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81 İl İçin ISO Akıllılık, Sürdürülebilirlik ve Dayanıklılık Kent Endekslerinin Belirlenmesi ve Radar Grafik Haritalarının Görselleştirilmesi

Determination of ISO Smartness, Sustainability, and Resilience City Indices for 81 Turkish Provinces, and Visualization of Their Radar Chart Maps

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Öne Çıkanlar / Highlights

▪ Kentlerin ISO göstergeleri yardımıyla akıllılık, sürdürülebilirlik ve dayanıklılık endekslerinin oluşturulması	▪ Creating smartness, sustainability and resilience indexes of cities with the help of ISO indicators
▪ Kentlerin akıllılık, sürdürülebilirlik ve dayanıklılık performanslarını belirlemek için kent radar grafik haritalarını görselleştirme	▪ Visualizing city radar graphic maps to determine smartness, sustainability and resilience performances of cities
▪ Endeks sıralama ve kent radar haritaları yardımıyla kent yönetici ve paydaşlarının doğru strateji ve politikaları belirleyebilmesini sağlama	▪ Ensuring that city managers and stakeholders can determine the right strategies and policies with the help of index ranking and city radar maps

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Keywords

Smart City, Sustainable City, Resilient City, Critical Success Factor, City Radar Chart Map

Özet

Yeni mobil ve dijital teknolojiler dijital nesnelerle bütünleşerek kentlerin dijital dönüşümünü veya akıllı kent haline gelmesini sağlamaya başlamışlardır. Bu akıllanma seviyesinin hangi aşamada olduğunun ölçülmesi kent strateji ve politikalarının belirlenmesi için gereklidir. Ancak günümüzde dijitalleşen kentlerin akıllanması yanında sürdürülebilirlik ve dayanıklılığının da ölçülmesini gerektirmektedir. Bu yüzden "ISO Kritik Başarı Faktörleri (KBF) ve ilgili gösterge verileri vasıtasıyla kentlerin akıllılık, sürdürülebilirlik ve dayanıklılık endekslerinin hesaplanması" bu araştırmanın amacı olarak belirlenmiştir.
Dünyada ve Türkiye'de kentlerin akıllanmasıyla ilgili çok farklı araştırmalar olmasına rağmen bu araştırmada ISO KBF ve göstergeleri kentlerin küresel olarak karşılaştırılabilmesini sağlamak için kullanılmıştır. Araştırmada ISO'nun endeks çalışmalarında kullandığı 20 KBF'si ve herbir endeks için kullandığı göstergeler kullanılmıştır. ISO tarafından farklı alanlarda belirlenen farklı sayıda gösterge değerleri öncelikle belediyeler, TUİK, BTK, SGK, MEB, TİM, TOBB, SB, ÇŞB vs. gibi resmî kurumlardan toplanmıştır. Toplanan verilerden öncelikle KBF bazında ISO akıllılık, sürdürülebilirlik ve dayanıklılık kent radar grafik haritaları çıkarılmış ve bu haritalar yardımı ile farklı ISO kent endeksleri hesaplanmıştır. Bu endeks değerleri ve kent radar grafik haritaları yardımıyla ilgili kent yönetici ve paydaşları kentle ilgili daha doğru stratejiler ve politikalar belirleyebilir ve kent paydaşlarının kent yönetici performansları ve diğer kentlere göre durumları hakkında bilgi sahibi olmasını sağlanabilir.
Bu araştırma ISO göstergeleriyle Türkiye'de yapılan ilk akıllılık, sürdürülebilirlik ve dayanıklılık kent araştırmasıdır.

Abstract

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New mobile and digital technologies have begun to integrate with digital objects and enable cities to digitally transform or become smart cities. Measuring the stage of this level of smartness is necessary to determine city strategies and policies. However, today, digital cities require measuring their sustainability and resilience as well as smartness. Therefore, the purpose of this research was determined as "calculating the smartness, sustainability, and resilience indexes of cities through ISO Critical Success Factors (CSF) and related indicator data".
Although there are many different studies on the smartness of cities in the world and Turkey, ISO CSF and indicators were used in this research to ensure that cities can be compared globally. In the research, 20 CSFs used by ISO in index studies, and the indicators used for each index were used. Different numbers of indicator values determined by ISO in different areas were collected primarily from official institutions such as municipalities, TUİK, BTK, SGK, MEB, TİM, TOBB, SB, ÇŞB, etc. From the collected data, ISO smartness, sustainability, and resilience urban radar chart maps were first extracted based on CSFs, and different ISO urban indexes were determined with the help of these maps. With the help of these index values and urban radar chart maps, relevant city managers and stakeholders can determine more accurate strategies and policies regarding the city and provide information to city stakeholders about the performance of city managers and their city status compared to other cities. This research is the first smartness, sustainability, and resilience city research conducted in Turkey with ISO indicators.

1. INTRODUCTION

Ensuring the digital transformation of cities by integrating developing mobile and digital technologies with digital sensors in cities becomes important in fulfilling municipal and other city services effectively, sustainably, and efficiently. Smart city applications that started to emerge with the digital transformation of cities have begun to offer important opportunities in ensuring urban security, finding addresses, collecting garbage, monitoring municipal vehicles, and activating and ensuring the sustainability and resilience of other municipal services (TürkTelekom, 2018).

Here, a Smart City (SC) is defined as a city where data and information flow in a digital environment and physical entities in the city communicate in this digital environment. The digital transformation of a city means becoming a "Smart City" (Satyam, 2017). Smart cities owe their birth to "Wireless Internet Networks" (Çoruh, 2022). Today, it has become impossible to collect and analyze city data that has not been digitalized (Kayan, 2019). Therefore, cities need to be equipped with smart sensors and services and their digital twins need to be created. However, today, in addition to being smart, cities are also required to be "Sustainable and Resilience".

A sustainable city is defined as a development that prevents the irreversible destruction of natural values as a result of use above the natural carrying capacity and meets the needs of future generations as well as current generations (Bayram, 2001, s. 255).

Although there are many sources in the literature on the smartness and sustainability of cities, the concept of urban resilience is a relatively new concept and one of the new research areas (Ernstson, et al., 2010). It has been defined as "the degree to which cities can withstand the stresses that occur during the change process before they are reorganized with a new structure" (Alberti, et al., 2003, p. 1170). However, the subject of this research is not about the smartness, sustainability, and resilience features of cities, but about calculating the degree to which they have these features with the help of indicators and ranking them accordingly.

Many organizations and research groups around the world make classifications such as the most livable city, the best global city, the smartest city, the most digital city, and the city with the best job opportunities. In this context, various indices regarding the digitalization, sustainability, resilience, and smartness levels of cities in the world and Turkey are developed by different national and international institutions. Because numerical indicators related to the digitalization of cities are becoming extremely important for the design of international and national policies (TÜBİSAD, 2020, s. 19). These city index rankings are generally used by cities to increase their promotion and improve their position in the competition among cities in the world (SCRanking, 2007).

Many Critical Success Factors (CSF) that affect the smartening or digitalization of cities have been revealed in SC indexing studies around the world. In line with these CSF indicators that determine the smartening of cities in the world and Turkey have been made and published, showing the level of smartness of cities. However, due to recent climate, economy, demography, and political developments, it has been seen that cities need to be smarter as well as ensure their sustainability and resilience. Therefore, the smartness, sustainability, and resilience levels of cities need to be measured and reported to relevant city stakeholders. In this way, relevant city institutions and stakeholders can make strategic and political decisions in line with these measurements and ensure the development of life and services in the city. It should not be forgotten that the smartening of cities should be read as the digitalization of cities (Satyam, 2017). Today, it has become impossible to collect and analyze urban data that is not digitalized (Kayan, 2019). Therefore, cities need to be equipped with smart sensors and services and their digital twins must be created.

In smart city indexing studies around the world, many CSFs affecting the smartness or digitalization of cities have been revealed. In line with these CSFs, indicator data determining the smartness of cities in the world and Turkey have been collected, and many different national and global "Smart City Index (SCI)" calculations or different "Assessment Models" showing the level of smartness of cities have been made and published. All these smart city index studies have been influenced by the "SC Wheel" which is defined in (Cohen, 2012). In this field, many institutions such as Cisco, IBM, the European Union, and ISO in the World, IBB, Vodafone-Deloitte, the Turkish Informatics Foundation, and the Ministry of Environment and Urbanization in Turkey have published smart city indices. A list of these index studies can be accessed from (Çoruh, 2022a). PAS 181, ISO 37120, and ISO 37122 in the world determine the international standards in the field of Smart Cities.

As emphasized before, due to climate, economic, demographic, and political developments, it has been seen that cities need to become smarter as well as their sustainability and resilience. Therefore, in addition to measuring the smartness levels of cities, it is also necessary to measure their sustainability and resilience levels and report them to relevant city stakeholders. In this way, relevant city institutions and stakeholders can determine the right policies and make the right strategic decisions in line with these measurements, thus ensuring the development of life and services in the city. A literature review on smart cities and sustainability can be found in (Shmelev & Shmeleva, 2025). Some of the index studies on urban resilience are listed in Table 1.

Table 1. Resilient City Index Research

Name	Developer and Supporter	Dimensions	CSF #	Ind #	Website	Year
City Resilience Index	Developed by the ARUP group and supported by the Rockefeller Foundation	Infrastructure resilience, social inclusion, environmental sustainability, and leadership in resilience planning	12	52	https://mercociudades.org/wp-content/uploads/2020/10/CRI-total-Booklet.pdf	2016
Resilient Cities Index	Developed by Economist Impact and supported by Tokio Marine Group	Climate change, social inequality, disaster preparedness, and long-term sustainability	8	24	https://www.preventionweb.net/publication/resilient-cities-index-2023	2013
Global Resilience Index	Aon	Climate risk exposure, infrastructure vulnerability,	3	40	https://global.infrastructureresilience.org/guide	2016

		economic stability, and social resilience				
UN Habitat's City Prosperity Index (CPI)	UN-Habitat	Social inclusion, economic opportunity, infrastructure, and environmental sustainability	10	50	https://unhabitat.org/city-prosperity-index	2012
Resilience Capacity Index (RCI)	The Rockefeller Foundation	Economic resilience, governance, infrastructure, and social resilience	3	8	https://www.rockefellerfoundation.org/	2015
The Urban Resilience Index	University of Melbourne and Australian National University	Governance, urban infrastructure, and environmental resilience	4		https://www.unimelb.edu.au/	2017
Global Cities Resilience Index	The Economist Intelligence Unit (EIU)	Social stability, economic resilience, infrastructure, and governance	6	40	https://www.eiu.com/	2015
ICLEI's Resilient Cities Assessment	ICLEI (Local Governments for Sustainability)	Environmental sustainability, disaster risk management, and adaptive capacity	6	40	https://www.iclei.org/	2006
European Resilience Index	European Commission	Economic resilience, climate adaptation, social integration, and governance	4	30	https://commission.europa.eu/index_en	2018
ISO 37122:2019 Sustainable cities and communities-indicators for resilient cities	International Standard Organization (ISO)	No dimension	20	78	https://www.iso.org/standard/69050.html	2019

As stated on the website of the "Resilient City Index 2023" in the table, it was developed by Economist Impact to support policymakers and stakeholders of 25 global cities in the world to understand the risks related to their cities and design effective policies and is renewed every year. Four dimensions are used to measure the resilience of cities in the index: critical infrastructure, environment, socio-institutional, and economy. "Economist Impact" defines urban resilience as the ability of a city to avoid, withstand, and recover from shocks and long-term stresses. In the words of Economist Impact, a resilient city should be able to organize itself after a shock event, adapt to emerging risks, and plan ahead rather than react (EconomistImpact, 2023). In this index of 25 global cities, where the most resilient city is New York with 84.9 out of 100 points and the least resilient city is Lagos with 39.6, Istanbul appears in 16th place with 65.9 points.

The "City Resilience Index" in the table was developed by the Arup group in 2014 with the support of the Rockefeller Foundation. This city resilience index provides a comprehensive, technically sound, and globally applicable basis for measuring city resilience. The research, consisting of 52 indicators evaluated according to the answers given to 156 questions through a combination of qualitative and quantitative data, is reported in line with 12 objectives (or CSF). The index was first piloted in the following 5 cities: Shimla, India, Concepcion, Chile, Arusha, Tanzania, Hong Kong, China and Liverpool, England (Arup, 2019). The Australian firm Arup, the designer of the index, has been bringing together design and engineering studies with social purpose since 1946. Arup encourages city policymakers and other city stakeholders around the world to start this vital analysis by using the interactive online assessment tool at www.cityresilienceindex.org. The document at https://mercociudades.org/wp-content/uploads/2020/10/CRI-total-Booklet.pdf shows that the same research has been carried out in 23 other cities. No other city in Turkey has implemented this index. The updated 2024 framework version of the index is available at https://resilientcitiesnetwork.org/downloadable_resources/Publications/City%20Resilience%20Framework%2024%20FINAL_.pdf.

The ”Global Resilience Index” has been developed by Aon, a global risk management firm, which focuses on cities' resilience to climate risks, environmental hazards, and socioeconomic factors. The details of the remaining indexes info can be reached from their websites in Table 1.

On the other hand, it is seen in the literature that the dimensions, CSFs, and indicators used in the studies measuring the level of smartness, sustainability, and resilience of cities are generally technology and special subject-oriented (Vodafone, 2016). Therefore, when measuring the smartness, sustainability, and resilience of cities, more holistic research is needed that measures values in many areas such as economy, education, transportation, governance, energy, demographic structure, health, environment, smart city applications, and technical infrastructure. For this purpose, CSFs and indicators used in different areas by the International Organization for Standardization (ISO) can be used as global standards.

So, the purpose of this research “*is to calculate the smartness, sustainability, and resilience levels of digitalized cities within the framework of a specific model with ISO CSFs and indicators*”. In the research, 129 ISO 37120 sustainability city indicators, 81 ISO 37122 smart city indicators, and 78 ISO 37123 resilience city indicators were used. The ISO reports used in the research are:

1. ISO 37120:2018 Sustainable cities and communities-indicators for city services and quality of life.
2. ISO 37122:2019 Sustainable cities and communities-indicators for smart cities.
3. ISO 37123:2019 Sustainable cities and communities-indicators for resilient cities.

The 20 CSFs and the number of indicators used in these index reports published by ISO are listed in Table 2. No research has been found on the internet using these three ISO index indicators together.

Table 2. ISO Critical Success Factors and Indicator Numbers

#	Critical Success Factors (CSF)	ISO 37120 Indicators #	ISO 37122 Indicators #	ISO 37123 Indicators #
1	Economy	11	4	7
2	Education	6	3	4
3	Energy	9	10	3
4	Environment and climate change	9	3	9
5	Finance	6	2	7
6	Governance	4	4	6
7	Health	6	3	4
8	Housing	10	2	6
9	Population and social conditions	9	4	5
10	Recreation	2	1	2
11	Safety	10	1	4
12	Solid waste	10	6	1
13	Sports and Culture	3	4	3
14	Telecommunication	2	3	1
15	Transportation	9	14	1

16	Urban/local agriculture and food security	4	3	2
17	Urban planning	7	4	6
18	Wastewater	4	5	4
19	Water	7	4	2
20	Reporting and record maintenance	1	1	1

In this research, ISO index values showing the smartness, sustainability, and resilience levels of 81 provinces in Turkey were calculated with the help of ISO CSFs and indicators listed in Table 1 (indicators can be viewed from relevant ISO reports above). These are briefly named Smart City Index (SCI), Sustainable City Index (SUCI), and Resilient City Index (RCI).

In the "Smart Cities White Paper" prepared by the Geographic Information Systems (GIS) Directorate in Turkey in 2019, it was stated that individuals and institutions seeking solutions to the needs of cities need some evaluation tools that will show how "Smart" the city is, to produce smart city solutions. In the same bulletin, it was stated that quantitative and qualitative analysis tools were needed to make these evaluations. The indexing model and radar chart maps used in this research can meet the needs of these evaluation and analysis tools (Çoruh, 2021). Briefly, with the help of the "Index Calculation Model" used in the research, it was tried to explain how to rank the cities according to these different ISO index values and how to visualize the smartness, sustainability, and resilience of the cities through city radar chart maps.

This study is the first research measuring the "Smart, Sustainable and Resilient City" level of 81 provinces in Turkey in line with ISO standards. In this research, under the coordination of the Turkish statistical institution (TUİK), institutions such as YÖK, CSB, SB, TOBB, SGK, MEB, ATGM, TIM, TBB, EPDK, STB, HGM, TPK, Işkur, MGM, AFAD, BTGM, BTK, Türk Telekom, Gazbir and SBB’s published official statistical data on a provincial basis and data collected from 81 provincial municipalities were used.

2. METHOD

In the research, the city index calculation method, which shows how to measure the smartness, sustainability, and resilience levels of cities and how to rank cities, was used, as explained in detail in (Çoruh M., 2021). Specially prepared Access database and Excel spreadsheet programs were used to record, process, visualize, and analyze the data used in the research. The calculation details of these tables are explained in the "The Research Findings and Discussion" section. The process model consisting of the "Discovery, Data Collection, Index Calculation, and Evaluation" stages seen in Figure 1 was used in the research.

As can be seen from the model in the figure, the indicators, CSFs, and dimensions required for measuring the smartness, sustainability, and resilience levels of cities were taken from ISO standards in the “Discovery” phase. Then, the indicator data were collected from primary and secondary sources in the “Data Collection” phase and CSF ratios and maximum R values were calculated with the help of the formulas determined in this research. The average indicator values of Turkey used in these calculations were obtained from the official websites (secondary source) of institutions such as TUİK, BTK, TOBB, MEB, TUSİAD, TİM, SGK, YÖK, TUBİSAT. It was observed that these secondary source data, which are published on an annual and monthly basis, are generally published on a Turkey and province basis (Çoruh & Cebeci, 2020). The primary source municipal data required for the research were collected from the “Information Technology (IT)” departments of the provincial center municipalities with the help of “Survey Forms”.

Firstly, by visualizing the smartness, sustainability, and resilience ratio values calculated based on CSF with the help of indicator values, smartness, sustainability, and resilience radar chart maps were created that city managers can use in making decisions about the city. After the areas on the radar chart maps were calculated with the "Polygonal Area Calculation", the smartness, sustainability, and resilience index values of the cities were calculated using the "Satyam Technique". In the "Evaluation" stage, different ISO rankings of the cities were determined according to the relevant index values.

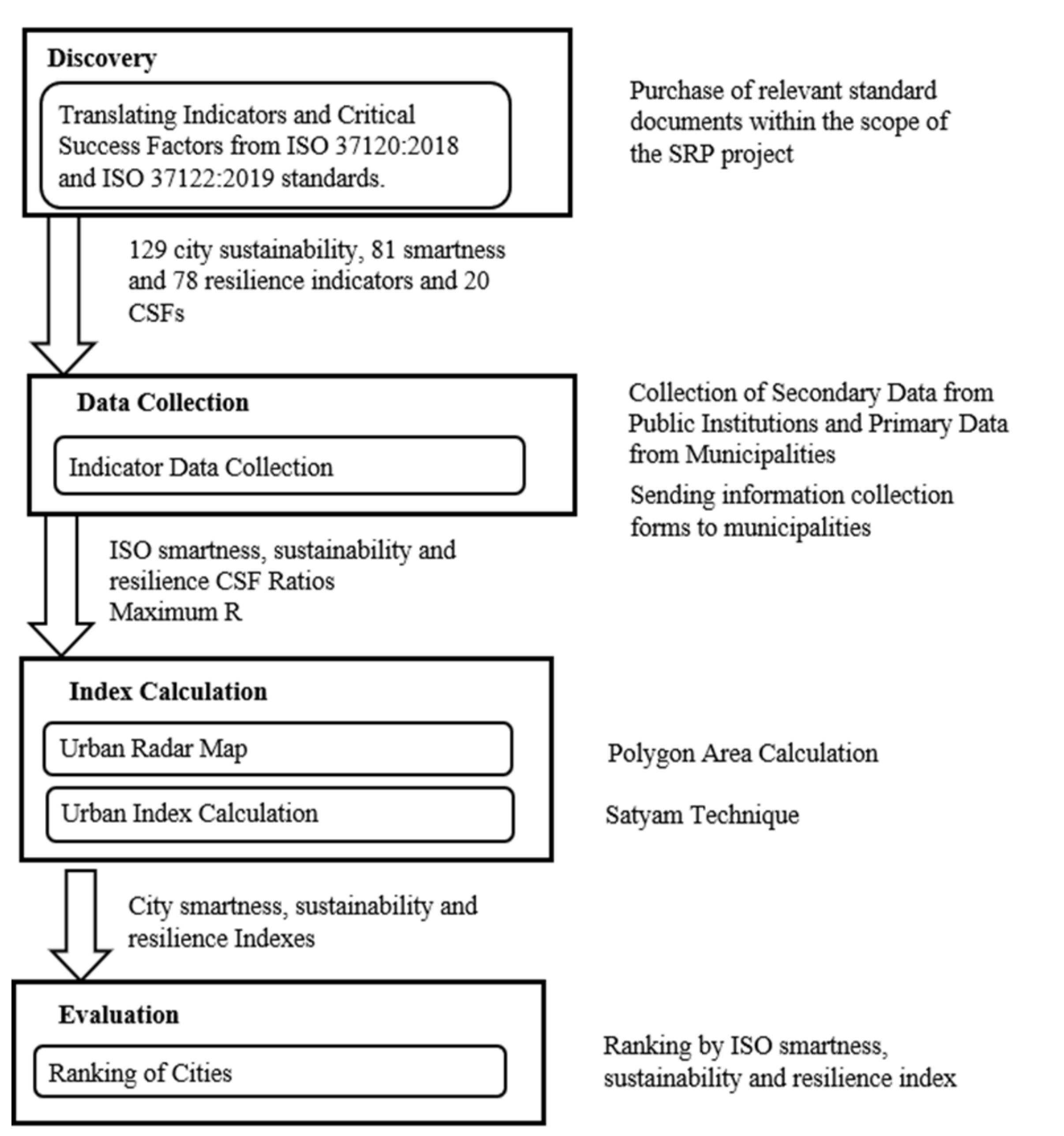

Figure 1. Application Model of Research

Source: Çoruh, M. (2021). *Çok kriterli karar verme tekniklerine dayalı yeni bir kent dijitalleşme endeks hesaplama modeli önerisi: Türkiye uygulaması*. Doktora Tezi. Sakarya Üniversitesi İşletme Enstitüsü YBS Bölümü, Sakarya. The model was rearranged for this research.

In summary, for the calculation of the ISO smartness index of the cities, the collected indicator values were divided by the Turkish averages or standard values and first the "Indicator Ratio" was found. The total ratio of each smartness CSF was found by adding these indicator ratios and this ratio was divided by the CSF indicator number and the "CSF Ratio" used in creating the radar chart maps was calculated. "Smart City Radar Chart Maps (SCRCM)" were created with these CSF ratio values and after calculating the areas (x) of these SCRCMs, the "Smart City Indexes" of the cities were calculated by dividing the radar chart areas suggested in (Satyam, 2017) by the circle area (y) containing this area.

This (x/y) calculation formula is called the "Satyam Calculation Technique". In this formula, the x triangular areas on the radar chart maps were calculated with the formula ($x = (A * B * \sin 18)/2$) and their totals were taken. For the calculation of a single common circle area (y) for each city, the largest CSF value from 81 provinces was selected and the maximum (R) value was determined. The radar chart map areas of the cities were divided by the circle area calculated with this R ($y = \pi R^2$) and the calculated index values were also used in the ranking of the cities (Çoruh M., 2021). These processes were repeated for the calculation of "ISO Sustainable City Indices" and "ISO Resilient City Indices".

Different city ranking indices and city radar chart maps have been published in Turkish and English on http://www.mustafacoruh.com/WebSC/SC_Default site regularly every year since (2020) for the use of city municipalities, public institutions, citizens, and researchers.

This calculation method used in the research is explained in the findings section through the example of Ankara.

In this research, first, the collection of 2022 data published by different institutions on a provincial and Turkish basis in line with the relevant official statistics publication calendar coordinated by TUIK (TURKSTAT) was ensured and the newly published 2020 and 2021 data was added, or updated. Because many annual statistical publications can be one or two years behind. For this reason, the rankings published on the relevant site change as the data for that year comes in. On the other hand, a Scientific Research Project (SRP) was created in the newly opened "EYON341 Smart Cities" course in the 2023-24 fall semester at Nişantaşı University, Faculty of Economics and Administrative Sciences, Department of Management Information Systems to collect provincial municipality data not published by official statistical institutions. Within the scope of this SRP project, the data of provincial municipalities were collected with the help of students. The situation was explained to the 34 students who were initially enrolled in the course and as a result, 23 students decided to continue the course to help with the project.

In the first 4 weeks, data was collected from municipality websites, municipal activity, and performance reports by sharing the 81 provinces among 23 students. The data collected by the students were entered into the SQL Server + MS Access database in the 5th week. The students used the "Survey Form" which was created to collect data from the municipalities. These data survey forms, which report the data collected in each provincial municipality, were sent to the relevant municipality by e-mail and were asked to correct the incorrect information or complete the missing information and send it back. An attempt was made to collect data by contacting the provincial municipalities by phone and email of the students who collected the relevant provincial municipality data.

However, despite the efforts of the students to communicate by phone and email, the majority of the provincial municipalities did not prepare and send back the survey forms. Many municipalities reported that they were very busy due to the election year and could not answer the survey. Thereupon, a second round of data collection sessions was held with the students. This second round of data collection started on December 10, 2023, and ended on December 31, 2023. At this stage, in addition to municipal activity reports and websites, the reports titled "_______ Province 2020/2021/2022 Environmental Status Report" published by the "Provincial Directorates of Environment, Urbanization, and Climate Change" operating within the governorships for the relevant province were also used. This new data collected was entered into the relevant database in the first week of 2024.

On the other hand, the data published by TURKSTAT on a Turkey basis but not on a provincial basis (Table 3) were requested in (2024) three times from the TURKSTAT website https://ty.tuik.gov.tr with the letter of the rectorate numbered E-53822972-042-24884 on 10.01.2024. Some of the data listed in the table also consist of data that has not yet been published for 2022.

Table 3. Data Requested from TURKSTAT (2020, 2021, 2022, if applicable, 2023)

1	Number or rate (%) of computer and internet usage of the public on a provincial basis
2	Number or rate (%) of computer usage by businesses on a provincial basis
3	Number or rate (%) of websites owned by businesses by province
4	Number or rate (%) of social media usage by people and businesses by province
5	Number or rate (%) of e-Government users and usage by province
6	Number or rate (%) of employees working in enterprises in the ICT sector on a provincial basis
7	Number or rate (%) of employees working in enterprises in the education sector on a provincial basis
8	Number or rate (%) of foreign capital enterprises and employees on a provincial basis
9	R&D expenditure amounts (₺) and number or rates (%) of employees in R&D on a provincial basis
10	E-Commerce amount (₺), number of businesses, number of transactions or rates (%) by province
11	Number of online education institutions by province
12	Electricity consumption per capita by province, Kwh (2022)
13	Amount of solid waste burned/used for BES energy production in municipalities (Ton or Kg)
14	Number of social support recipients (total, widow/orphan, disabled/disabled, retired/elderly) by province
15	2- and 5-year survival numbers or rates of neonatal interventions on a provincial basis
16	Number or rate (%) of SME enterprises and employees by province
17	Number of citizens born abroad by province
18	Number of immigrants coming to Turkey in the last 5 years by province
19	Greenhouse gas emission amounts by province
20	Number of electric and hybrid cars by province
21	Total amount of plant food production by province (ton)
22	Total animal food production amount by province (ton)
23	Total plant food consumption amount by province (ton)
24	Total amount of animal food consumption by province (ton)
25	Number of 100% electric cars registered by province
26	Number of registered hybrid cars by province
27	Number of registered LPG cars by province
28	Total number of people receiving disabled/invalidity pension by province
29	Total number of people receiving pension/elderly pension by province
30	Total number of people receiving widow/orphan pension by province
31	Number of people receiving benefits and salaries within the scope of social protection on a provincial basis
32	Police numbers by province
33	Number of fire-related deaths by province
34	CPI rates by province or statistical region1 or region2 (2022)
35	E-Commerce amounts by province

Again, on 28.1.2024, details of the Waste data published annually on a provincial basis were requested from the "Ministry of Environment, Urbanization, and Climate Change" through CİMER, but the data could not be received.

On the other hand, it has been observed that many of the ISO resilience indicator data in Turkey have not been collected and published. This situation is seen in the urban resilience radar chart maps.

As a result of the data collected for the research being entered into the system, the ISO smartness, sustainability, and resilience city indexes of 81 provinces for 2022 were extracted and reported at the end of April 2024. With these indices, an attempt was made to create an international index comparison infrastructure for 81 provinces.

3. THE RESEARCH FINDINGS AND DISCUSSION

As explained briefly in the method section, in the process of calculating the ISO SCI, SUCI, and RCI indices on a provincial basis, the data of each province were first collected, and Turkey's standard data were calculated from the average of these collected data or taken from official statistical data. Each provincial indicator data value collected was divided by the relevant Turkish standard indicator value and an indicator ratio was found. If these ratio values are above 2.0, they are limited to 2.0 to normalize the effect of the indicator on the index. In this way, the effects of the outlier indicator values on the indices are limited by ensuring that all indicator values are calculated to be between 0 and 2. Each CSF ratio value was found by adding up the calculated indicator values of each CSF listed in Table 1 and dividing by the number of indicators of that CSF. For example, after calculating the total of Ankara's ISO 37122 Smart City "Economy CSF" indicator values as 3.69853, this total was divided by 4, which is the indicator number of the "Economy CSF", and Ankara's "Economy CSF" value was found as 3.69853/4 = 0.9246325. If this value is less than 1, it indicates that the Economy CSF value of Ankara province is lower than the Turkey average, and in the case that Ankara's performance is not good in this CSF. Values greater than one indicate that the performance is higher than the Turkey average. After 20 CSF values for ISO 37122 Smart City were calculated one by one in this way, they were converted into Smart City Radar Chart Map (SCRCM) as seen in Figure 2 for Ankara. The same calculations were made for Sustainable City Radar Chart Map (SUCRCM) and Resilient City Radar Chart Map (RCRCM) values, and they are visualized in Figure 3 and Figure 4 for Ankara. The red-lined area in the figures shows the average area of Turkey and is the same for each province. The performance of the province on a Turkey basis can be determined by looking at the red and blue lines.

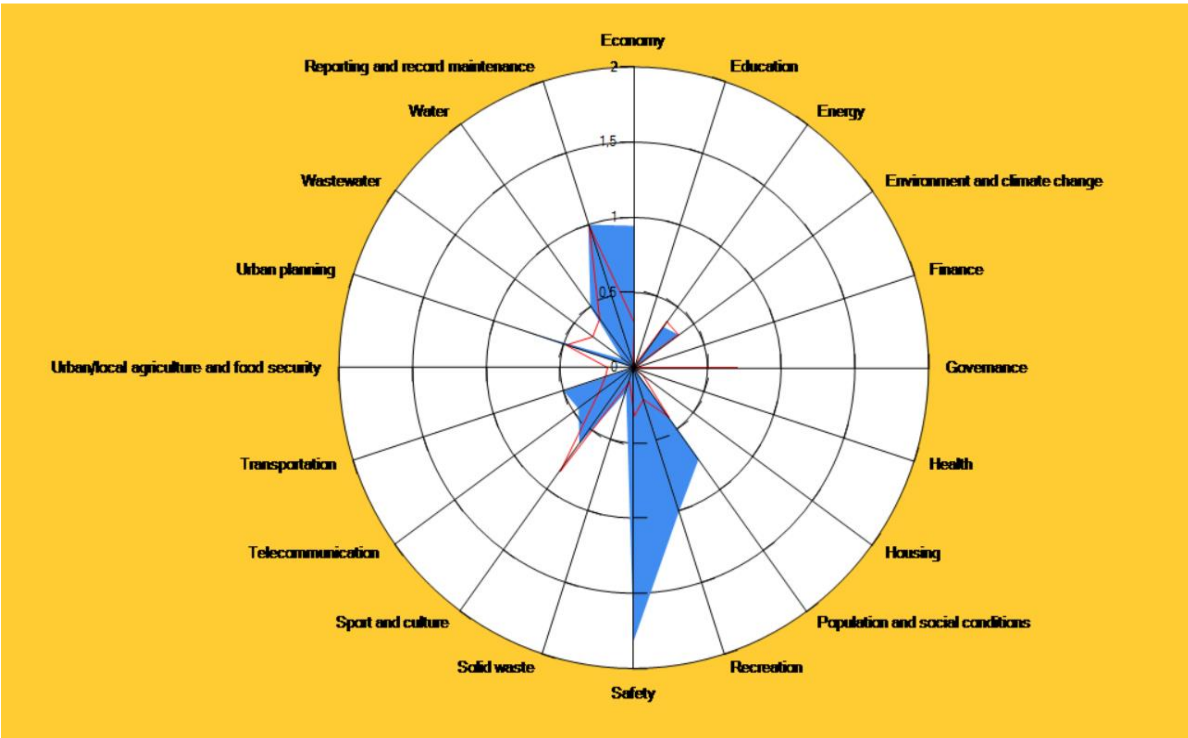

Figure 2. Smart City Radar Chart Map of Ankara Province (SCRCM)
Source: SCPortal. (2020). Smart city portal. Retrieved from http://www.mustafacoruh.com/WebSC/EN_Default

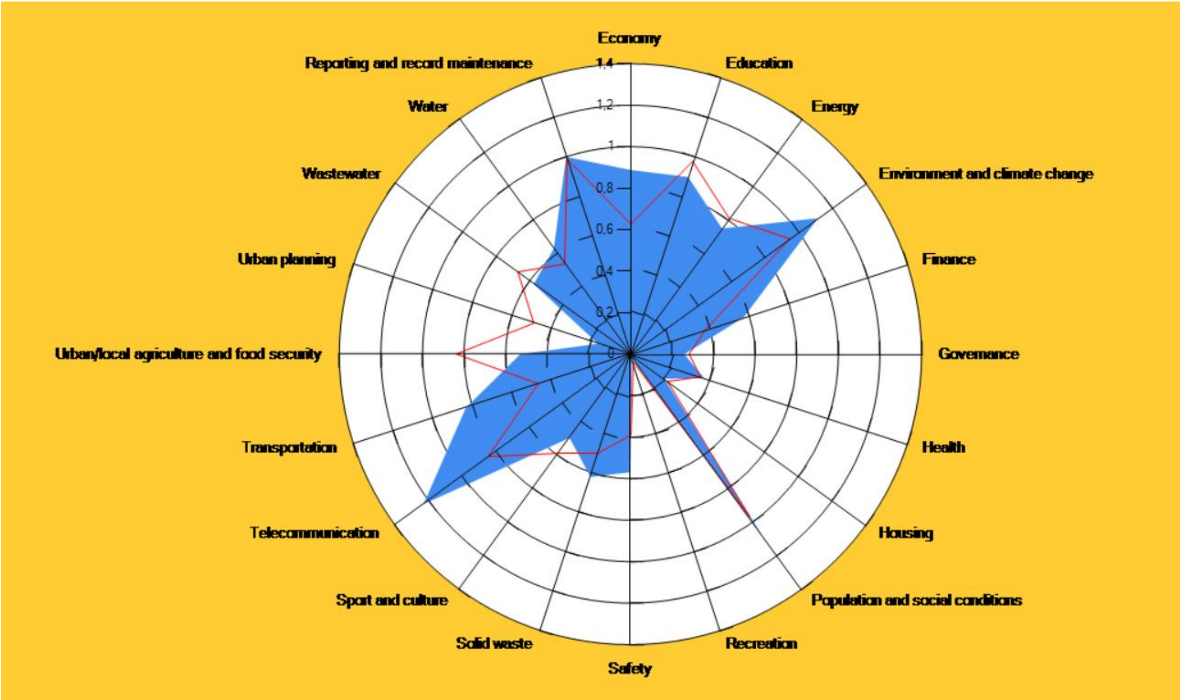

Figure 3. Sustainable City Radar Chart Map of Ankara Province (SUCRCM)
Source: SCPortal. (2020). Smart city portal. Retrieved from http://www.mustafacoruh.com/WebSC/EN_Default

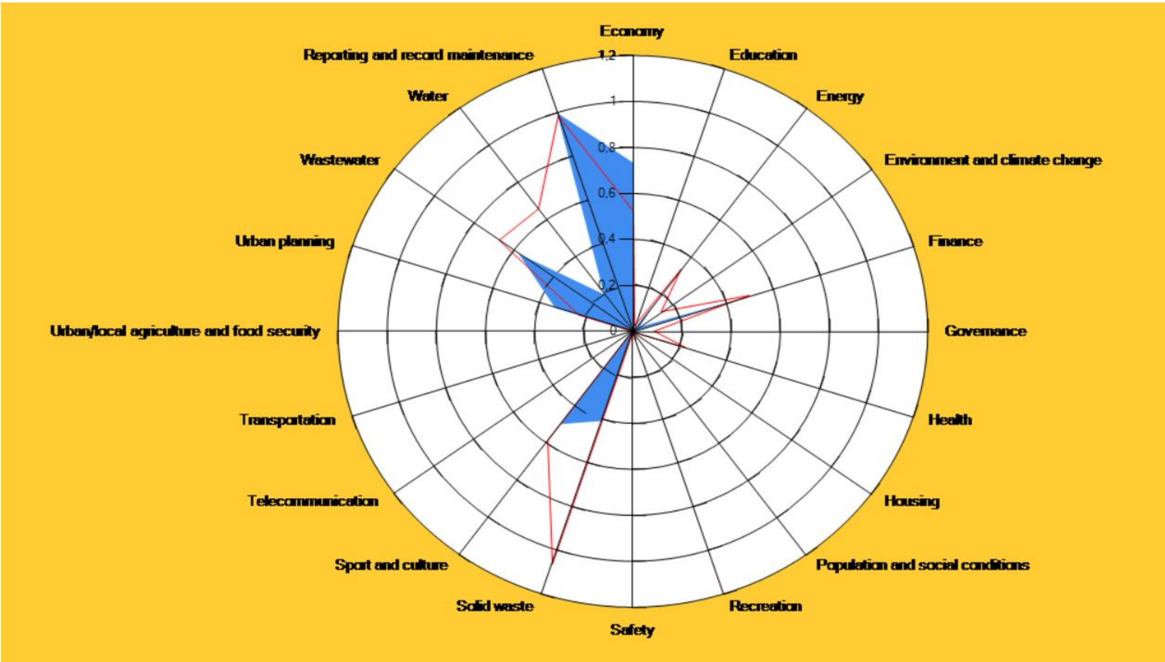

Figure 4. Resilient City Radar Chart Map of Ankara Province (RCRCM)
Source: SCPortal. (2020). Smart cities portal. Retrieved from http://www.mustafacoruh.com/WebSC/EN_Default

To calculate the Ankara SCI values, firstly the values of the blue areas in the figures were calculated in line with the formulas explained in the method section. By dividing these area values by the circle area surrounding this area, the SCI, SUCI, and RCI values of that province were found. However, the R-value of the Circle used in calculating these index values was calculated according to the maximum R-value, which is the highest among 81 provinces. In other words, indices were calculated by dividing the total triangular area of the cities calculated to rank all the provinces by the circle area produced from this maximum R. For example, when calculating the SCI of Ankara (and all other provinces), the rate of 1.414 from Karabük province was used instead of Ankara's maximum R-value of 1.317. The radar chart map areas seen in Figure-2, Figure-3, and Figure-4 were substituted into the "Satyam Index Calculation" formulas and calculated as SCI=0.15514, SUCI=0.31623 and RCI=0.04371 for Ankara province. These calculated index values were also used in Ankara's Turkey province ranking.

This calculation process explained for Ankara, 2022 SCI, SUCI, and RCI values were calculated separately for 81 provinces with the help of an Excel table as of 30.4.2024 and are listed in Table 4. However, the ranking in the table is made according to the "ISO 123 RCI (Resilience) Ranking" column. The different rankings can be done on the column name in the Excel table or by clicking on different columns on the website where it is published. In the third column of the table, information is given on whether there is an SC project in the relevant provincial municipality. As can be seen from the bottom line of the table, municipalities reported that 59 province municipalities have SC projects out of 81.

Table 4. 2022 Ranking of Provinces According to ISO 120, 122, and 123 Indexes

Province Code	Province Name	Is There SC Project?	ISO 120 SCI Ranking	ISO 120 SCI	ISO 122 SUCI Ranking	ISO 122 SUCI	ISO 123 RCI Ranking	ISO 123 RCI
50	Nevşehir	1	9	0,34346	56	0,03951	1	0,1848
40	Kırşehir	1	14	0,32346	53	0,04248	2	0,1688
34	İstanbul	1	1	0,47968	1	0,22341	3	0,16127
58	Sivas	1	27	0,30429	6	0,10407	4	0,15057
17	Çanakkale	1	2	0,42328	17	0,07239	5	0,14678
53	Rize	1	43	0,26144	46	0,0455	6	0,13677
77	Yalova	0	40	0,26906	33	0,05612	7	0,13432
37	Kastamonu	1	35	0,27769	75	0,02539	8	0,11903
81	Düzce	0	37	0,2715	27	0,06504	9	0,1161
74	Bartın	0	45	0,25637	45	0,04624	10	0,114
19	Çorum	1	22	0,30702	38	0,05083	11	0,11237
64	Uşak	1	6	0,35123	9	0,08794	12	0,11196
39	Kırklareli	1	23	0,30662	43	0,04732	13	0,11149
23	Elazığ	1	41	0,26506	32	0,0573	14	0,10985
11	Bilecik	0	31	0,28968	7	0,09481	15	0,10629
14	Bolu	1	18	0,31457	31	0,05831	16	0,10386
22	Edirne	1	33	0,28547	34	0,05461	17	0,10078
28	Giresun	1	61	0,22468	5	0,10552	18	0,09982
15	Burdur	0	21	0,30772	37	0,05154	19	0,09911
5	Amasya	1	19	0,31195	57	0,0387	20	0,0968
16	Bursa	1	10	0,34299	29	0,05902	21	0,09672
57	Sinop	0	42	0,26181	48	0,04315	22	0,09578
71	Kırıkkale	1	50	0,24933	36	0,05171	23	0,09576
41	Kocaeli	1	11	0,33919	18	0,07034	24	0,09467
59	Tekirdağ	1	29	0,29588	13	0,08128	25	0,09374
10	Balıkesir	1	4	0,35792	14	0,07487	26	0,09356
24	Erzincan	0	15	0,32338	59	0,03775	27	0,09348
12	Bingöl	1	57	0,23303	47	0,04509	28	0,09254
35	İzmir	1	8	0,34387	25	0,06557	29	0,08773
79	Kilis	0	39	0,26981	64	0,03488	30	0,08645
8	Artvin	1	60	0,22598	35	0,05228	31	0,08519

62	Tunceli	0	68	0,20389	73	0,0291	32	0,08504
7	Antalya	1	7	0,34729	30	0,05848	33	0,08485
61	Trabzon	1	56	0,23546	44	0,04625	34	0,08395
69	Bayburt	0	48	0,25396	49	0,04308	35	0,08085
45	Manisa	1	26	0,30475	10	0,08732	36	0,07854
67	Zonguldak	0	36	0,27514	23	0,06703	37	0,07816
3	Afyonkarahisar	1	30	0,28999	62	0,03639	38	0,07725
48	Muğla	1	20	0,30919	15	0,07351	39	0,07719
30	Hakkari	0	80	0,15168	80	0,01826	40	0,07559
54	Sakarya	1	32	0,28854	2	0,1632	41	0,07539
29	Gümüşhane	0	53	0,24251	42	0,04799	42	0,0749
60	Tokat	0	49	0,25307	40	0,05001	43	0,07461
32	Isparta	1	16	0,32091	24	0,06618	44	0,07336
18	Çankırı	1	44	0,25916	54	0,04068	45	0,07224
20	Denizli	1	13	0,32519	19	0,06979	46	0,07171
44	Malatya	1	73	0,18502	58	0,03825	47	0,07108
2	Adıyaman	1	70	0,1976	76	0,02505	48	0,07073
78	Karabük	0	51	0,24854	41	0,04844	49	0,06692
33	Mersin	1	47	0,25524	65	0,03443	50	0,06553
76	Iğdır	0	63	0,2219	68	0,03147	51	0,06396
13	Bitlis	0	74	0,18095	79	0,01942	52	0,06235
51	Niğde	1	52	0,24726	26	0,06508	53	0,05917
52	Ordu	1	58	0,23267	4	0,11362	54	0,0577
42	Konya	1	5	0,35303	16	0,07269	55	0,05611
56	Siirt	0	66	0,20742	72	0,02939	56	0,05598
65	Van	0	69	0,19951	61	0,03692	57	0,05505
72	Batman	1	78	0,16365	63	0,03502	58	0,05437
68	Aksaray	1	65	0,21181	60	0,03694	59	0,05376
80	Osmaniye	1	62	0,2223	69	0,03145	60	0,05318
26	Eskişehir	1	3	0,39029	11	0,0872	61	0,05314
36	Kars	1	67	0,20627	71	0,03049	62	0,05247
9	Aydın	1	38	0,27139	22	0,06737	63	0,05201
46	Kahramanmaraş	1	64	0,22007	74	0,0278	64	0,05167
66	Yozgat	1	55	0,23616	66	0,03426	65	0,05093
70	Karaman	1	12	0,33462	21	0,06781	66	0,05081
73	Şırnak	0	81	0,13828	77	0,02485	67	0,05009
43	Kütahya	1	24	0,30617	20	0,0683	68	0,04795
55	Samsun	1	46	0,25586	39	0,05037	69	0,04517
6	Ankara	1	17	0,31623	3	0,15514	70	0,04371
31	Hatay	1	59	0,23181	51	0,04268	71	0,04243
25	Erzurum	1	28	0,30307	12	0,08686	72	0,04122
1	Adana	1	25	0,30576	8	0,09479	73	0,03782
27	Gaziantep	1	54	0,24187	50	0,04276	74	0,03753
4	Ağrı	1	72	0,18809	70	0,03072	75	0,03708
47	Mardin	1	76	0,17239	78	0,0208	76	0,03639
49	Muş	0	75	0,1738	52	0,04251	77	0,03057
38	Kayseri	1	34	0,28526	28	0,0625	78	0,02726

75	Ardahan	0	79	0,15626	81	0,01445	79	0,02559
21	Diyarbakır	1	77	0,17013	67	0,03411	80	0,02529
63	Şanlıurfa	1	71	0,19276	55	0,03981	81	0,02027
	Total	**59**						

The table shows that the index values calculated according to the smartness, sustainability, and resilience indicators of the provinces are different. This situation shows that each province needs to develop different strategies for different areas. For example, although Ankara province showed a better performance than Turkey's average by being 3rd in the SCI value, it remained very low at 70th in the RCI value. In this case, it can be said that Ankara Metropolitan Municipality and its stakeholders need to develop different policies and strategies to increase city resilience. The fact that two neighboring provinces in Central Anatolia, Nevşehir and Kırşehir, are in the top two places in the resilience ranking may also be an issue that needs to be investigated.

When the rankings made according to different index values seen in the table are examined, it can be said that these rankings have a value or statistical significance for city municipality managers and stakeholders.

4. RESULTS

The index results and maps of the research can help municipal administrators, other city stakeholders, and local public institutions in cities to make better city-related decisions. Since the smartness, sustainability, and resilience indices of cities are calculated with the help of data provided by city institutions, municipal activity reports, and national statistical institutions, they can provide better visual and quantitative information to the relevant city institution managers. In line with this information, relevant city managers and stakeholders can be enabled to determine more accurate strategies, policies, and service decisions regarding the city. The strategic plans prepared by municipalities for 5 years can be revised. On the other hand, publishing comparable smartness, sustainability, and resilience indices of cities can provide the city stakeholders with information about the performance of city managers and their situation compared to other cities.

In addition, the relevant ranking results measured by ISO indicators should not be perceived as just a general ranking list. With the help of these ranking results, cities can be compared in detail with the help of indicators used on an international scale, and their strengths and weaknesses in the fields of smartness, sustainability, and resilience can be revealed on a global basis. Smarting of cities can help increase the competitiveness of cities in the world, ensure their sustainability and resilience, maintain their economic development, use city resources effectively and efficiently, and protect their ecological balance (Çoruh, 2021, s. 185).

In addition, as the smartness, sustainability, and resilience of cities are visualized with city radar chart maps, city managers can compare the relevant performances of their cities with other cities. For example, the average values of Turkey given as red lines in SCRCMs can be used by city managers to determine the smart performance of the city. If the city's SCRCM area value is larger than Turkey's area value, it can be said that the city has a good performance in terms of smartness level, and if it is smaller, it can be said to have a poor performance. The same comparison can also be made with each CSF. According to this performance, municipalities and city managers can develop different policies and strategies and make decisions in the field of digital transformation (Çoruh, 2021, s. 185) or being a smart city.

It is obvious that in today's world, due to population and data growth, governors have to deal with many technological, social, political, and ecological problems in cities. To solve these problems, there should be more cooperation and data sharing among city stakeholders. For this purpose, by sharing the results of this research, appropriate projects can be quickly implemented to improve low-performing areas.

Data Science (DS) demonstrates the potential to tackle new challenges and uncover alternatives that enable the opportunities presented by the expanding mass of digital data. Data mining and artificial intelligence techniques allow machines to learn what to do and analytics to predict and prevent problems before they occur. The results of such analyses can be used, for example, in estimating traffic density in cities and in forecasting infrastructure maintenance in cities (Holanda, Adorni, & Obata, 2019). Therefore, the data collected in the research can be examined with the help of data science techniques or algorithms and the correlations between them can be revealed.

Solutions can be produced to eliminate differences by examining the relationships between the areas of smartness, sustainability, and resilience of cities. For example, it can be said that Ankara's ranking 3rd in smartness, 70th in resilience, and 17th in sustainability is an issue that needs to be investigated. However, it should not be ignored that there are inadequacies in data collection in the formation of such different rankings.

The most important limitation of this research was the dependence on municipalities to collect the necessary data and the reluctance of municipalities to send the data due to the election year. On the other hand, two earthquakes of magnitude 7.7 and 7.6, centered in Kahramanmaraş and affecting 15 provinces on February 6, 2023, prevented data collection from municipalities in these regions. No data could be obtained from any of these 15 municipalities. In particular, most of the 89 ISO 37223 urban resilience indicator data are not produced by municipalities and are not collected by statistical institutions. Therefore, it can be suggested that it would be more beneficial to carry out this project through an official institution in the coming years. For example, it may be suggested that this project be turned into a TUBITAK or Ministry of Urbanization project.

When Table 3 is examined, it can be said that the most important result in the field of resilience is that non-metropolitan provinces such as Nevşehir, Kırşehir, Sivas, Çanakkale, Rize, Yalova, Kastamonu, and Düzce are at the top levels. This may be an important issue that needs to be investigated in determining the smartening, sustainability, and resilience policies and strategies of cities. It may be considered normal that metropolitan cities such as Istanbul, Ankara, Izmir, Bursa, and Konya are at the top, but explaining the reasons why small provinces are at the top in terms of population can provide important data to city municipal managers. In addition, the fact that Çanakkale province is at the top of the three index rankings (17th in SCI, 2nd in SUCI, and 5th in RSI) can be noted as an important result. The fact that all metropolitan cities except Istanbul are at the bottom of the RCI rankings may be an important warning for city and country governors. The fact that the eastern and southeastern provinces are at the bottom of all three rankings may be important in terms of considering the imbalance between regions.

The results of this research could not be compared with the results of another research because no other data-based research was found in Turkey regarding SCI, SUCI, and RCI, which were calculated with the ISO indicators of the cities in 81 provincial centers. When the SCI ranking of this research is visually compared with the results of the "Smart Cities Maturity Assessment Model (https://sehirendeksi.gov.tr/endekspublic/)" prepared within the scope of the "2020-2023 National Smart Cities Strategy and Action Plan" carried out by the Ministry of Urbanization in Istanbul, Ankara and Sakarya can be said that they have approximate ranking values (Sehirendeksi.gov.tr, 2024). However, the fact that many provinces such as Konya, Kayseri, Izmir, and Kütahya, which are at the top of the Maturity Index rankings, are ranked lower in the ISO SCI rankings may reveal the difference in the indicators that make up these two index rankings or the difference in data collection. Therefore, making ISO indexes through the Ministry of Urbanization can help determine more consistent international city index values of cities.

As a result, it should not be forgotten that the SCI, SUCI, and RCI values measured by ISO standards are not just a technical issue, but technological, social, economic, and administrative transformation developed to enable institutions, cities, and countries to provide comparable services to their citizens on a global basis.

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