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Ranking Model of Smart Cities in Turkey

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Abstract— This paper demonstrates a ranking model to evaluate smart cities in Turkey. Structure of proposed model is based on the six characteristics that considered as main components of smart cities. These characteristics are smart people, smart living, smart mobility, smart economy, smart environment and smart governance respectively, which were described in the "Smart City Wheel" that developed by Prof. Boyd Cohen (2013). In order to achieve more realistic and applicable results, an online survey was conducted to assess weights for the indicators. Z-transformation method was used in order to standardize the values of indicators, and other steps of data processing were described in detail.

Working platform of the model is MATLAB and Microsoft SQL databases; database is holding the datasets of all the examined cities and the calculation results, and the MATLAB is responsible for the process of calculations and rankings. Indicator values of each city are held in the database as raw data and then converted into a single index by necessary procedures, and the overall ranking is made according to this index. Ranking results not only give us the overall ranking, but it can also provide us with separate rankings by six characteristics.

Keywords : *City rankings, Indicators, Smart city, Z-Transformation.*

1. Introduction

In recent years, with the advancement of technology, the 'Smart City' concept has spread rapidly with the aim to make cities more livable. This term has no general definition and used by different institutions in different meanings for different purposes, but in most cases, we are encountering the technology-focused definitions (Kaygısız, 2017; Türkiye Bilişim Vakfı (TBV), 2016). With the popularity of this concept, smart city projects have accelerated in many cities. In some developed cities around the world, smart city applications and projects have been implemented in different fields, and various rankings (Giffinger et al. 2007; Manvılle et al. 2015; Ricart et al. 2014) have been made to evaluate smart cities.

When we examine the current situation of Turkey, we can find that most of the cities are just taking new steps on smart city projects to become 'smarter' (TBV, 2017; Sağıroğlu, 2017; U.S Commercial service, 2016), so, there is not an existing study on smart city rankings. However, there is an annual publication (Ricart et al. 2018) named "IESE Cities in Motion Index (CIMI)" about city rankings that has been published by IESE Business School since 2014, which including three cities from Turkey except the latest version (CIMI 2018). Positions of the cities of Turkey in the rankings for last three years are shown in Table 1. Unfortunately, the results are not very pleasant for us.

According to the results in the table, Istanbul is the best one among the three cities and showing the best performance in 2017, but ranked 104 among 180 cities in the general ranking (Ricart et al. 2017).

Table 1. Cities of Turkey that included in the CIMI rankings.

Cities	CIMI 2016 (181 Cities)	CIMI 2017 (180 Cities)	CIMI 2018 (165 Cities)
İstanbul	109	104	114
Ankara	127	147	120
Bursa	128	154	--

City rankings can provide the smartness level of cities and increase their competitiveness (Giffinger et al. 2010), therefore, it is necessary to make a national city ranking for Turkey in order to ensure our cities make progress through competition. The purpose of this study is to build a ranking model to evaluate all the cities of Turkey that implemented smart city projects in certain fields, so that make the cities more competitive and improve their performances according to the evaluation results.

2. Model Structure and Working Principle

Proposed model is implemented using MATLAB and Microsoft SQL database. The database is holding the dataset of each city examined in the ranking, and corresponding tables that record the calculation results and ranking results. The MATLAB is responsible for processing the data and updating results. The following sections will describe both parts of the model.

2.1 Structure of the dataset

Dataset structure of cities is based on the six characteristics that defined by Boyd Cohen (2013) in his ‘Smart City Wheel’ as shown in Figure.1. The smart city wheel is describing the six characteristics with some factors, which can give us a rough direction to define our indicators.

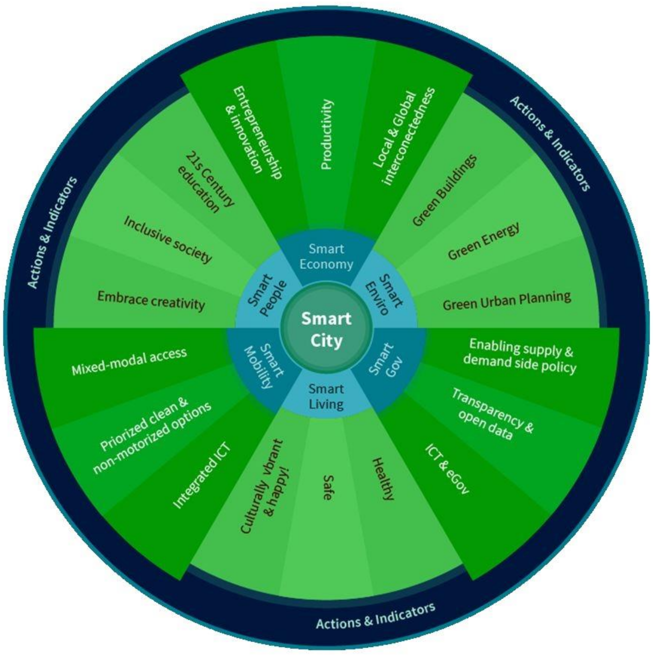

Figure 1. Smart City Wheel.

These same six characteristics are deployed by a number of studies (Benamrou, et al. 2016) to develop indicators for city rankings and Smart City development strategies, but the ranking models (Giffinger et al. 2007; Manville et al. 2015) that applied this structure have different factors and indicators according to their data source and ranking purposes. The proposed model in this study also has different factors and indicators. We have initially determined 23 factors and 66 indicators by reference to existing studies (Cohen, 2014; Giffinger et al. 2007; Deloitte and Vodafone, 2016). Indicators are stored in the database as raw data, and the upper layer values like factor values, characteristics values and overall performances are calculated using indicator values and their weights.

Database of the model contains the same number of *Dataset* tables as the number of examined cities, a *Results* table that records the performance values of six characteristics and general performances of all cities, and a *Ranking* table that records the ranking results. All of the dataset tables have the same structure, so it can be explained by a single example as shown in Table 2.

Table 2. Dataset structure of examined cities.

ID	Indicators	IndicatorValue	Weight	Zscore	Factors	FactorValue	Categories	CategoryValue
1	Yüksek eğitim görenlerin yüzdesi	85.410	NULL	1.153	• Eğitim seviyesi	0.913	Akıllı Toplum	0.614
2	İSCED'in 5-6. Seviyesindeki nüf...	83.587	NULL	1.069	• Yaşam boyu öğrenm...	0.259	Akıllı Yaşam	-0.185
3	Yabancı dil yeteneği	71.545	NULL	0.516	• Yaratıcılık	0.518	Akıllı Yönetim	-0.130
4	Hayat boyu öğrenmeye katılım o...	50.289	NULL	-0.461	• Katılımcılık	0.768	Akıllı Ulaşım	-0.568
5	Dil kuruşlarına katılım oranı	84.926	NULL	1.131	• Sosyal tesisler	0.370	Akıllı Çevre	0.459
6	Kişi başı kitap sayısı	62.626	NULL	0.106	• Sağlık hizmetleri	-0.740	Akilli Ekonomi	0.334
7	Yeni bir iş bulma yüzdesi	48.058	NULL	-0.563	• Sosyal güvenlik	-0.533	NULL	NULL
8	Yaratıcı endüstrilerde çalışanları...	95.120	NULL	1.599	• Barınma koşulları	-0.658	NULL	NULL
9	Seçimlere katılım oranı	90.075	NULL	1.367	• Eğitim tesisleri	0.635	NULL	NULL
10	Gönüllü çalışmalara katılım oranı	64.013	NULL	0.170	•Karar vermede toplu...	0.150	NULL	NULL
11	Sinema ve tiyatroya katılım oranı	69.798	NULL	0.436	•Dijital altyapı	0.022	NULL	NULL

The table is showing only a part (first 11 lines) of the *Dataset* table in order to demonstrate the table structure. As we mentioned before, the dataset of cities consist of 66 indicators, 23 factors and 6 characteristics. Therefore, the first 5 columns of original table has 66 lines of records as the number of indicators, and the next 2 columns (Factors, FactorValue) have 23 records. The highlighted part of the table, which named *Categories*, stands for the six characteristics of smart city respectively: Smart People, Smart Living, Smart Governance, Smart Mobility, Smart Environment, and Smart Economy.

2.2. Working principle of the model

Dataset table contains values of indicators as raw data, weights of indicators that assessed by an online survey (Ahmet, 2017), Zscore as standardized values that calculated by Z-transformation method, and performance values on factor level and characteristic level that calculated during the ranking process. These processes are completed through the following steps:

1. MATLAB connects to the database and then reads the indicator values. These values are standardized by equation (3) and then recorded on Zscore column.
2. Factor values are calculated using indicator values and their weights, then updated on the FactorValue column.
3. Performance of six characteristics are calculated using factor values and then recorded on the CategoryValue column.

After the above steps, performance values of six characteristics (Category values) of all examined cities are collected on the *Results* table (as shown in Table 3 at results section), and then general performances of each city are calculated by category values. So far, all the calculations are done and ready for ranking. Ranking results are recorded on *Ranking* table, which has the same structure as *Results* table, the only difference is the performance values are replaced by ranking numbers (as shown in Table 4).

3. Methodology

3.1. Selection of cities and indicators

In order to achieve more realistic and applicable results, we need to make some efforts on the selection of cities and determination of indicators. A broad scope and some certain selection methods were already defined by some existing rankings (Benamrou, et al. 2016), but a further selection is necessary according to the goal of ranking. As we mentioned before, the purpose of this ranking is to evaluate all the cities of Turkey that have implemented smart city applications in certain fields, therefore, selection of the cities simply depends on data availability.

For the indicators, over the past few decades, various national and international organizations have produced studies focusing on the definition, creation and use of indicators with a variety of aims, although mainly to contribute to a diagnosis of the state of cities. Today we have a lot of “urban” indicators, although many of them are neither standardized nor consistent or comparable among cities. As for the indicators developed by international organizations, it is true that they strive for the consistency and solidity necessary to compare cities; however, in the most case, they tend to be biased on a particular area like technology, economy, and the environment, among others (Ricart et al. 2017).

In this study, we referenced the existing ranking models (Giffinger et al. 2007; Manville et al. 2015; Ricart et al. 2016) and other studies (Dilek et al, 2016; Deloitte and Vodafone, 2016) about smart cities in order to define the most suitable indicators for the state of cities in Turkey. In fact, numerous attempts have been made to develop city indicators at the national, regional and international level. However, few have been sustainable in the medium term, as they were created for studies meant to cover the specific information needs of certain bodies, whose lifespan depended on how long the financing would last (Ricart et al. 2017). Taking all this into account, we initially determined 66 indicators to test our model, and that could be change depending on available data for actual rankings.

3.2. Assessment of weights

Indicators should have different weights according to their importance to the smartness of cities. We made an online survey[3] to assess weights for indicators. In the survey, each indicator has four choices as 0, 1, 2 and 3; 0 means that the indicator is unimportant or irrelevant with smartness of a city, and 3 indicates that the indicator has a significant influence on the smartness of cities. Figure 2 shows an example from the survey results.

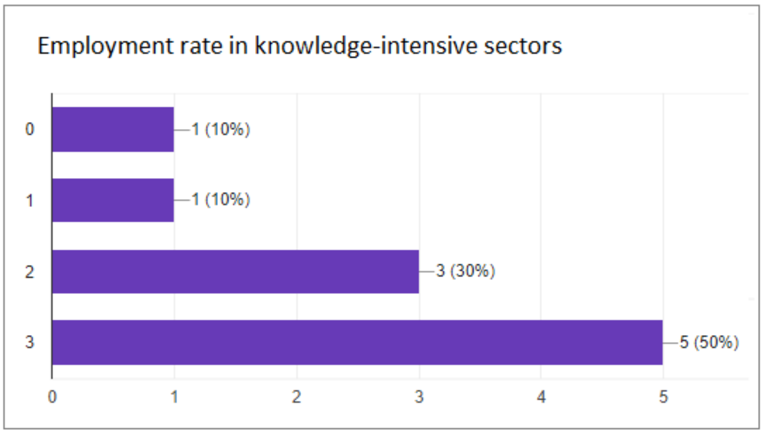

Figure 2. Part of the Survey Results

Survey results give us statistic values of each indicator as shown in Figure 2, and we need to do further calculations in order to get the exact weights of indicators. The weights can be calculated as

$$W=0*P_0 + 1*P_1+ 2*P_2 + 3*P_3 \tag{1}$$

In the equation, P_0, P_1, P_2 and P_3 is the proportion of 0, 1, 2, and 3 correspondingly in the answers that given to the calculated indicator, it also means $P_0 + P_1 + P_2 + P_3 =100\%$.

As an example, we can calculate actual weight of the indicator that named as "Employment rate in knowledge-intensive sectors" which shown in Fig.2, and the calculation result is:

$$0*0.1 + 1*0.1 + 2*0.3 + 3*0.5 = 2.20.$$

Weights of all the indicators should be calculated by this equation, and results should be recorded on the dataset tables of all examined cities.

Calculation results of weights are range from 0 to 3, and we need to rescale these weights into values between 1 and 2 in order to make the weights more reasonable. Rescale formula is:

$$newW_i = \frac{w_i - \min(w)}{\max(w) - \min(w)} + 1 \tag{2}$$

In the equation, W_i is original weights, *max(w)* is the maximum value, and *min(w)* is the minimum value of weights. Results of the survey can also be used to further selection of indicators by eliminating the indicators that the weights are very small or equal to zero. However, survey results show that we don't have such kind of indicators.

3.3. Standardization of indicators

The equations are an exception to the prescribed specifications of this template. You will need to determine whether or not your equation should be typed using either the Times New Roman or the Symbol font (please no other font). To create multileveled equations, it may be necessary to treat the equation as a graphic and insert it into the text after your paper is styled.

In order to compare the different indicators, we need to standardize the values. A well-known and widely used method to standardize is Z-transformation. This method, as shown in (3), transforms all the values into standardized values, and mean of transformed sample is always zero (μ=0) and standard deviation is always one (σ =1).

$$\text{Zscore} = \frac{(x_i - \mu)}{\sigma} \tag{3}$$

In this formula, x_i is original values of the sample data, μ is the mean of the sample, and σ is standard deviation. Calculation of standard deviation is shown in (4).

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2} \quad (4)$$

3.4. Further data processing

After the calculation of weights and standardization of indicators, we need to calculate factor values, characteristic values, and overall performances by using the weights and zscores. Factor values are calculated by the following equation.

$$F = \frac{1}{N}\sum_{x=1}^{N}(Z_x * W_x) \quad (5)$$

In the equation, N is the number of indicators that a factor has, Z_x is zscore values of indicators belong to this factor, and W_x is weights of the indicators.

Results are aggregated on upper level without any weights, therefore the characteristic values are just an arithmetic average of the factors as shown in (6).

$$C = \frac{1}{N}\sum_{x=1}^{N} F_x \quad (6)$$

According to the dataset, each characteristic has about 4 factors, and each factor has about 3 indicators on average. In order to make sure the correctness of results, we must consider which indicators belong to which factor, and which factors belong to which characteristic

4. Test Results

Since we did not get enough data for actual ranking, the proposed model was tested by virtual dataset for randomly selected 40 cities. Calculated values of the six characteristics and the general performances of all examined cities are given in Table 3 (*Results* table).

Table 3. Performance values of examined cities.

ID	Cities	Smart People	Smart Living	Smart Governance	Smart Mobility	Smart Environment	Smart Economy	General Performance
1	Adana	0.774	-0.324	-0.121	-0.839	0.602	0.48	0.572
2	Agri	0.213	-0.775	-0.258	-0.049	0.434	0.574	0.139
3	Aksaray	0.353	0.4	-0.036	-0.015	-0.195	-0.172	0.334
4	Ankara	-0.163	-0.044	-0.432	-0.035	0.034	0.411	-0.229
5	Antalya	0.062	-0.55	0.835	0.214	-0.54	0.019	0.041
6	Artvin	0.216	-0.235	0.093	-0.047	-0.674	1.088	0.442
7	Aydin	0.084	0.242	-0.741	0.466	-0.179	0.029	-0.099
8	Balikesir	0.018	-0.715	0.636	-0.014	0.321	0.487	0.732
9	Bartin	-0.742	0.059	-0.473	0.96	-0.117	-0.306	-0.619
10	Batman	0.079	-0.288	0.432	0.067	0.292	-0.322	0.26
11	Bayburt	-0.093	0.242	-0.118	-0.157	0.704	-0.766	-0.187
12	Bilecik	0.409	-0.486	-0.205	-0.141	0.593	0.058	0.227
13	Bingol	0.183	0.22	-0.302	-0.533	-0.066	0.263	-0.236
14	Bursa	-0.043	-0.144	-0.017	0.015	0.158	0.584	0.552
15	Canakkale	-0.193	0.026	-0.454	0.313	0.742	-0.145	0.289
16	Corum	0.092	-0.9	0.012	0.285	0.125	0.622	0.236
17	Denizli	-0.187	-0.057	-0.367	0.415	1.02	-0.553	0.271
18	Duzce	-0.705	0.538	-0.076	-0.553	0.432	0.349	-0.015
19	Edirne	0.546	-0.123	-0.529	0.119	-0.34	0.394	0.066

20	Erzincan	-0.439	0.361	0.149	0.001	-0.234	-0.513	-0.676
21	Erzurum	-0.714	-0.265	0.669	0.372	0.945	-0.663	0.344
22	Eskisehir	-0.6	0.79	-0.317	-0.083	-0.262	0.261	-0.21
23	Gaziantep	-0.001	0.288	-0.317	-0.702	0.06	0.754	0.082
24	Istanbul	0.461	0.38	-0.698	-0.178	-0.346	0.358	-0.022
25	Izmir	-0.597	-0.25	-0.126	0.359	0.618	0.247	0.252
26	Kars	0.088	0.513	-0.502	0.395	-1.896	0.474	-0.929
27	Kayseri	0.545	0.244	0.077	0.401	-0.416	-1.032	-0.182
28	Kilis	0.308	0.117	1.21	-0.135	-0.967	-1.043	-0.51
29	Kocaeli	-0.27	0.756	-0.271	-0.558	0.598	-0.133	0.121
30	Konya	-0.17	-0.253	-0.054	0.211	0.421	0.312	0.466
31	Mersin	-0.262	0.033	0.41	0.336	-0.899	-0.058	-0.441
32	Nigde	0.656	-0.204	0.031	0.197	-0.687	-0.3	-0.306
33	Ordu	0.474	0.127	0.077	-0.179	0.161	-0.319	0.342
34	Rize	-0.719	-0.088	0.375	-0.349	0.552	0.326	0.096
35	Sakarya	0.13	0.667	0.443	0.228	-0.928	-0.534	0.007
36	Samsun	-0.166	-0.304	1.512	0.607	-1.139	-0.614	-0.103
37	Sirnak	-0.209	-0.075	0.089	-0.133	-0.029	0.46	0.102
38	Sivas	0.817	-0.614	-0.123	-0.106	0.591	-0.396	0.168
39	Tokat	0.305	-0.02	-0.336	-0.287	0.309	-0.001	-0.031
40	Usak	0.129	0.034	-0.593	-0.761	0.872	0.194	-0.124

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The ranking table records the ranking results that performed by the six characteristics and the general performances as shown in Table 4. However, this model also records the factor values in database during the process, and make it possible to compare cities in factor level.

Table 4. Ranking results.

Cities	Smart People	Smart Living	Smart Governance	Smart Mobility	Smart Environment	Smart Economy	General Ranking
Balikesir	22	38	5	20	15	6	1
Adana	2	34	22	40	7	7	2
Bursa	24	26	17	18	19	4	3
Konya	28	30	19	14	14	15	4
Artvin	12	28	11	23	34	1	5
Erzurum	38	31	4	7	2	37	6
Ordu	6	14	14	32	18	30	7
Aksaray	9	6	18	21	27	27	8
Canakkale	30	19	34	10	4	26	9
Denizli	29	22	32	4	1	35	10
Batman	20	32	7	17	17	31	11
Izmir	35	29	24	8	6	18	12
Corum	17	40	16	11	20	3	13
Bilecik	8	35	25	29	9	20	14
Sivas	1	37	23	26	10	32	15
Agri	13	39	26	24	12	5	16
Kocaeli	33	2	27	37	8	25	17
Sirnak	31	23	12	27	23	9	18
Rize	39	24	9	34	11	14	19
Gaziantep	23	9	30	38	21	2	20
Edirne	4	25	37	16	30	11	21
Antalya	21	36	3	13	33	22	22
Sakarya	15	3	6	12	37	34	23
Duzce	37	4	20	36	13	13	24
Istanbul	7	7	39	31	31	12	25

Tokat	11	20	31	33	16	23	26
Aydin	19	11	40	3	26	21	27
Samsun	27	33	1	2	39	36	28
Usak	16	17	38	39	3	19	29
Kayseri	5	10	13	5	32	39	30
Bayburt	25	12	21	30	5	38	31
Eskisehir	36	1	29	25	29	17	32
Ankara	26	21	33	22	22	10	33
Bingol	14	13	28	35	24	16	34
Nigde	3	27	15	15	35	28	35
Mersin	32	18	8	9	36	24	36
Kilis	10	15	2	28	38	40	37
Bartin	40	16	35	1	25	29	38
Erzincan	34	8	10	19	28	33	39
Kars	18	5	36	6	40	8	40

As shown in the table, ranking results provide us with the overall position of cities and their positions in each characteristic. As the main purpose of this study, the results and detailed evaluations can contribute to a diagnosis of the states of cities.

5. Conclusions

Test results show the proposed model is working well and can be used for actual ranking of smart cities. Structure of the model, methodology, and working process are described in detail so that it can be reproduced, and can be implemented in other kind of rankings by simple modifications.

Ranking result of this model is not just an overall list, it also provides detailed rankings by six characteristics. The ranking process also records the factor values, and it is possible to compare cities on factor level. These detailed results can reveal actual strength and weakness of cities, so that cities can improve their competitiveness according to the evaluations.

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