An Evaluation Model for Smart City Performance with Less Than 50,000 Inhabitants: A Greek Case Study

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Abstract: New intelligent technologies are seen as a key factor in fighting against climate change and improving the sustainability in cities. A smart city is a place where services use advanced information and communication technologies. According to literature, a smart city includes actions in 6 main domains: economy, environment, governance, living, mobility and people. The aim of the current study is to compose a holistic smart city ranking model for cities with population less than 50,000 inhabitants, applicable in the context of Greece. Based on the European guidelines, 25 crucial factors have been determined and 68 indicators have been adopted for the development of the evaluation model. The case of Municipality of Elefsina is analyzed and actions to improve its smartness profile are proposed. The proposed model will help cities with similar characteristics (less than 50.000 inhabitants) evaluate their status in the field of "smart cities" in order to develop programs and strategies.

1 INTRODUCTION

A city is the centre for all sustainable urban development strategies. Today, more than half of the world's population live in cities, and it is predicted that by 2050 urban areas will occupy 70% of the population (Miloševic et al., 2019). Nowadays there has been observed a shift in a new city pattern based on smart targets instead of only sustainability goals. Smart city provides better urban services based on the use of advanced Information and Communication Technologies (ICT). Although the dominant part of the smart cities profile is the infrastructure, the involvement of people and citizens is, also, crucial (Shen et. al, 2018).

As the exact definition of a smart city does not exist, the smart city concept contains several dimensions: Smart Economy, Smart Mobility, Smart Environment, Smart People, Smart Living and Smart Governance. These smart characteristics have been identified through a literature review: Giffinger and Hainlmaier, 2010; Lazaroiu and Roscia, 2012; Tahir and Malek, 2016; Shen et al., 2018; Petrova-Antonova and Ilieva, 2018; Alibegović and Šagovac, 2015; Miloševic et al., 2019; Akande et al., 2019. Smart economy is driven by economic competiveness, entrepreneurship and innovation. Smart mobility refers to local accessibility, safe transport systems and availability of ICT (Tahir and Malek, 2016). The smart environment is related to the quality of environment, including the attractiveness of nature, lack of pollution and sustainable resource management. Smart people refers not only to the level of education of the citizens but, also, to the key role of people in developing a smart city. Smart living includes factors all around quality of life. Smart governance comprises aspects of political participation, public services and e-governance.

A smart city is a city well perfoming in these six smart characteristics (Giffinger et al., 2007). In the literature, there are a few studies that have proposed ranking models to examine the performance of a smart city: Giffinger et al. (2007) ranked 70 European smart cities by adopting a set of 74 indicators under the above analysed six dimensions. All the examined cities had population between 100,000 and 500,000

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inhabitants and their data have been aggregated and standardized with z-transformation. Lazaroiu and Roscia (2012) used z-transformation and fuzzy logic for evaluating 10 Italian cities, by adopting 18 crucial indicators. Alibegović and Šagovac (2015) implement a ranking methodology for Croatian large cities by using indicators in strategic decision-making. Shen et al. (2018) developped an evaluation model of smart city performance specialized for China. The evaluation process has been carried out by applying entropy method and the multicriteria method, TOPSIS. Akande et al. (2019) ranked 28 European capital cities on how smart and sustainable they are, by using 32 indicators. Their methodology has been based on hierarchical clustering and principal component analysis (PCA). Finally, Miloševic et al. (2019) incorporated 35 key indicators for the assessment of Serbian smart cities. Their approach has been based on a hybrid fuzzy multicriteria decision making model.

In summary, all the above mentioned papers focused their reseach on metropolises with more than 100,000 inhabitants. Furthermore, their methodologies are based on multicriteria decision anlysis. So, it appears that there is no existing study examining smart city performance for cities with population less than 50,000 inhabitants. The aim of this study is to propose a holistic smart city ranking model, based on multicriteria analysis, for cities with population less than 50,000 inhabitants and, at the same time, recommend actions for improving the smart city performance. The majority of Greek municipalities cover this feature, as 95% of Greek municipalities have less than 50,000 inhabitants, and an evaluation process for smart cities' profile has not been carried out in Greek cities until now. A representative case study has been selected and so the proposed methodology has been implemented for Municipality of Elefsina.

The remainder of this paper is structured as follows: Section 2 presents the methodology of the study. Section 3 contains the analysis results for the performance of Municipality of Elefsina including, also, some improvement actions. The new city's profile after the implementation of the proposed actions is indicated. Finally, Section 4 concludes the study including, also, future thoughts.

2 RESEARCH METHODOLOGY

The approach adopted in this research comprises of four steps. Firstly, the selected set of smart city indicators are presented. Secondly, the evaluation methodology is described. In the third step, a questionnaire is developed according to the selected indicators in order to determine their values and in the fourth step, the classes of a smart city footprint are presented.

2.1 Smart City Indicators

As smartness of a city is not easily measurable, a European or International agreement on smart city indicators does not exist (Lazaroiu and Roscia, 2012). The overall goal is to improve sustainability with the help of technology. It should meet the needs of the population and is composed of several smart characteristics that interact with each other (Miloševic et al., 2019).

According to literature each smart characteristic (Smart Economy, Smart Mobility, Smart Environment, Smart People, Smart Living and Smart Governance) is defined by a number of factors. Furthermore, each factor can be broken into relevant indicators, which reflect the most important aspects of every smart characteristic (Giffinger et al., 2007), (Giffinger and Haindlmaier, 2010). The research team has identified 36 factors and 136 indicators through the literature review process.

In this study, the evaluation indicators have been selected by applying a hybrid research methodology including literature review and structured interviews. The significance of each candidate indicator is examined with the aid of local stakeholders. A questionnaire has been developed which is addressed to the municipalities, based on the European guidelines for smart cities. The selection of the factors and their indicators has been based on their applicability in cities with population less than 50,000 inhabitants. In total, 25 crucial factors have been selected and 68 indicators were elicited (Table A, Appendix). These factors with their relevant indicators are based on the European trends for smart cities and the local needs.

2.2 Evaluation Process

The problem has been modelled using multicriteria analysis. The aim of multicriteria analysis is to solve complicated problems taking into consideration all the criteria that affect the decision process. In the current study, the criteria are the selected indicators.

All factors have their internal impact reclassified to a common scale so that it is necessary to determine each criteria's (indicator's) relative impact. Weight is assigned to the criteria-indicators to indicate its relative importance. Different weights could influence directly the results and it is necessary to obtain the rationality

and veracity of criteria-indicators weights (Jia et al., 1998), (Wang et al., 2009).

The method of equal weights has been adopted in the proposed methodology. The criteria weight in equal weights method is defined as:

$$p_i = \frac{1}{n}, i = 1,2, \dots, n \text{ (n: indicators)} \quad (1)$$

This method is very popular and is applied in many decision-making problems since Dawes and Corrigan argued that the obtained results are nearly as good as those optimal weighting methods (Dawes and Corrigan, 1974).

All the values of the indicators have been normalised from 0 to 1, as the standardization of indicators is required, in order to compare them.

The ranking is obtained through the additive value model. The formulae describing the additive value model is the following:

$$u(g) = \sum_{i=1}^{n} p_i u_i(g_i) \quad (2)$$

$$u_i(g_{i*}) = 0, \ u_i(g_i^*) = 1 \ , i = 1,2, \dots, n \quad (3)$$

$$\sum_{i=1}^{n} p_i = 1 \quad (4)$$

$$p_i \geq 0 \ for \ i = 1,2, \dots, n \quad (5)$$

where g=(g_1,…,g_n) is the performance of each smart characteristic based on n indicators, $u_i(g_{i*})$ and $u_i(g_i^*)$ are the least and most preferable levels of indicator g_i , respectively, $u_i(g_i), i = 1, \dots, n$ are non-decreasing marginal value functions of the performances $g_i, i = 1, \dots, n$. p_i is the relative weight of the i^{th} function $u_i(g_i)$. Thus, for a candidate city $\alpha, g(\alpha)$ and $u[g(\alpha)]$ represent the multicriteria vector of performances and the global value of the alternative solution (in case that there are more than one city to be compared and evaluated), respectively (Siskos et al., 2014), (Androulaki and Psarras, 2016), (Strantzali et al., 2018).

The results have been aggregated on all levels without further weighting (Giffinger et al., 2007), (Lazaroiu and Roscia, 2012). The aggregation has been done additive but divided through the number of values added.

2.3 Questionnaire

The development of the questionnaire is based on literature and the special features of Greek cities. Zong et al. (2019) developed an evaluation indicator system of green and smart cities studying ten aspects: resource utilization, environmental governance and environmental quality, green and smart medical care, green and smart facilities, network security and citizens' experience. A similar questionnaire relative to the selected 68 indicators has been developed. It is addressed to the authorities, in order to answer the questions with their existing actions towards smart cities, and so the score for each factor and therefore for each smart characteristic has been calculated.

2.4 The Footprint of a Smart City

The aim of the proposed approach is for each city to be able to rank itself. The proposed footprint of a smart city includes 9 classes, from I to H (Figure 2). The range of scores in the higher classes is smaller than the range in the lower classes. As a result, the candidate city is obligated to implement more actions towards smart cities strategy when it is in the lower classes. The classification is elicited by aggregating the score from each separate Smart Characteristic. The result is aggregated on all levels by using equal weights and the method of additive value model (Table 1).

3 THE CASE OF MUNICIPALITY OF ELEFSINA

The municipality of Elefsina is in West Attica, Greece, situated about 18 km northwest from the centre of Athens. The municipality Elefsina was formed at the 2011 local government reform by the merger of the following two former municipalities, that became municipal units: Elefsina and Magoula. The municipality has an area of 36.589 km^2, the municipal unit 18.455 km^2 and a population of 29.902. Elefsina is a major industrial centre, at least 40% of the industrial activity of the country is concentrated there, with the largest oil refinery in Greece. On 11 November 2016 Elefsina was named the European Capital of Culture for 2021 (Wikipedia).

3.1 Smart City Performance across 6 Different Characteristics

The aim of this step is to record all the actions, fulfilling the requirements of each indicator, that Municipality of Elefsina has, already, implemented towards the smart city concept. The necessary information has been collected from the developed questionnaire and the individual interviews, addressed to the responsible Departments of the Municipality (Department of revenues, IT Department, Department

of Economics, Department of Transparency Programming and Department of Environment). All the answers have been matched with the selected indicators and their values have been normalized from 0 to 1. The total score for each smart characteristic is calculated following the additive value model. Based on these data, the evaluation process has indicated the following results:

Smart Economy: The indicators in the group of smart economy measure the performance of productivity, innovation, entrepreneurship and the integration with international markets. The total score in this smart characteristic is 0.224 (Table 1).

Smart Environment: Indicators in the group of smart environment addresses the issues related to the energy saving in public buildings, ecological awareness, sustainable resource management, air pollution and attraction of natural conditions. Municipality of Elefsina has already implement some actions in this direction and the total score in the field is 0.171 (Table 1).

Smart Governance: The indicators in the group of smart governance are associated with transparency in governance: municipality expenditure, e-government online availability, political strategies and perspectives and participation in decision making. In this field municipality of Elefsina has its higher score, 0.409 (Table 1).

Smart Living: Smart Living improves the quality of life and it is measured by the following indicators: educational and cultural facilities, individual safety and health conditions. The total score in this Characteristic is 0.268 (Table 1).

Smart Mobility: Smart Mobility indicators refer to local accessibility, touristic attractivity, availability of ICT infrastructure, public database and in general sustainable, innovative and safe transport systems. Here the score is very low, 0.194 (Table 1).

Smart People: Lifelong learning, level of qualification and participation in public life are the indicators that determine the Characteristic of "Smart People". The score is, also, high, 0.310 in comparison to the other fields (Table 1).

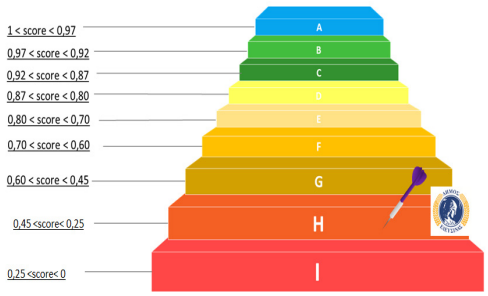

Figure 1: Municipality Elefsina's smart footprint.

Table 1: Weights and scores for Municipality of Elefsina.

Characteristics/ Factors	Weights	Scores
I) Smart Economy	**0.17**	**0.224**
Innovation	0.25	0.100
Entrepreneurship	0.25	0.094
Productivity	0.25	0.700
Integration with international markets	0.25	0
II) Smart Environment	**0.17**	**0.171**
Attraction of natural conditions	0.20	0
Air pollution integrated index	0.20	0.286
Sustainable resource management	0.20	0.171
Ecological Awareness	0.20	0.400
Energy Saving in Public Buildings	0.20	0
III) Smart Governance	**0.17**	**0.409**
Participation in decision-making	0.25	0.710
Political strategies & perspectives	0.25	0.643
E-Government on-line availability	0.25	0.285
Municipality expenditure	0.25	0
IV) Smart Living	**0.17**	**0.268**
Cultural facilities	0.25	0.020
Health conditions	0.25	0.550
Individual safety	0.25	0
Educational facilities	0.25	0.500
V) Smart Mobility	**0.17**	**0.194**
Touristic attractivity	0.20	0.429
Local accessibility	0.20	0.066
Availability of ICT infrastructure	0.20	0.473
Sustainable, innovative and safe transport systems	0.20	0
Public Database	0.20	0
VI) Smart People	**0.17**	**0.310**
Participation in public life	0.34	0.600
Level of Qualification	0.34	0.330
Affinity to lifelong learning	0.34	0

3.2 Overall Performance for Municipality Elefsina

Figure 2 gives the overall smartness of Municipality Elefsina for all the Characteristics and Figure 1 shows its smart footprint. It is classified in level H (aggregated total score 0.263). Therefore, its overall smart city performance is poor. The aggregate scores from all the Characteristics are low, even under 0.5, with a slight promotion of smart governance and smart people among the rest ones. The domains of smart environment and smart mobility have the

lowest scores. It is obvious that the authorities are working towards the direction of smart cities, but more effort is needed. In that direction, a set of indicative actions will be recommended in order to improve their smart footprint.

3.3 Recommended Actions for Improving Smart City Performance

Transformation of a city into a smart city is a long process. As appreciated in literature, smart infrastructure is the key to implement smart city programs (Shen et al., 2018). Infrastructure facilities will enable the development of all smart characteristics: smart economy, smart environment, smart governance, smart living, smart mobility and smart people. Actions for improving smart city performance are recommended in the context of Municipality of Elefsina. Although the recommended actions are based on data from Elefsina, their content could be implemented from any candidate smart city.

Examining the field of smart environment, leak detectors for water saving are suggested to be installed in residential and commercial buildings and other public areas. Smart meters and sensors could be used in all public buildings in order to collect the real-time data about energy consumption. These data could be further used for the proper energy management in buildings, by analyzing people' consumption behavior. The obtained data could be incorporated in authorities' policies in order to guide citizens, and especially students, towards energy saving life style. Alongside the improvement of energy efficiency of at least part of existing public buildings is of key importance. Smart street lighting will, also, help energy management and will improve the city' profile both in smart environment and smart governance.

Smart waste management should be adopted by using smart refuse bins with filling sensors. Furthermore, contributory recycling in combination with smart refuse bins and smart applications for the citizens could enhance the ecological awareness of inhabitants in a more efficient and effective way of waste management. All these actions will contribute to the performance improvement of smart environment, smart governance and smart living, collectively.

Applications for smart devices with useful information on points of interest according to the user's location will facilitate inhabitant's life. It could, also, provide the opportunity of emergency alert in case it is needed. This way the authorities will strengthen the characteristics of smart governance and smart living.

For the domain of smart transportation, smart bus stops should be implemented. Smart bus stops will provide information on bus routes combined with smart parking and rent bicycles. This action will, also, improve the performance of smart economy, as it reduces the time wasted on transportation and increase productive time.

The development of a smart business gate which will include all the local companies is very crucial for the smart economy. There will be two benefits: the inhabitant will be informed for each company's profile and the companies for available funding, national and European.

As Elefsina has been named the European Capital of Culture for 2021, some smart actions towards the field of culture will enhance its profile. Photorealistic visualization for historic buildings and important historic events will make citizens and tourists understand historical aspects that lost over time but remain important and necessary for today. At the same time, organized points for virtual reality tours could serve except from tourists, education in schools.

Finally, policy instruments should be introduced in order to encourage the promotion of smart city practices.

It is obvious that most of the above-mentioned actions will contribute to job creation, reducing the local unemployment rate, significantly, which is, also, a key indicator in smart economy.

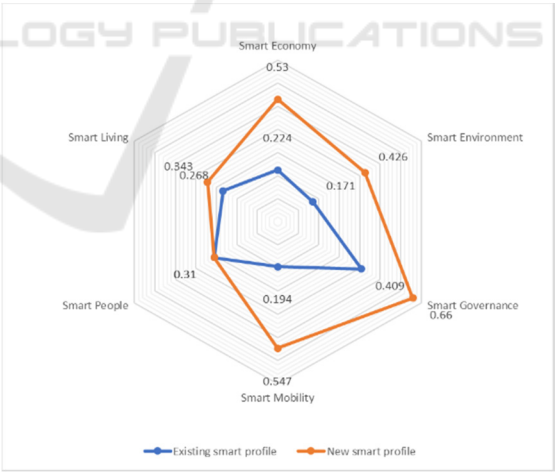

Figure 2: The overall performance of Municipality of Elefsina.

3.3.1 The New Smart "Footprint" of Municipality of Elefsina

The smart footprint of Municipality of Elefsina has been calculated again, by assuming that all the above recommended actions have been implemented. The

new overall score is now, 0.469 (Figure 2) and Municipality of Elefsina is categorised in class G (one class above the previous one). Almost all the smart characteristics have increased their performance, and especially, smart economy, smart environment, smart governance and smart mobility. Particular emphasis has been given on actions concerned smart environment and smart mobility as they were the characteristics with lower rating. The benefit is that one single action influences at the same time more than one smart characteristic. There are of course a lot of actions that could improve the performance of a smart city but here the most common and most important are recommended.

4 CONCLUSIONS

Cities are viewed as a part of the solution to many of today's economic social and environmental problems (Akande et al., 2019). The smart city represents the future challenge. An effective holistic evaluation model on the performance of a smart city is of utmost importance. Unlike previous studies, this study attempts to evaluate small smart cities in the context of Greece. In this article, a smart city ranking model has been proposed for cities with less than 50,000 inhabitants, including 25 factors and 68 indicators, and the case study concerned a Greek city, Municipality of Elefsina. The selected indicators fall into the most crucial axes for the evaluation of a small smart city.

The multicriteria method, Additive Value Model, and the method of equal weights have been selected for the evaluation process. The combination of these two methods simplified and summarized a complex concept into a manageable form. The smart footprint of a city is introduced as a result of the evaluation process.

Although it seems that Municipality of Elefsina has already taken small steps towards the smart cities, its overall score is very poor. It is remarkable its low score on smart environment, as the development of actions for improving the local environmental conditions should be a prime objective of the authorities.

A set of the most important actions, customized for its needs, have been recommended. The proposed actions are able to improve the smart city performance and the new evaluation process after their implementation has shown that the new score is markedly higher than the initial score in almost all the smart characteristics. The proposed evaluation mechanism should be applied alongside the actions in order to record in real-time the progress of smart city.

The contribution of the research is indicated by two axes: the proposed evaluation methodology for small smart cities and the implemented case study for a Greek city. Future research could focus on testing the methodology in more than one case studies, its holistic application will be improved. The presented model could be further enhanced with the evaluation of more Greek cities and the ranking of their results using multicriteria analysis. Furthermore, the comparison with other cities will enable the share of experience and effective actions could be formulated for the development of smart city in the whole country.

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APPENDIX

The proposed model includes 25 crucial factors and 68 relative indicators, shown in Table 2:

Table 2: The selected factors and their indicators.

Factors	Indicators
I) Smart Economy	
Innovation	Public Expenditure on R&D
	Funded projects
Entrepreneurship	New businesses registered
	Promotion of digital adoption
	Entrepreneurship Programs
Productivity	Unemployment rate
Integration with international markets	Research grants funded by international projects
II) Smart Environment	
Attraction of natural conditions	Green space
Air pollution integrated index	CO_2 emissions
	Air Pollutants
Sustainable resource management	Waste separation and disposal
	Annual thermal energy consumption
	Street lighting
	Electricity consumption
	Renewable resources
	Intelligent management of waste and recycling products
	Smart resource management
Ecological Awareness	Ecological consciousness
Energy Saving in Public Buildings	Public Schools
	Town hall and office buildings
	Museums / Theatres
	Sports Facilities
	Library
III) Smart Governance	
Participation in decision-making	City representatives per inhabitant
	Political activity of inhabitants
	Share of female city representatives
Political strategies & perspectives	Communication of economic and community development to the outside world
	Strategies for economic & social development
E-Government on-line availability	Employment services
	Online Payments
	Social services
	Public cultural and sporting activities
	Services for disabled people
	Safeguard system
	Public Health
	Urban management
	Public security
	E-commerce
Municipality expenditure	Bridging the digital divide
IV) Smart Living	
Cultural facilities	Theatres/Cinemas
	Culturally active citizens
	Technologies for cultural facilities
	Museums and historic monuments
	Public Libraries
Health conditions	Public care facilities
	Doctors
Individual safety	Safety at playgrounds
	Safety at sport facilities
	Safety at parks
	Safety at pools and beaches
	Safety at public buildings
Educational facilities	Public lessons
	Quality of educational system
V) Smart Mobility	
Touristic attractivity	Municipality's site
Local accessibility	Availability of public transport
	Quality of public transport
	Cycle paths
Availability of ICT infrastructure	Internet facilities
	Wireless networks
Sustainable, innovative and safe transport systems	Green mobility share
	Use of economical cars
Public Database	Urban infrastructure database
	Urban economy and society database
VI) Smart People	
Participation in public life	Voters
Level of Qualification	Computer skills
	Foreign language lessons
	After school study
Affinity to lifelong learning	Book loans