UNIVERSITY OF NIS FACULTY OF MECHANICAL ENGINEERING

THE SIXTH INTERNATIONAL CONFERENCE
TRANSPORT AND LOGISTICS

til 2017

AHP METHOD IN THE FUNCTION OF LOGISTIC IN DEVELOPMENT OF SMART CITIES MODEL

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Abstract

A growing number of challenges that cities in the 21st century are faced, leads to the need for a new model of urban development. At the core of successful urban transformation stands the application of criteria for the necessary interventions and formation of cities in a "smarter" way, which will provide people adequate conditions for living while enhancing sustainable development in all areas. The papersubject is ranking the various criteria in the field of management, economics, livability, mobility, putting at the center people and their environment, in planning the "smart cities" development.Multi-criteria analysis is a good framework for stucturing steps in planning the smart cities. The aim is to provide decision-makers to rank the alternatives in order to find optimal solution using AHP and fuzzy AHP methods.

Keywords*: Smart City, Development, Analytic Hierarchy Process, Criteria.*

1 INTRODUCTION

The ratio of rural and urban population has changed significantlyover the past centuries, with more than half of the world's population whonowadays lives in urban areas. About 75% of the European continent is already urbanized, and conducted researches clearly indicate that the migration processes from rural to urban areas are still active, so the expansion of the urban part of the world's population to 70% by 2050.is predicted [1]. In this regard, the phenomenon of urbanization, followed by an increase in population, migrations and urban transformations that are reflected through cities agglomeration growth and irrational land use, considered to be one of the primary challenges of the XXI century. Moreover, climate changes, environmentdegradation, unsustainable exploitation of non-renewable resources, technological development and digitalization are just some of the nowadays problems and changes that set new requirements that cities must tackle. Nevertheless, cities are key drivers of sustainable development in economic, social, environmental and cultural terms. Adequate logistic of planning and spatial organization of the city, as a complex mechanism, with the support of stakeholders, greatly affectsthe performance, progress, productivity and city conservation in all fields. Therefore, cities now occupy a central places in all regional, national and global directives and strategies regarding their future urban sustainable development.

In recent years, due to the many global problems,there is a need to find new principles and models of urban development in order to successfully transform and regenerate cities, providing a far better living conditions suited to the needs of contemporary man. With the progress in science, technology and global digitalization, over the time,the ideas about the formation of future cities, by information technology implementation in all segments and functions, began to devalop, with the aim to overcome existing problems and to foster prosperity in all directions. As a result, similar to the new technologies, future cities were given the label„smart“, and eminent experts have developed numerous theories about the „smart“citymodel. Although the concept of „smart“ cityis variously defined,it does not implyjust the application of technologies.It represents far more complex system createdby strategic and sustainable logistics solutionsdevelopment, aimed at improving the quality of life, urban functionspermeation, servicesavailability, energy and resourcesmanagement, pollution reduction and efficient transport. The concept of smart city wasoriginally linked only to the future development of modern metropolis,as a highly developed centers, but today it is the ideological model of urban development of all sizescities.

Although definitions and opinions about „smart“ cities differ between theorists, it is generally accepted that the smart city model necessarily consists six interrelated components: „smart“ government, „smart“ economy, „smart“ mobility, „smart“ environment, „smart“ living and „smart“ people [2,3]. Each of these components includes a number of factors (criteria) that must be simultaneously taken into account in the development of smart city model logistic in practice. Since the cities differ in history, culture, mentality of the population and other characteristics, factors that are crucial for one city in the process of its transformation into a smart, for some others are not. The main barrier for the adoption of „smart“ cities solutions is the complexity of ways to manage cities, finance their regulation and planning, because it is multidimensional and requires decision making at various levels. Therefore, there is a need to find appropriate methodology by which indicators, that are essential for the successful development of „smart“ city solution, can be defined. In the process of a large number of criteria consideration and decision making, inherent in the concept of „smart“ city, multi-criteria analysis can be of great importance. The paper examines the issue of multi-criteria analysis in the planning of „smart“ cities, looking at the potentials and the challenges that medium-sized cities are faced with. The study is based on a ranking the indicators by applying mathematical methods the Analytic Hierarchy Process (AHP) and fuzzy AHP. The aim is to enable decision makers to rank indicators, by applying these methods, and to prioritize from which of them is necessary to start in the process of city transformation in their smarter version. The initial assumption is that research results can provide insights for developing methodology that local governments can follow in determining the criteria of greater importance in planning the „smart“ cities.

2 SMART CITY MODEL

The development of science and technology has brought a number of problems that are primarily associated with cities as entities with a high concentration of population, motor vehicles, architectural buildings and infrastructures. Cities are responsible for 75% of total energy consumption in the world, are considered as major emitters of greenhouse gases, the biggest pollutants of water, soil and air, and the biggest consumers of conventional non-renewable resources [4,5]. Due to urbanization, climate change caused by global warming and rising level of natural and built environmentpollution, contemporary urban and architectural practice is focused actively to the implementation of the principles of energy-efficiency, construction of environmentally friendly buildings and cities, use of renewable energy sources and regeneration of underused and contaminated sites. At the same time, the overall progress of society has caused the increase in the needs of contemporary man and set a higher level of living standards in urban areas, especially in highly developed countries. The search for more quality, safer and economically profitable way of life, is the main driver of migration processes, which are present in the world. In economically underdeveloped countries, like Serbia, population migrations from rural to urban areas are still active, and the population often moves from smaller to larger urban areas, creating the pressure on the major cities as the most perspective centers. Economic, political and social circumstances force people to migrate, not only in other cities, but also in more developed countries, and even to other continents. Migrations are present in all urban levels - local, regional, national and international levels. On the other hand, the population of some economically developed countries,looking for a healthier environment,often "returns" in rural areas, which are generally less pollution loads. Therefore, nowadays principles of urban development and planning strive for healthy environment and high quality of life in cities, for residents, employees and visitors, with the support of innovative information technologies [5].

In order to transform cities into more efficient entities, the idea of „smart“city, as an ideal urban system of the future, has been developed. The term „smart“was first used in the 90s, as the term linked to the implementation of smart information technology in the planning and development of cities in all its segments [1]. In the followed years, the numerous debates between experts fromdifferent fields, about the meaning of label„smart“, were carried out. For this reason, the diverse and contradictory interpretations and definition of this urban phenomenonwere created. One of the generally accepted contentions is that "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 a high quality of life, with a wise management of natural resources through parcipatory governance" [6]. Taking into account its complexity, there is no precise interpretation of the appearance of „smart“ city, but itis perceived as an interactive mechanism that allows cities more flexibility and faster adaptation to existing and new problems and challenges. Today, it is considered that the label„smart“pointto the improvement of performances concerning the specific characteristics of urban development - economy, people, governance, mobility, environment and way of living in the city [1,7]. Because of that we say that the „smart“ city model is an integrated system of „smart“governance, „smart“economy, „smart“people, „smart“ environment, „smart“ mobility and „smart“ living, as well as six basic criteria for urban development in the future. Each of these components is an important indicator of sustainability, but primarily contributes to improvementof the quality of life in the city. Therefore, we are not talking only about „smart“ cities, but also about liveable and resilientfuture cities [8].

Many organizations and associations work on projects of new technological solutions in the field of “smart“ cities(„smart“roads, lighting, buildings, etc.), but also on consideration of the potentials and limitations of existing cities in term of their further improvement. Stockholm, Paris, Barcelona, London, Singapore and Copenhagen are just a few of the metropolis that can be classified as„smart“cities. Given that the most of the urban population today lives in medium-sizedcities, counted between 100,000 and 500,000 inhabitants, contemporary urban plans are focused on them and see them as the biggest potential for the formation of future „smart“cities [4]. In Serbia, still there is no city that can be treated as a smartone, but many cities have the potentials for integrated urban development in the „smart“way [5]. Solutions logisticin the development of medium-sized„smart“ cities must take into account the various challenges, motivations, limitations and strategies, but also colaborativity between different scientific disciplines and stakeholders at all levels of the hierarchy. The concept of „smart“ city is a multidisciplinary process of resolving the challenges and problems of city management, finance, resources and energy, of coordinating transport, education, culture and tourism, along with enhancing social cohesion of citizens and their participation in city management. In the process of forming a model of medium-sized „smart“ city, it is necessary to examine a large number of influencing factors and make a series of complex decisions.Therefore, in recent years there is a need to establish a methodology that would help local authorities in determining the criteria which are of greater importance in the transformation process of cities into smart ones.

If we look at the basic components of the „smart“city model, „smart“governanceand economy are key indicators of the urban development of contemporary cities, because of their development level depends the planning of transportation systems, and they also directly affect the quality of the environment and people lives in cities. Under the „smart"governance we mean all the forms of management and city coordination, strategies and perspectives of local governments, access to public and social services, citizens participation in making important decisions as well as the transparency of the management process [9]. For sustainable urban development within the field of governance, the strategic plans are crucial, because a good long-term strategy lead to quality solutions and improvements. On the other hand, a "smart"economy includes productivity, innovations, the flexibility of the market, the integration with international markets, entrepreneurship, the market ability to transform and the promotion of local brands [10]. Although all of these criteria are interwined, productivity and entrepreneurship are crucial factors without which the market can not be developed further, but as important indicators of economical city development, the innovations, ability to transform and promotion of local brandsmust also be isolated. „Smart"governance and economy can notbe developed without the people, so they are important actors of the whole concept of „smart"city.

The term „smart"people mean citizens awareness as the most important factor, followed by the participation of residents in the community and public life, social and ethnic diversity of the population, their qualificationlevel, their flexibility, creativity and affinity for life-long learning [2,3]. In order to develop a „smart"city model, the most important is to awakethe citizens awareness about the need for environment conservation and protection, rational consumption of energy and other non-renewable resources, and to motivate them to participate directly in making decisions concerning the improvement of quality of life in the city. Another important criterion is the level of qualifications of the residents, as well as their flexibility and creativity in finding innovative solutions.

„Smart"mobility includes local and international accessibility of the city, safe and innovative transport system and the availability of infrastructure information technologies network [2]. Information technologies and their availability in all segments of the people public life are the most important factors in term of mobility, as they enable networking the public and social services, and direct control of the processes that take place in city. In the development of „smart" cities it is also required to consider safe transport within the urban structure,to find new technological solutions that will carry out energy-saving in the organization of public transport and to promote bicycle and pedestrian traffic. The quality of life in the city is reflected in providing security of each individual, quality housing, social integration, health services, education and the promotion of culture and tourism through a variety of institutions and activities. Finally, „smart" city model includes a component related to the creation of „smart" environment. Under the „smart" environment we mean adequate and rational land use and urban planning, efficient water use, pollution control and environmental protection, use of renewable energy sources, construction of sustainable buildings, preservation of the natural and attractive landscape and natural resource management [4]. Rational use and land planning is crucial, but the factors related to the control and protection of the environment, primarily water and waste recycling, are also important.

3 METODOLOGY

For the purposes of proposed criteria ranking in this paper the AHP methods are applied - method of Analytic hierarchy process and fuzzy AHP (FAHP). AHP method is designed to assist in solving complex decision problems. Methodologically speaking, AHP is a multi-criteria technique based on the interpretation of complex problem in the hierarchy. AHP initially enables interactive creationof problems hierarchy asscenario of decision-making prepare, and then evaluation of the pairs of hierarchy elements. In this paper, the parameters are evaluated by experts involved in different aspects of the issue that habe been investigating. Any comparison between two elements of the hierarchy is carried out using a scale of Saati [11]:

$$S = \left\{ \frac{1}{9}, \frac{1}{8}, \frac{1}{7}, \frac{1}{6}, \frac{1}{5}, \frac{1}{4}, \frac{1}{3}, \frac{1}{2}, 1,2,3,4,5,6,7,8,9 \right\} \quad (1)$$

The priority which one alternative has over another is expressed by descriptive values. On the basis of comparison in pairs a matrix of criteria comparison is formed. AHP method allows monitoring the consistency of estimates at any time in the process of comparing the pairsof alternativesby using the index:

$$CI = \frac{\lambda_{\max} - n}{n - 1}, \quad CR = \frac{CI}{RI} \quad (2)$$

where: CI is index of consistency, CR is the ratio of the consistency, RI is a random index (consistency index of the matrix), n is the dimension of comparison matrix, λ_{max} is the maximum eigenvalue of a matrix. If the comparison matrix applies to the CR <0.10 alternatives priorities are counted as acceptable [12,13,14].

Thomas Saaty had developedthe AHP algorithm 1980. in[15]. In this algorithm, comparing marks are represented as natural numbers (1 to 9). However, in many practical applications people find difficult to choose the exact number of values by which would compare two solutions. Because of that, Van Laarhoven and W. Pedrycs 1983. in the paper [16] proposed a method of fuzzy AHP with vague marks using triangular fuzzy numbers. Method has applied operations with triangular fuzzy numbers and logarithmics of least squares for ranking fuzzy numbers. Chang was 1996. in the paper [17] proposed a new approach to the comparison of fuzzy numbers. This method has not proved numerically stable and in the application often came to divide by zero, or the data was out of range. Method was improved in 1999. by K. J. Zhu, Z., and Jing Z. D. Chang in paper [18].

3.1. Triangular fuzzy numbers and fuzzy AHP

Let$F(R)$be fuzzy set on$R$and let $M \in F(R)$. If exists$x_0 \in R$such that $\mu_m(x_0) = 1$, for all $\lambda \in (0,1), M_\lambda =$

$\{x \mid \mu_M(x) \geq \lambda\}$is convex set, $\mu_M$is membership function $M\colon R \to [0,1]$equal to

$$\mu_M(x) = \begin{cases} \frac{1}{m-l}x - \frac{1}{m-l}, & x \in [l,m], \\ \frac{1}{m-u}x - \frac{u}{m-u}, & x \in [m,u], \\ 0, & otherwise, \end{cases} \quad (3)$$

Then *M*is triangular fuzzy number.In formula (3),*u*and*l*are upper and lower value of the support of M respectively, and *m*is the modal value. Triangular fuzzy number can be denoted by (l, m, u).

Let us consider now two triangular fuzzy numbers $M_1 = (l_1, m_1, u_1)$and$M_2 = (l_2, m_2, u_2)$. Theiroperationallaws are as follows:

$$(l_1, m_1, u_1) \oplus (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2);$$
$$(l_1, m_1, u_1) \odot (l_2, m_2, u_2) \approx (l_1 l_2, m_1 m_2, u_1 u_2);$$
$$(l_1, m_1, u_1)^{-1} \approx (1/u_1, 1/m_1, 1/l_1).$$

Let us suppose in the sequel that we have in the square matrix $A = (\tilde{a}_{ij})_{n\times m}$ pair-wise comparisons at each level, where $\tilde{a}_{ij}$is the fuzzy value about the relative importance of alternative *i* over the alternative *j*. For square matrix*A* holds that $\tilde{a}_{ij} = 1$ for$i = j$and$\tilde{a}_{ij} = 1/\tilde{a}_{ji}fori \neq j$.

Meaning of the triangular fuzzy numbers using fuzzified Saaty's scale are:

- Equal importancei $(1,1,1+\delta)$;
- Week dominance$(3-\delta, 3, 3+\delta)$;
- Strong dominance$(5-\delta, 5, 5+\delta)$;
- Demonstrated dominance$(7-\delta, 7, 7+\delta)$;
- Apsolute dominance$(9-\delta, 9, 9)$.

As recomanted in paper [14], in order to obtain the most consistent results, we are used fuzzy distance of$\delta = 2$.For the intermediate values 2,4,6and 8 we are used fuzzy distance $\delta = 1$.

In the first step of the algorithm, using triangular fuzzy numbers from the matrix $A = (\tilde{a}_{ij})_{n\times m}$,we calculate synthetic triangular fuzzy numbers $S = (s_1, s_2, \dots, s_n)^T$, where:

$$s_i = \sum_{j=1}^{m} \tilde{a}_{ij} \odot \left(\sum_{i=1}^{n} \sum_{j=1}^{m} \tilde{a}_{ij} \right)^{-1}, \qquad i = 1, \dots, n.$$

In order to obtain approximation of the weighting vector it is necessary to compare obtained synthetic triangular fuzzy numbers s_i, $i = 1, \dots, n$. For two fuzzy numbers$M_1$and M_2, we involve degree of possibility of $M_1 \geq M_2$with function

$$V(M_1 \geq M_2) = \sup_{x \geq y} \left[\min\left(\mu_{M_1}(x), \mu_{M_2}(y) \right) \right].$$

Since $M_1$and$M_2$are convex fuzzy numbers we have that

$$V(M_1 \geq M_2) = 1 \; iff \; m_1 \geq m_2 \text{and}$$
$$V(M_2 \geq M_1) = \text{hgt}\,(M_1 \cap M_2) = \mu_{M_1}(d) = \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)},$$

where$d$ is the ordinate of the highest intersection point betweenμ_{M_1}andμ_{M_2}. The degree possibility for a convex fuzzy number M to be greathethan *k*convex fuzzy numbers $M_i, i = 1, \dots, k$ is defined by

$$V(M \geq M_1, M_2, \dots, M_k) = \min V(M \geq M_i),$$

for*i=1,…,k.* The obtained degree possibility, normalized to 1, for each row of the matrix *A*represents the weighting vector approximation$W = (w_1, w_2, \dots, w_n)^T$.

4 RESULTS AND DISCUSION

The research focuses on the ranking the six main groups of criteria that must be taken into accountin the processof forming the model of „smart“ city:G - „smart“governance; E - „smart“ economy; P - „smart“ people; L - „smart“living; M - „smart“ mobility; S - „smart“ environment.

Sub-criteria relating to „smart“governance, economy, people, living, mobility and environment are marked as follows:G_1 - strategies and perspectives; G_2 - accessibility of public and social services; G_3 - participation of citizens in decision-making; G_4 - transparency of management; E_1 - entrepreneurship; E_2 - productivity; E_3 - innovations; E_4 - market ability to transform; E_5 - brand promotion; E_6 - market flexibility; E_7 - integration with international markets; P_1-citizens awareness; P_2 - qualificationslevel; P_3 - flexibility, creativity; P_4 - affinity for life-long learning; P_5 - participation in community and public life; P_6 - social and ethnic diversity;M_1 - availability of information technology (IT) infrastructure; M_2 - safe and innovative transport system; M_3 - local and international city accessibility; L_1 - individual security; L_2 - quality housing; L_3 - social integration; L_4 - health services; L_5 - educational institutions; L_6 - culture; L_7 - tourism;S_1- rational land use and urban planning; S_2 - efficient use of water; S_3 - control of environmental pollution; S_4 - environmental protection; S_5 - the use of renewable energy sources; S_6 - construction of sustainable buildings; S_7 - management of natural resources; S_8 - the attractiveness of the natural environment.

In Table 1 the comparison matrix with the triangular fuzzy numbers is given, obtained on the basis of expert opinions about„smart“governance, economy, people, living, mobility and environment.

Table 1 The pairwise comparation matrix of subcriteria in relation to the „smart“ city

	G	E	P	L	M	S
G	$\tilde{1}^{-1}$	$\tilde{2}$	$\tilde{3}$	$\tilde{3}$	$\tilde{4}$	$\tilde{4}$
E	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{2}$	$\tilde{2}$	$\tilde{3}$	$\tilde{3}$
P	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}^{-1}$	$\tilde{1}$	$\tilde{2}$	$\tilde{2}$
L	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}^{-1}$	$\tilde{1}$	$\tilde{2}$	$\tilde{2}$
M	$\tilde{4}^{-1}$	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{1}$
S	$\tilde{4}^{-1}$	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}^{-1}$	$\tilde{1}$

In Table 2 the appropriate synthetic triangular fuzzy numbers (STFN) and the weight forfuzzy AHP (FW) and AHP methods (W) for data from Table 1 are given.

Table 2 Fuzzy numbers and weights(„smart“city)

STFN	FW	W
(0.1240,0.3312,0.8219)	0.2790	0.3631
(0.0661,0.2240,0.6164)	0.2292	0.2276
(0.0562,0.1721,0.5479)	0.2029	0.1310
(0.0479,0.1331,0.3425)	0.1464	0.1310
(0.0380,0.0698,0.2511)	0.0913	0.0736
(0.0298,0.0698,0.1826)	0.0512	0.0736

Triangular fuzzy numbers in fuzzy AHP method better describe the linguistic sentences like „a little better“, „better“, „much better“, and are more natural to compare and more consistent with the language. If the fuzzy numbersare replaced with their modal values then the comparationmatrix of fuzzy numbers is reduced to a standardcomparison matrix by AHP method. For comparison matrix (Table 1) corresponding to the AHP method index of consistency and the ratio of consistencyare CI = 0.0083, CR = 0.0067 <0.10.

Table 3 represents the fuzzy numbers of strategies and perspectives, access to public and social services, the participation of citizens in decision-making and transparency in governance.

Table 3 The pairwise comparation matrix of subcriteria in relation to the „smart“ governance G

	G_1	G_2	G_3	G_4
G_1	$\tilde{1}$	$\tilde{3}$	$\tilde{3}$	$\tilde{4}$
G_2	$\tilde{3}^{-1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{2}$
G_3	$\tilde{3}^{-1}$	$\tilde{1}^{-1}$	$\tilde{1}$	$\tilde{2}$
G_4	$\tilde{4}^{-1}$	$\tilde{2}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$

In Table 4 synthetic triangular fuzzy numbers (STFN) are shown and proper weightsforfuzzy AHP and AHP methods are presented. For comparison matrix corresponding to AHP method index of consistency and the ratio of consistency are CI = 0.0069, CR = 0.0076 <0.10.

Table 4 Fuzzy numbers and weights(„smart“governance)

STFN	FW	W
(0.1800,0.5019,1.1765)	0.4597	0.5158
(0.0960,0.1977,0.5882)	0.2634	0.1894
(0.0760,0.1977,0.4412)	0.2124	0.1894
(0.0560,0.1027,0.2451)	0.0645	0.1054

„Smart“ economy through: entrepreneurship, productivity, innovations, transforming ability, the promotion of brands, the flexibility of the market, the integration with the international markets, is presented in a comparison matrix of the fuzzy numbers in Table 5.For comparison matrix corresponding to theAHP method index of consistency and the ratio of consistency are CI = 0.0121, CR = 0.0092 <0.10.Table 6 presents the appropriate weights for fuzzy AHP and AHP and synthetic triangular fuzzy numbers(STFN).

Table 5 The pairwise comparation matrix of subcriteria in relation to the „smart“ economy E

	E_1	E_2	E_3	E_4	E_5	E_6	E_7
E_1	$\tilde{1}$	$\tilde{2}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$	$\tilde{4}$	$\tilde{5}$
E_2	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{2}$	$\tilde{2}$	$\tilde{2}$	$\tilde{3}$	$\tilde{4}$
E_3	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{2}$	$\tilde{3}$
E_4	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{2}$	$\tilde{3}$
E_5	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}^{-1}$	$\tilde{1}^{-1}$	$\tilde{1}$	$\tilde{2}$	$\tilde{3}$
E_6	$\tilde{4}^{-1}$	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{2}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{2}$
E_7	$\tilde{5}^{-1}$	$\tilde{4}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$

Table 6 Fuzzy numbers and weights(„smart“ economy)

STFN	FW	W
(0.0991,0.2999,0.7826)	0.2417	0.3252
(0.0751,0.2070,0.5302)	0.1989	0.2068
(0.0498,0.1261,0.4292)	0.1583	0.1184
(0.0438,0.1261,0.3787)	0.1491	0.1184
(0.0378,0.1261,0.3282)	0.1374	0.1184
(0.0306,0.0726,0.2104)	0.0794	0.0686
(0.0205,0.0421,0.1431)	0.0352	0.0444

In Table 7 a comparison matrix of the triangular fuzzy numbers for citizens awareness, qualification level, flexibility and creativity, affinity for life-long education, participation in the community and public life, social and the ethnic diversity, is shown. For comparison matrix corresponding to the AHP index of consistency and the ratio of consistency areCI = 0.0113, CR = 0.0091 <0.10.

Table 7 The pairwise comparation matrix of subcriteria in relation to the „smart“ people P

	P_1	P_2	P_3	P_4	P_5	P_6
P_1	$\tilde{1}$	$\tilde{2}$	$\tilde{3}$	$\tilde{3}$	$\tilde{5}$	$\tilde{5}$
P_2	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{2}$	$\tilde{2}$	$\tilde{4}$	$\tilde{4}$
P_3	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{3}$	$\tilde{3}$
P_4	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}^{-1}$	$\tilde{1}$	$\tilde{2}$	$\tilde{2}$
P_5	$\tilde{5}^{-1}$	$\tilde{4}^{-1}$	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{1}$
P_6	$\tilde{5}^{-1}$	$\tilde{4}^{-1}$	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}^{-1}$	$\tilde{1}$

In Table 8 the appropriate weights for fuzzy AHP and AHP and synthetic triangular fuzzy numbers(STFN)which are related to „smart“ people, are represented.

Table 8 Fuzzy numbers and weights(„smart“ people)

STFN	FW	W
(0.1200,0.3471,0.8532)	0.3101	0.3727
(0.1120,0.2466,0.5485)	0.2512	0.2383
(0.0544,0.1614,0.4875)	0.2060	0.1442
(0.0464,0.1248,0.3047)	0.1407	0.1243
(0.0345,0.0600,0.2031)	0.0696	0.0602
(0.0265,0.0600,0.1422)	0.0223	0.0602

In Table 9 a comparison matrix of the triangular fuzzy numbers for mobility, through availability of information technology infrastructure, safeand innovative transport system and local and international city accessibility, is shown.For comparison matrix corresponding to the AHP index of consistency and the ratio of consistency areCI=0.0193, CR=0.0332 < 0.10.

Table 9 The pairwise comparation matrix of subcriteria in relation to the „smart“mobility M

	M_1	M_2	M_3
M_1	$\tilde{1}$	$\tilde{3}$	$\tilde{5}$
M_2	$\tilde{3}^{-1}$	$\tilde{1}$	$\tilde{3}$
M_3	$\tilde{5}^{-1}$	$\tilde{3}^{-1}$	$\tilde{1}$

In Table 10 the appropriate weights for fuzzy AHP and AHP (FW and W) and synthetic triangular fuzzy numbers(STFN),which are related to „smart“mobility, are represented.

Table 10 Fuzzy numbers and weights(„smart“mobility)

STFN	FW	W
(0.2727,0.6115,1.2595)	0.5733	0.6370
(0.1200,0.2548,0.5725)	0.3754	0.2583
(0.0836,0.1338,0.2672)	0.0512	0.1048

In Table 11 acomparation matrixof fuzzy AHP method triangular fuzzy numbers is given, for individual security, quality housing, social integration, healthcare, educational institutions, culture and tourism. In Table 12 synthetic triangular fuzzy numbers (STFN) and correct weights for fuzzy AHP and AHP (FW and W) are presented. For comparison matrix corresponding to the AHP index of consistency and the ratio of consistency areCI = 0.0073, CR = 0.0055 <0.10.

Table 11 The pairwise comparation matrix of subcriteria in relation to the „smart“living L

	L_1	L_2	L_3	L_4	L_5	L_6	L_7
L_1	$\tilde{1}$	$\tilde{2}$	$\tilde{2}$	$\tilde{3}$	$\tilde{4}$	$\tilde{4}$	$\tilde{4}$
L_2	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{2}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$
L_3	$\tilde{2}^{-1}$	$\tilde{1}^{-1}$	$\tilde{1}$	$\tilde{2}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$
L_4	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{2}$	$\tilde{2}$	$\tilde{2}$
L_5	$\tilde{4}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$
L_6	$\tilde{4}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}^{-1}$	$\tilde{1}$	$\tilde{1}$
L_7	$\tilde{4}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}^{-1}$	$\tilde{1}^{-1}$	$\tilde{1}$

Table 12 Fuzzy numbers and fuzzy weights(„smart“living)

STFN	FW	W
(0.1193,0.2916,0.6807)	0.2492	0.3109
(0.0581,0.1968,0.5798)	0.2067	0.1910
(0.0520,0.1968,0.5294)	0.2025	0.1910
(0.0446,0.1215,0.3277)	0.1372	0.1130
(0.0361,0.0644,0.2605)	0.0955	0.0647
(0.0300,0.0644,0.2101)	0.0712	0.0647
(0.0239,0.0644,0.1597)	0.0377	0.0647

In Table 13 fuzzy numbers for environment criteria (rational land use and urban planning, efficient use of water, control of environmental pollution, environment protection, use of renewable energy sources, sustainable buildings, natural resource management, the attractiveness of the natural environment) are given. In AHP method,index of consistency and the ratio of consistency areCI = 0.0101, CR = 0.0071 <0.10. In Table 14 synthetic triangular fuzzy numbers (STFN) and correct weights for fuzzy AHP and AHP (FW and W) are presented.

Table 13 The pairwise comparation matrix of subcriteria in relation to the „smart“environment (surrounding) S

	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
S_1	$\tilde{1}$	$\tilde{2}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$	$\tilde{3}$	$\tilde{4}$	$\tilde{5}$
S_2	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{2}$	$\tilde{2}$	$\tilde{2}$	$\tilde{2}$	$\tilde{3}$	$\tilde{4}$
S_3	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{2}$	$\tilde{3}$
S_4	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{2}$	$\tilde{3}$
S_5	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{2}$	$\tilde{3}$
S_6	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{1}$	$\tilde{2}$	$\tilde{3}$
S_7	$\tilde{4}^{-1}$	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{2}^{-1}$	$\tilde{2}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$	$\tilde{2}$
S_8	$\tilde{5}^{-1}$	$\tilde{4}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{3}^{-1}$	$\tilde{2}^{-1}$	$\tilde{1}$

Table 14 Fuzzy numbers and weights („smart“environment)

STFN	FW	W
(0.0834,0.2707,0.7252)	0.2088	0.2930
(0.0649,0.1861,0.4835)	0.1723	0.1872
(0.0454,0.1109,0.4029)	0.1392	0.1052
(0.0408,0.1109,0.3626)	0.1328	0.1052
(0.0361,0.1109,0.3223)	0.1251	0.1052
(0.0315,0.1109,0.2820)	0.1157	0.1052
(0.0259,0.0630,0.1880)	0.0699	0.0600
(0.0170,0.0365,0.1326)	0.0363	0.0390

5 CONCLUSION

By studying a large number of different criteria and their evaluation, the ranking was donein order to facilitate the logistics in development of „smart“cities model in practice.The results of the criteria ranking are obtained on the basis of the weight coefficients, using the AHP methodsfrom Table 1 to Table 14, and are represented by a final ranking. In the first column of Table 15 results show the dominant role of strategies and perspectives, accessible of information technology infrastructure, entrepreneurship, access of citizens to public and social services, and their participation in decision-making.Then citizens awareness, productivity in economy and transparency of governance are of great importance. The results indicate that, in the process of „smart“ city formation, management of natural resources and attractiveness of the natural landscape have lowest role according to the importance.

By applying the fuzzy AHP methodsomewhat different results were obtained and are represented in Table 16.The first column also gives the greatest importance to strategies and perspectives, accessibility of the information technology infrastructure and to the public and social services, but entrepreneurship is not perceived as one of the most significant factors.The method also gives priority to the development of citizens awareness, their participation in making decisions, as well asto the safe and innovative transport system and the level of qualification.The application of fuzzy AHP method pointed to the smallest importance of tourism, management of natural resources and their attractiveness in the development of „smart“city.It can be concluded that the proposed methods can be successfully applied in decision-making in the field of urban development and transformation of cities into smarter urban entities.The results of the study provide information that can be used to develop a methodology that city governments and authorities may follow in determining what criteria have a greater significance in developing smart city logistics.

Table 15 Ranking criteria by AHP method

Rank	Criteria	Wk	Wa	WkxWa
1.	G_1-strategies and perspectives	0.3631	0.5158	0.1873
2.	M_1-availability of IT infrastructure	0.1310	0.6370	0.0834
3.	E_1-entrepreneurship	0.2276	0.3252	0.0740
4.	G_2-services accessibility	0.3631	0.1894	0.0688
5.	G_3-participation in decision-making	0.3631	0.1894	0.0688
6.	P_1-awareness of citizens	0.1310	0.3727	0.0488
7.	E_2-productivity	0.2276	0.2068	0.0471
8.	G_4-management transparency	0.3631	0.1054	0.0383
9.	M_2-safe and innovative transport	0.1310	0.2583	0.0338
10.	P_2-qualification degree	0.1310	0.2383	0.0312
11.	E_3-innovations	0.2276	0.1184	0.0269
12.	E_4-transformation ability	0.2276	0.1184	0.0269
13.	E_5-brand promotion	0.2276	0.1184	0.0269
14.	L_1-individual safety	0.0736	0.3109	0.0229
15.	S_1-land using and planning	0.0736	0.2930	0.0216
16.	P_3-flexibility and creativity	0.1310	0.1442	0.0189
17.	P_4-affinity for life-long learning	0.1310	0.1243	0.0163
18.	E_6-market flexibility	0.2276	0.0686	0.0156
19.	L_2-housing quality	0.0736	0.1910	0.0141
20.	L_3-social integration	0.0736	0.1910	0.0141
21.	S_2-efficient use of water	0.0736	0.1872	0.0138
22.	M_3-accessibility local, international	0.1310	0.1048	0.0137
23.	E_7-the international market integration	0.2276	0.0444	0.0101
24.	L_4-health care	0.0736	0.1130	0.0083
25.	P_6-social and ethnic diversity	0.1310	0.0602	0.0079
26.	P_5-participation in community, public	0.1310	0.0602	0.0079
27.	S_3-environmental pollution control	0.0736	0.1052	0.0077
28.	S_4-environmental protection	0.0736	0.1052	0.0077
29.	S_5- renewable energy use	0.0736	0.1052	0.0077
30.	S_6-sustainable objects construction	0.0736	0.1052	0.0077
31.	L_5-educational institutions	0.0736	0.0647	0.0048
32.	L_6-culture	0.0736	0.0647	0.0048
33.	L_7-tourism	0.0736	0.0647	0.0048
34.	S_7-management of natural resources	0.0736	0.0600	0.0044
35.	S_8-attractive natural landscapes	0.0736	0.0390	0.0029

Table 16 Ranking criteria by fuzzy AHP method

Rank	Criteria	FWk	FWa	FWkFWa
1.	G_1-strategies and perspectives	0.2790	0.4597	0.1283
2.	M_1-availability of IT infrastructure	0.1464	0.5733	0.0839
3.	G_2-services accessibility	0.2790	0.2634	0.0735
4.	P_1- awareness of citizens	0.2029	0.3101	0.0629
5.	G_3-participation in decision-making	0.2790	0.2124	0.0593
6.	E_1-entrepreneurship	0.2292	0.2417	0.0554
7.	M_2-safe and innovative transport	0.1464	0.3754	0.0550
8.	P_2-qualification degree	0.2029	0.2512	0.0510
9.	E_2-productivity	0.2292	0.1989	0.0456
10.	P_3-flexibility and creativity	0.2029	0.2060	0.0418
11.	E_3-innovations	0.2292	0.1583	0.0363
12.	E_4-transformation ability	0.2292	0.1491	0.0342
13.	E_5-brand promotion	0.2292	0.1374	0.0315
14.	P_4-affinity for life-long learning	0.2029	0.1407	0.0285
15.	L_1-individual safety	0.0913	0.2492	0.0228
16.	L_2-housing quality	0.0913	0.2067	0.0189
17.	L_3-social integration	0.0913	0.2025	0.0185
18.	E_6-market flexibility	0.2292	0.0794	0.0182
19.	G_4-management transparency	0.2790	0.0645	0.0180
20.	P_5-participation in community, public	0.2029	0.0696	0.0141
21.	L_4-health care	0.0913	0.1372	0.0125
22.	S_1-land using and planning	0.0512	0.2088	0.0107
23.	S_2-efficient use of water	0.0512	0.1723	0.0088
24.	L_5-educational institutions	0.0913	0.0955	0.0087
25.	E_7-the international market integration	0.2292	0.0352	0.0081
26.	M_3-accessibility local, international	0.1464	0.0512	0.0075
27.	S_3-environmental pollution control	0.0512	0.1392	0.0071
28.	S_4-environmental protection	0.0512	0.1328	0.0068
29.	L_6-culture	0.0913	0.0712	0.0065
30.	S_5- renewable energy use	0.0512	0.1251	0.0064
31.	S_6-sustainable objects construction	0.0512	0.1157	0.0059
32.	P_6-social and ethnic diversity	0.2029	0.0223	0.0045
33.	S_7-management of natural resources	0.0512	0.0699	0.0036
34.	L_7-tourism	0.0913	0.0377	0.0034
35.	S_8-attractive natural landscapes	0.0512	0.0363	0.0019

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