (9), the defuzzified value is $\frac{1}{8}\left(l^U + u^U + l^L + u^L + H\left(\tilde{M}^U\right)\left(\left(m^l\right)^U + \left(m^r\right)^U\right) + H\left(\tilde{M}^L\right)\left(\left(m^l\right)^L + \left(m^r\right)^L\right)\right)$.

Results

In this section, we have applied the methods outlined in section "Methodology: fuzzy numbers and analysis". Tables 8.5, 8.6, 8.7, 8.8, 8.9, 8.10 and 8.11 give fuzzy matrices of criteria and sub-criteria comparison obtained from experts. Based on the obtained value of CR < 0.1, one can conclude that all comparison matrices are consistent.

In Table 8.12, the indicators are ranked using the AHP method, triangular FAHP, triangular IT2FS, trapezoidal FAHP, and trapezoidal IT2FS as the methods of fuzzy logic. The ranking results are shown in Fig. 8.2.

The obtained results show that, in this case, the use of AHP and FAHP methods does not prioritize the same indicators. Comparing the finally ranked indicators using the AHP method, triangular FAHP, triangular IT2FS, trapezoidal FAHP, and trapezoidal IT2FS as the methods of fuzzy logic, all applied methods favor as the most crucial indicators for developing Smart Cities: development of a legislative and strategic framework of Smart City platform and its implementation in COVID-19 pandemic circumstances (A_1), standardization of ICT and ICT management (A_2), and entrepreneurship and innovation (B_1). The results of applying the AHP method slightly over the FAHP methods favor the ICT sector development and job

Table 8.5 Pairwise evaluation matrix of criteria, CI = 0.00827004, CR = 0.00666939

	A	B	C	D	E	F
A	EI	I_1	WI	WI	I_2	I_2
B	$1/I_1$	EI	I_1	I_1	WI	WI
C	1/WI	$1/I_1$	EI	I_1	I_1	I_1
D	1/WI	$1/I_1$	1/EI	EI	I_1	I_1
E	$1/I_2$	1/WI	$1/I_1$	$1/I_1$	EI	EI
F	$1/I_2$	1/WI	$1/I_1$	$1/I_1$	1/EI	EI

Table 8.6 Pairwise evaluation matrix of sub-criteria A, CI = 0.0034543, CR = 0.00383811

	A_1	A_2	A_3	A_4
A_1	EI	I_1	WI	WI
A_2	$1/I_1$	EI	I_1	I_1
A_3	1/WI	$1/I_1$	EI	I_1
A_4	1/ WI	$1/I_1$	1/EI	EI

Table 8.7 Pairwise evaluation matrix of sub-criteria B, CI = 0.0140206, CR = 0.0099437

	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8
B_1	EI	I_1	I_1	WI	I_2	I_2	FI	FI
B_2	$1/I_1$	EI	EI	I_1	WI	WI	I_2	I_2
B_3	$1/I_1$	1/EI	EI	I_1	I_1	WI	I_2	I_2
B_4	1/WI	$1/I_1$	$1/ I_1$	EI	I_1	I_1	WI	WI
B_5	$1/I_2$	1/WI	1/WI	$1/I_1$	EI	EI	I_1	I_1
B_6	$1/I_2$	1/WI	1/WI	$1/I_1$	1/EI	EI	I_1	I_1
B_7	1/FI	$1/I_2$	$1/I_2$	1/WI	$1/I_1$	$1/I_1$	EI	EI
B_8	1/FI	$1/I_2$	$1/I_2$	1/WI	$1/I_1$	$1/I_1$	1/EI	EI

Table 8.8 Pairwise evaluation matrix of sub-criteria C, CI = 0.0289418, CR = 0.0233402

	C_1	C_2	C_3	C_4	C_5	C_6
C_1	EI	I_1	WI	WI	FI	SI
C_2	$1/ I_1$	EI	I_1	I_1	I_2	I_3
C_3	1/WI	$1/I_1$	EI	EI	WI	FI
C_4	1/WI	$1/I_1$	1/EI	EI	WI	FI
C_5	1/FI	$1/I_2$	1/WI	1/WI	EI	WI
C_6	1/SI	$1/I_3$	1/ FI	1/FI	1/WI	EI

Table 8.9 Pairwise evaluation matrix of sub-criteria D, CI = 0.014781, CR = 0.0111977

	D_1	D_2	D_3	D_4	D_5	D_6	D_7
D_1	EI	I_1	I_1	WI	I_2	FI	FI
D_2	$1/I_1$	EI	EI	I_1	WI	I_2	I_2
D_3	$1/I_1$	1/EI	EI	I_1	I_1	I_2	I_2
D_4	1/WI	$1/I_1$	$1/ I_1$	EI	I_1	WI	WI
D_5	$1/I_2$	1/WI	1/WI	$1/I_1$	EI	I_1	I_1
D_6	1/FI	$1/I_2$	$1/I_2$	1/WI	$1/I_1$	EI	EI
D_7	1/FI	$1/I_2$	$1/I_2$	1/WI	$1/I_1$	1/EI	EI

opportunities within it (B_2) compared to public-private stakeholder partnership with active citizen's participation (A_3). According to importance, the higher data openness and transparency (A_4) has the same rank for all applied methods. Triangular IT_2FS slightly favors indicator personal safety (D_1) compared to indicator higher

Table 8.10 Pairwise evaluation matrix of sub-criteria E, CI = 0.00914735, CR = 0.0157713

	E_1	E_2	E_3
E_1	EI	I_1	I_2
E_2	$1/I_1$	EI	WI
E_3	$1/I_2$	1/WI	EI

Table 8.11 Pairwise evaluation matrix of sub-criteria F, CI = 0.0280297, CR = 0.0212346

	F_1	F_2	F_3	F_4	F_5	F_6	F_7
F_1	EI	I_1	WI	WI	I_2	FI	SI
F_2	$1/I_1$	EI	I_1	I_1	WI	I_2	I_3
F_3	1/WI	$1/I_1$	EI	EI	I_1	I_2	FI
F_4	1/WI	$1/I_1$	1/EI	1/EI	I_1	WI	FI
F_5	$1/I_2$	1/WI	$1/I_1$	$1/I_1$	EI	I_1	I_2
F_6	1/FI	$1/I_2$	1/WI	1/WI	$1/I_1$	EI	WI
F_7	1/SI	$1/I_3$	1/FI	1/FI	$1/I_2$	1/EI	EI

awareness level in the community (C_1). Further, the AHP method favors personal safety over ICT infrastructure integration (E_1).

Discussion

Multi-criteria decision analysis (MCDA) is necessary to identify key indicators developed to create optimal conditions for the cities' evolution into smart ones. The obtained results may differ from each other regarding the research aspect, the existence of an appropriate strategy for creating a Smart City, or the degree of its application in practice.

Previous research has mainly focused on urban areas that, by their characteristics, have implemented urban policies and implemented technological advances and strategies that are already classified as a positive example of Smart City development.

Our research as a case study takes cities that are in the process of developing to become smart. These cities are often part of developing countries, and therefore the preconditions for the development of Smart Cities are often not oriented toward a particular urban sector, which is recognized as underdeveloped and needs to be improved but is a problem of a broader nature and requires through the parallel development of different sectors.

The proposed methods rank the criteria, using all available information to take advantage of opportunities and overcome barriers to the development Smart City concept. By precise implementation of the applied methods, the following significant indicators have been obtained.

The eight most significant Smart City indicators are given in Fig. 8.3.

Table 8.12 The final ranking of sub-criteria

AHP		Triangular FAHP, IT2FS				Trapezoidal FAHP, IT2FS			
A_1	0.16535	A_1	0.14588	A_1	0.15216	A_1	0.14465	A_1	0.15117
A_2	0.09543	A_2	0.08682	A_2	0.08956	A_2	0.08644	A_2	0.08924
B_1	0.08452	B_1	0.07871	B_1	0.08058	B_1	0.07855	B_1	0.08044
B_2	0.05436	A_3	0.05741	A_3	0.05597	A_3	0.05714	A_3	0.05583
A_3	0.05115	B_2	0.05178	B_2	0.05279	B_2	0.05174	B_2	0.05275
A_4	0.05115	A_4	0.04820	A_4	0.04857	A_4	0.04827	A_4	0.04861
D_1	0.04137	E_1	0.04554	E_1	0.04446	E_1	0.04541	E_1	0.04441
E_1	0.04113	C_1	0.03992	C_1	0.03962	D_1	0.04151	C_1	0.03952
C_1	0.03811	D_1	0.03909	D_1	0.03951	C_1	0.03975	D_1	0.03951
B_3	0.03320	B_3	0.03701	B_3	0.03609	B_3	0.03711	B_3	0.03618
B_4	0.03320	B_4	0.03306	B_4	0.03294	B_4	0.03328	B_4	0.03308
D_2	0.02580	C_2	0.02788	C_2	0.02712	D_2	0.02817	C_2	0.02705
D_3	0.02580	E_2	0.02783	E_2	0.02653	E_2	0.02806	E_2	0.02671
F_1	0.02483	D_2	0.02671	D_2	0.02649	C_2	0.02775	D_2	0.02647
C_2	0.02429	C_3	0.02572	C_3	0.02540	C_3	0.02565	C_3	0.02536
C_3	0.02429	D_3	0.02438	D_3	0.02459	F_1	0.02395	D_3	0.02460
E_2	0.02354	F_1	0.02390	F_1	0.02398	D_3	0.01995	F_1	0.02402
F_2	0.01629	C_4	0.01778	C_4	0.01695	D_4	0.01818	C_4	0.01709
D_4	0.01582	D_4	0.01696	D_4	0.01643	C_4	0.01796	D_4	0.01661
C_4	0.01503	F_2	0.01618	F_2	0.01612	F_2	0.01626	F_2	0.01618
B_5	0.01469	B_5	0.01568	B_5	0.01525	B_5	0.01590	B_5	0.01541
F_3	0.01003	C_5	0.01159	F_3	0.01097	D_5	0.01177	F_3	0.01104
F_4	0.01003	F_3	0.01143	C_5	0.01086	C_5	0.01166	C_5	0.01092
D_5	0.00988	E_3	0.01123	E_3	0.01048	F_3	0.01151	E_3	0.01060
C_5	0.00909	D_5	0.01079	D_5	0.01038	E_3	0.01139	D_5	0.01050
C_6	0.00909	C_6	0.01064	F_4	0.01015	C_6	0.01073	F_4	0.01023
E_3	0.00898	F_4	0.01038	C_6	0.01013	F_4	0.01049	C_6	0.01020
B_6	0.00764	B_6	0.00763	B_6	0.00758	D_6	0.00815	B_6	0.00762
F_5	0.00623	C_7	0.00692	D_6	0.00662	B_6	0.00769	D_6	0.00666
D_6	0.00617	D_6	0.00686	C_7	0.00653	C_7	0.00695	C_7	0.00656
D_7	0.00617	F_5	0.00669	F_5	0.00647	A_1	0.14465	F_5	0.00654
C_7	0.00555	C_8	0.00635	D_7	0.00613	A_2	0.08644	D_7	0.00617
C_8	0.00555	D_7	0.00623	C_8	0.00609	B_1	0.07855	C_8	0.00613
F_6	0.00410	F_6	0.00461	F_6	0.00437	A_3	0.05714	F_6	0.00444
F_7	0.00214	F_7	0.00219	F_7	0.00214	B_2	0.05174	F_7	0.00215

Our research shows that, without the satisfactory legislative and strategic framework of the Smart City platform and its implementation and challenges, Smart City development will not be possible.

A clear vision and course of development of urban areas have to be accompanied by appropriate strategic and planning documents. Simultaneously, it implies the implementation and standardization of IC technologies, i.e., the introduction of

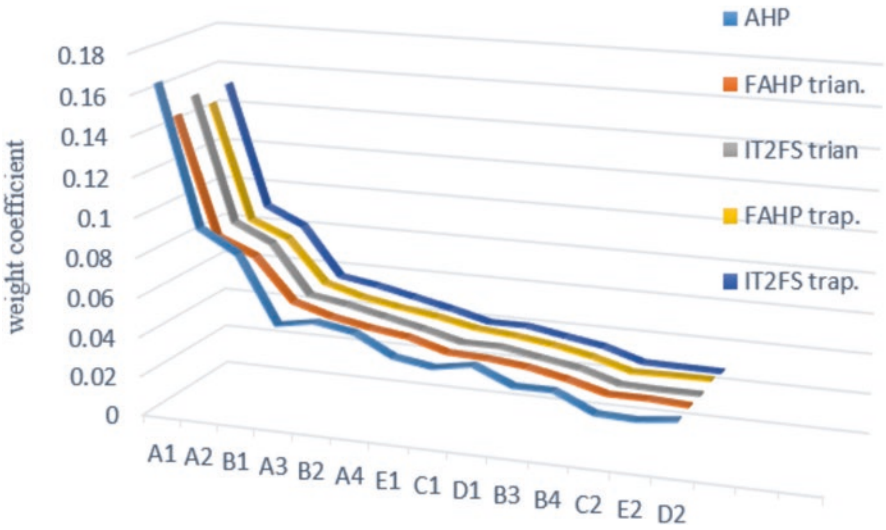

Fig. 8.2 Weights of key indicators for Smart City

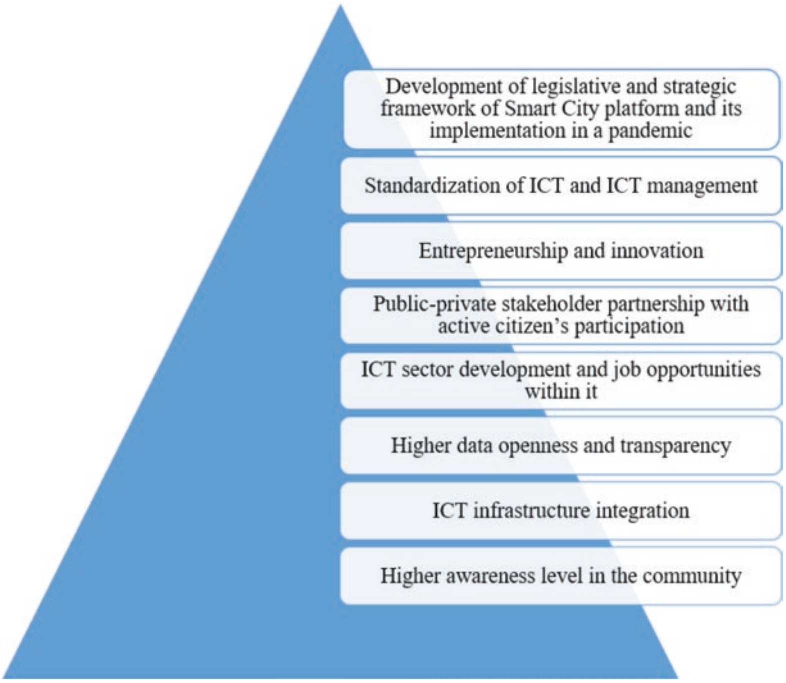

Fig. 8.3 Key indicators of opportunities for the development of Smart City using AI

"layers" of technological infrastructure through all levels of urban space as a system, in a way that has been precisely defined by the institutional framework, urban and planning regulations. The management of innovative technologies is related to the development of the ICT sector in the local and regional economy and the development of innovations within entrepreneurial activities (opening companies, production of smart devices and sensors, etc.). The expansion of urban development strategies for Smart Cities and the ICT sector requires the support of appropriate actors, as indicated by the dominant ranking of indicators obtained in this research. A public-private partnership, achieved through collaboration between urban government, local government, representatives of educational and scientific institutions, ICT experts, relevant planners, urban planners, architects and other engineers, private investors, and non-profit organizations, with active citizen participation, is a significant planning segment.

Given the role and importance of AI in a Smart City, to maximize the benefits of AI, it is necessary to use the following recommendations:

- To achieve close cooperation between the public and private sectors, between government organizations and citizens, and between universities and businesses to ensure the development of the necessary artificial intelligence technologies and their acceptance naturally.
- To create programs to inform citizens about the benefits and risks of using information and communication technologies, including artificial intelligence, by the level of education, age, and interests.
- Delineate through regulations the responsibilities of developers and users of artificial intelligence technologies.
- Conduct rigorous research about the side effects of ubiquitous sensors on human health and disseminate the results.

The role and participation of citizens in creating and improving the live environments are of particular significance because the planning process enables problem identifications that citizens face every day and the implementation of solutions that provides them with higher quality and standard of living.

Legislative and strategic framework for smart city development, with appropriate private-public partnership, citizen participation, development, and management of the ICT sector and infrastructure, is particularly important to align with the challenges of the COVID-19 pandemic. During the pandemic, cities turned to network tools and collaboration tools, digital communications platforms, and rapid development to move employees into virtual environments. The following stages in the continuum are budget reduction, economic slowdown, and return to growth. The final stage should involve cloud and infrastructure optimization, service deployment, and data analysis to help make decisions relevant to the future. The efforts of Smart Cities must rely on the digitization of data and content management. Without it, cities cannot get real-time insight into the data.

The ranking of indicators is carried out by taking into account the circumstances caused by the pandemic spread. This research is one of the contributions that can make decision-making easier for decision-makers.

Conclusion

Rigorous changes in the way of life in cities, which are happening every day, have made us think of ways to build a more sustainable society, one that will be able to resist the rapid development of our environment. The question is whether the existing model of the smart city is agile enough to cope with a situation similar to a pandemic. It also depends on our abilities to re-invent and refine Smart City models to adapt to the precarious situation we are facing today.

In this chapter, we explore the possibilities for the development of Smart Cities relying on AI. The theoretical background is primarily an attempt to explain the most important aspects and challenges of a Smart City. The task was to provide a theoretical overview of current scientific insights into the development and application of the Smart City concept, developing a discussion of a possible obstacle. In terms of applied methodology, the contribution lies in the comparative application of AHP methods, triangular and trapezoidal FAHP methods, and the corresponding hybrid IT2FS methods in the field of Smart City development. The research identifies crucial indicators as significant prerequisites for the development of the Smart City. By defining indicators of the Smart City formation, the concept of a Smart City, from idea to reality, is presented by emphasizing the symbiosis between the Smart City and AI and AI's role in Smart City development.

COVID's new challenges for urban areas indicate that an analysis of the current situation and quality of life indicators, a long-term vision of the city, and measurable goals are necessary. Human society must think and live more smartly, not only because of the pandemic but also because of globalization, environmental catastrophes, and overcrowding in general. This research is an attempt to model the concept of a Smart City in a pandemic using AI. Based on six criterion groups and thirty-five sub-criteria, the main dominant indicators were the development of a legislative and strategic framework of the Smart City platform and its implementation in COVID-19 pandemic circumstances, standardization of ICT and ICT management, entrepreneurship and innovation, public-private stakeholder partnership with active citizen's participation, and higher data openness and transparency. Making opportunities for developing Smart Cities can be achieved with well-defined goals with transparent regulatory frameworks. This research could be the basis for further research efforts relying on results related to the main indicators, proposed levels, and key tasks.

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