AN INTEGRATED MCDM APPLICATION FOR RANKING OF SMART CITIES

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ABSTRACT

Since the beginning of human history, people have felt the need to live in groups. This need for coexistence began to increase over time. Gradually growing human communities formed structures called "city". These buildings, where production and therefore job opportunities are high, have become centers of attraction for people. The population in the cities began to increase. This increasing population naturally caused some problems. At the beginning of these problems was the rapid depletion of resources. These problems pushed people to seek some solutions. As a solution, the concept of "smart city" emerged. In this study, a multi-criteria decision model has been developed to rank the success of some smart cities in Europe. As a result of this model, it has been revealed which city implements the concept of smartness better.

Keywords: Smart city, AHP, Entropy, MCDM, PROMETHEE, TOPSIS

1. Introduction

As time progressed, "smart city" concept became very important for better management of cities. Studies on the subject began to increase gradually. On the other hand, the smart city concept has been implemented by many cities, but it would not be right to expect every city to implement this concept at the same level. This study was carried out to see how successfully the smart city concept can be applied in cities in Europe. It is also one of the aims of this study to determine the elements that make the smart city smart and to reveal how much these elements are taken into account in the concept application.

2. Literature Review

As the interest in cities began to increase, problems such as air pollution, traffic jams, and public health problems began to emerge. In addition, most of the resources have become consumed in cities, and this rate seems to continue to increase (Albino et al., 2015). Since the implementation of the smart city concept is thought to have positive effects in areas such as transportation systems, environment and economy, the need to transform urban areas into smart cities has started to increase over time (Nunes et al., 2021). While cities are on the way to being smart, they should not harm the environment. In one of the smart city examples in China, it was observed that after the smart city initiatives started, the exhaust gas in the campus decreased by 20%, and the rate of industrial wastewater decreased by 12%, and as a result, it was determined that the eco-environmental quality in China also increased (Chu et al., 2021).

3. Hypothesis/Objectives

The aim of the study is to determine the factors that affect the success of smart cities and present a model that determines the success rankings of smart cities by considering the application situations of these factors.

4. Research Design/Methodology

In the study, firstly, the criteria to be used in the ranking were determined by literature review. At this stage, a very large pool of criteria emerged. The criteria in the preliminary list were screened out by investigating their frequencies of usage in the literature and whether there is up-to-date performance data of the cities with respect to the criteria. As a result, a hierarchy of 33 criteria in 6 main dimensions was created. These dimensions and sub-dimensions are demonstrated in Appendix 1. The performance data were obtained from the relevant sources, and the performance matrix to be used in the study was created. To determine the importance of criteria, in this study, we utilized two elicitation methods. As the entropy relates to the degree of diversity within an attribute dataset in the decision matrix, based on the fact that the smaller the entropy within the data associated to the attribute, the greater the discrimination power of the attribute in changing the ranks of alternatives, the priorities of criteria were revealed in an objective way. On the other hand, using the pairwise comparison questions posed to the 15 experts who are academicians working in the relevant departments of the universities, the priorities of criteria were revealed in a subjective way. The cities to be used in the study were also selected from the European region, but while determining these cities, care was taken to represent different geographic regions of Europe. After the cities to be used in the study were determined, the cities were analyzed and ranked using TOPSIS and PROMETHEE methods. According to the TOPSIS method, the ideal solution should be located at the shortest geometric distance from the positive ideal solution and the furthest geometric distance from the negative ideal solution. The PROMETHEE method is an outranking method that has been put forward based on the difficulties in other MCDM methods, such as incomparability, and performs ordering using preference functions.

5. Data/Model Analysis

In the study, the replies to the survey questions were collected, and then the geometric means of these replies were computed to obtain a ratio for each pairwise comparison. Subsequently, these ratios were entered into Super Decisions software, and the criteria priorities were determined. At this point, it was also checked whether the inconsistency ratios were below 10%. The priorities of the criteria are shown in Appendix 2. The table containing the results of the analyses (i.e. ranking of the cities with respect to their smartness) is given in Appendix 3.

6. Limitations

The questionnaire survey was conducted with the participation of 15 experts. Contacting more experts, especially civil authorities, would have made the results more reliable. In addition, the study was carried out only in the European continent. As it is known, there are smart city applications on many different continents in the world, so the scope of the study could have been expanded a little more in this sense. It is also possible to apply this model on different continents.

7. Conclusions

Although different results emerged from integrating famous MCDM methods, the city of London stood out as the smartest city in terms of average score. In the PROMETHEE method, when the priorities of the criteria obtained from AHP are used, the city of Copenhagen takes the first place, and when the priorities obtained from the entropy method are used, the city of Paris takes the first place. The reason for these differences is that the criteria have different importance according to each method, and the methods use different algorithms. As a further study, sensitivity analysis can be added to this study to observe what kind of differences will occur in the rankings of the cities when the priorities of the criteria change.

8. Key References

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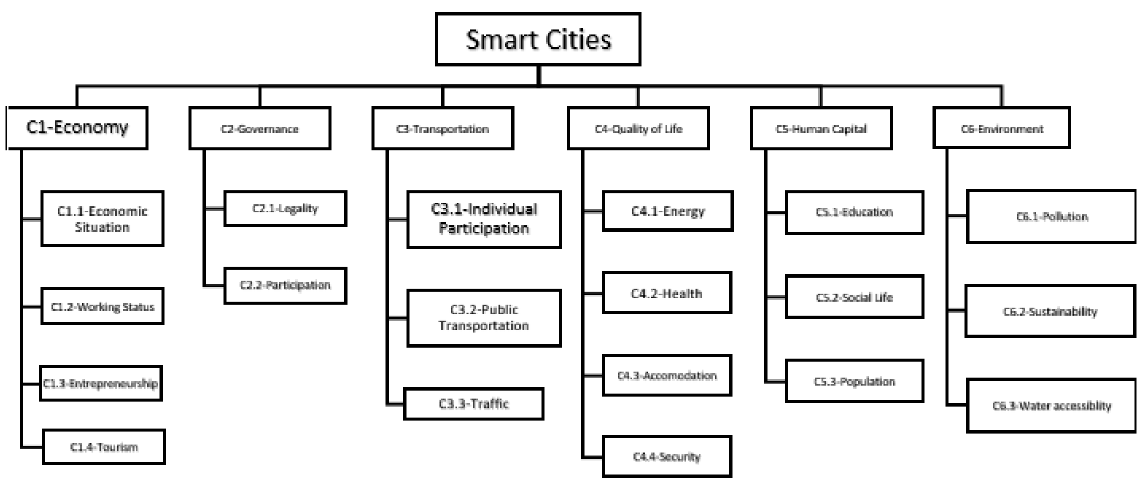
9. Appendices

Appendix 1. The Decision Hierarchy



Appendix 2. Importance of criteria

Criteria	**Priorities (AHP)**	**Priorities (Entropy)**
Green spaces	14.105%	3.84%
Consumer Expenditures on Health Products and Medical Services	10.381%	2.478%
Citizen Participation	8.719%	0.102%
Secondary and highly educated population	7.468%	0.058%
Housing quality	6.452%	0.274%
Number of metro/metro stations	5.773%	5.700%
Corruption Perceptions Index	5.481%	0.397%
Crime index	4.801%	0.780%
Water accessibility	4.687%	4.084%
Number of universities entering the QS World University Rankings	3.808%	4.173%
Number of library	3.110%	9.674%
Traffic index	2.151%	0.921%
The share of energy obtained from renewable sources in total energy	2.007%	2.478%
Number of museum	1.997%	4.055%
Unemployment rate	1.926%	2.343%
Death rate	1.761%	0.451%
Pollution index	1.730%	3.281%
Density of population	1.360%	3.600%
CO2 Emission	1.279%	7.305%
Ratio of real estate prices to income	1.223%	0.955%
Labor productivity	1.093%	0.174%
Number of universities entering the FT Global MBA Rankings	1.088%	4.661%
Number of flights	1.075%	3.006%
Bicycle lines	1.060%	0.763%
Patent per 1.000.000 person	0.825%	3.744%
International tourist number	0.766%	6.076%
The share of newly registered creative sector organizations	0.763%	10.445%
Housing affordability	0.746%	0.310%
Total early stage entrepreneurial activity	0.727%	1.353%
Road injury accidents	0.541%	0.784%
Total GDP	0.477%	4.188%
Population	0.368%	5.632%
Required time for new business	0.254%	2.271%

Appendix 3. Final Results

Ranking	TOPSIS + ENTROPY		TOPSIS + AHP		PROMETHEE II + ENTROPY		PROMETHEE II + AHP	
1	London	0.5717	London	0.6687	Paris	0.4108	Copenhagen	0.2133
2	Paris	0.5290	Wien	0.6257	London	0.2802	Helsinki	0.1917
3	Roma	0.4615	Rome	0.6051	Barcelona	0.1060	Wien	0.1671
4	Barcelona	0.4016	Helsinki	0.5810	Rome	0.0751	Amsterdam	0.1196
5	Wien	0.3007	Paris	0.4820	Wien	-0.0857	Paris	0.0503
6	Amsterdam	0.2980	Copenhagen	0.4753	Amsterdam	-0.1067	London	0.0472
7	Helsinki	0.2839	Barcelona	0.4353	Istanbul	-0.1954	Barcelona	-0.0610
8	Copenhagen	0.2811	Amsterdam	0.4169	Copenhagen	-0.2337	Rome	-0.2732
9	Istanbul	0.2618	Istanbul	0.1777	Helsinki	-0.2506	Istanbul	-0.4550