AN EVALUATION MODEL FOR TURKISH CITIES IN THE CONTEXT OF SMART CITY

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ABSTRACT

AN EVALUATION MODEL FOR TURKISH CITIES IN THE CONTEXT OF SMART CITY

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Researches indicate that urbanization rate has increased day by day, from 34% in 1960 up to 54% in 2015, and is expected to reach 66% in 2050. This means that not only urban areas, but the world will also be confronted with big problems, such as traffic congestions, bad air quality, depletion of resources, and so on. In order to solve these problems, traditional solutions will be inadequate if they are not integrated with smart solutions. The term smart city has emerged in the last few decades in order to integrate these solutions. City managers encouraged by technology firms have latterly introduced their cities as smart cities. Correspondingly, most of the studies concerning smart cities have quite recently concentrated on the evaluation and ranking process of smartness of the cities in order to show the performance of smart cities. Unfortunately, Turkish cities have not yet been included in these evaluations effectively.

This research aims to evaluate Turkish cities with regard to their smartness by certain factors and indicators that have been derived through careful analyses of earlier studies. Eventually, it is intended to develop some starting points concerning certain policies in order to navigate smartness processes of cities. In accordance with this purpose, characteristics, factors, and indicators of smart cities have been particularly adapted for Turkish cities. In the light of these, four multi-criteria decision analysis methods (MCDA) have been chosen including, GRA, TOPSIS, SAW, and PROMETHEE, as the most suitable methods for the study. According to the results, thematic maps have been created using ArcGIS 10.2 software in order to observe and evaluate smartness of Turkish cities on the map. Finally, Spearman’s correlation test is used to define relationships between methods and choose the most significant one. Although the final scores show that Istanbul and Ankara are undoubtedly the smartest cities in Turkey, defining the least smart cities has proven to be a difficult task.

Keywords: Smart City, Ranking, MCDA, Smart Cities in Turkey, Spearman’s Correlation

ÖZ

AKILLI KENT BAĞLAMINDA TÜRK KENTLERİ İÇİN BİR DEĞERLENDİRİLME MODELİ

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Yapılan çalışmalar, 1960'lı yıllarda %34 ve günümüzde %54 olan kentleşme oranının günden güne artarak 2050 yılında %66'ya ulaşacağını göstermektedir. Bu sonuçlar sadece kentlerin değil, tüm dünyanın trafik sıkışıklığı, hava kalitesinin kötüleşmesi ve kaynakların tüketilmesi gibi birçok konuda büyük problemlerle karşılaşacağı anlamına gelmektedir. Şayet akıllı çözümler geleneksel çözümlere entegre edilmezse bu problemleri çözmek için geleneksel çözümler yetersiz kalacaktır. Bu çözümleri entegre etmek için akıllı kent kavramı bir kaç on yıldan beri ortaya atılmıştır. Günümüzde birçok kent yöneticisi, teknoloji firmalarının da desteğiyle kendi şehirlerini akıllı kent olarak tanıtmaktadırlar. Buna bağlı olarak, akıllı kentleri değerlendirmek amacıyla yapılan birçok çalışma, kentlerin akıllılık performansının ölçülmesi ve bu kentlerin uygulamalarının değerlendirilmesi üzerine yoğunlaşmaktadır. Fakat ne yazık ki Türk kentleri bu çalışmaların içine henüz yeterince dâhil olamamıştır.

Bu araştırma, daha önceden yapılan analizler yardımıyla elde edilen bazı faktörler ve göstergeler yoluyla Türk kentlerinin akıllı kent bağlamında değerlendirilmesini amaçlamaktadır. Bu şekilde, akıllı kentleri yönlendirmeyi amaçlayan bazı politik tartışma noktaları geliştirilebilecektir. Bu çalışmayı yapabilmek için öncelikle, akıllı kent özellikleri, faktörleri ve göstergeleri Türk kentleri özeline uyarlanmıştır. Bunların ışığında, Çok Kriterli Karar Verme (ÇKKV) yöntemlerinden çalışma için en uygun olan 4 tanesi seçilmiştir. Bunlar; GRA, TOPSIS, SAW ve PROMETHEE'dir. Bu yöntemlerden çıkan sonuçlara göre, ArcGIS 10.2 programı yardımıyla akıllı kentlerin Türkiye'deki durumunu gözlemlemek ve değerlendirmek için tematik haritalar oluşturulmuştur. Son olarak, bu sonuçlar arasındaki ilişkiyi gözlemleyebilmek için Spearman Korelasyon testi yöntemi kullanılmıştır. Sonuç puanları, İstanbul ve Ankara'nın tartışmasız Türkiye'nin en akıllı kentleri olduğunu gösterirken, diğer uçtaki kentleri belirlemenin oldukça karmaşık bir görev olduğunu göstermektedir.

Anahtar Kelimeler: Akıllı Kent, Sıralama, ÇKKV, Türkiye'nin Akıllı Kentleri, Spearman Korelasyonu

To My Family and My Wife;

"I am truly thankful for having you in my life."

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ABBREVIATIONS

BREEAM : Building Research Establishment Environmental Assessment Method

BSTB : Ministry of Science, Industry and Technology (Bilim, Sanayi ve Teknoloji Bakanlığı)

BTK : Information and Communication Technologies Authority (Bilgi Teknolojileri ve İletişim Kurumu)

CSB : Ministry of Environment and Urbanization (Çevre ve Şehircilik Bakanlığı)

EGM : Turkish National Police (Emniyet Genel Müdürlüğü)

GRA : Grey Rational Analysis

ICT : Information and Communication Technology

IoT : Internet of Things

LEED : Leadership in Energy and Environmental Design

LQ : Location Quotient

MCDA : Multi-Criteria Decision Analysis

MCDM : Multi-Criteria Decision Making

MevkaStat : Mevlana Development Agency Statistical Database (Mevlana Kalkınma Ajansı İstatistik Veri Tabanı)

OGM : General Directorate of Forestry (Orman Genel Müdürlüğü)

OSB	: Ministry of Ministry of Forestry and Water Affairs (Orman ve Su İşleri Bakanlığı)
PROMETHEE	: Preference ranking Organization Method for Enrichment Evaluation
SAW	: Simple Additive Weighting
SEGE	: Socio – Economic Development Index of Turkey (Türkiye Sosyo-Ekonomik Gelişmişlik Endeksi)
TBB	: Union of Municipalities of Turkey (Türkiye Belediyeler Birliği)
TCDD	: Turkish State Railways (Türkiye Cumhuriyeti Devlet Demiryolları)
TOPSIS	: Technique of Order Preference by Similarity to Ideal Solution
TUIK	: Turkish Statistical Institute (Türkiye İstatistik Kurumu)
UDHB	: Ministry of Transportation, Maritime Affairs and Communications (Ulaştırma, Denizcilik ve Haberleşme Bakanlığı)
UN	: United Nations
WHO	: World Health Organization
YÖK	: The Council of Higher Education (Yükseköğretim Kurumu)
EUROSTAT	: Statistical Office of the European Union
ESPON	: The European Observation Network for Territorial Development and Cohesion
DGNB	: German Sustainable Building Council
GINI	: a standard economic measure of income inequality

CHAPTER 1

INTRODUCTION

1.1 Background

Cities are complex systems as being dynamic and living organisms that affect lives not only in physical, but also in social and economic terms. In the beginning of the third quarter of the 20th century, industrialization patterns along with technology and innovations have brought about dramatic aggregation in urban areas. Researches indicate that urbanization rates have been increasing day by day, from 34% in 1960, up to 54% in 2015 (WHO). In Turkey, this rate was 32% in 1960 and figured out as being 73% in 2015 (World Bank). It is expected that by 2050, 66% of the world population will live in urban areas, whereas only 34% will live in rural areas (UN, 2014). In other words, every 2 out of 3 people in the world will live in urban areas (Figure 1).

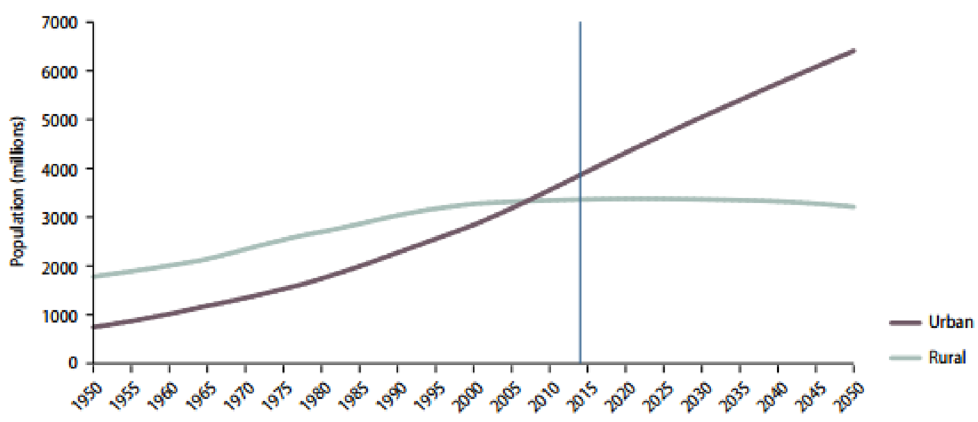


Figure 1 Urban and rural population of the World, 1950-2050 (UN, 2014)

By virtue of rapid urbanization and industrialization process, cities are under the process of transformation gradually. The transformation processes have basically been summarized in the President Council of Advisory on Science and Technology Report (PCAST, 2016). According to this report, cities are under the fourth stage of modern transformational change, embodied by technological innovation. "*Steam engine"* was the first stage of transformation, while *"electrical grid and reliable mass transit"* (e.g. subway systems) represented the second stage. The third was the "*personal automobile"* which leads to rapid suburbanization by means of finding out Fordist production type and assembly line. "*New physical and digital technologies"* constitutes the fourth stage of transformation in order to overcome cities' increasing demands (PCAST, 2016).

Additionally, scientists have conducted studies concerning the problems of traffic congestions, urban sprawl, and air pollution, and decided that these complex problems could not be solved with traditional solutions (Sağ, 2011). They require alternative physical and methodological approaches which relate to the economic, environmental, and social aspects of planning. The concept of "Smart City" is the key term that has best answers to questions involving cities in the technological era.

1.2 Research Problem

Today, many scientists, public institutions, and technology firms all over the world have attempted to conduct a wide range of studies on the smartness of cities. The studies have generally focused on the importance of evaluation of smart cities' implementations and have given clues about required policies in making cities smarter.

Against this background, the central question that motivates this thesis is the quest to discover smartness of Turkish cities in comparison to other cities in the world. In Turkey, this issue has not been given the importance required, except for a few GSM firms such as Vodafone and Turk Telekom. If this situation continues, Turkish cities will not know where in the era of technology they are in, will not be able to evaluate themselves in terms of smartness, and will not be able to catch the opportunity of the smartness process.

1.3 Research Aim

The aim of this study is to evaluate and rank smartness performance of Turkish cities, with inspiration from earlier studies; and to develop stepping stones concerning necessary policies in order to navigate the smartness process.

1.4 Research Methodology

In the present study, the indicator-based approach will be used to evaluate the smartness of Turkish cities in a holistic approach. Smartness performance of Turkish cities will be discussed and they will be ranked according to Multi Criteria Decision Analysis (MCDA) methods. Hence, all of the 81 provinces of Turkey will represent alternatives for the study. Although there are a number of MCDA methods which can be used for this process, only four suitable ranking methods have been chosen to be used for selection, ranking, and sorting. The reason for the choice of 4 methods is that it is seen that although all methods about ranking are applied for 81 province of Turkey, these 4 methods only answer the question of the study. According to the scores, the thematic maps of smart cities in Turkey have been created using ArcGIS 10.2 software. The maps give the author clues about the aggregations, concentrations, directions, and locations of smarter and less smart cities of Turkey. These maps have also been created for each characteristic of smart cities to observe changes in terms of smartness of cities. However, after these analyses, the obvious ranks of the cities have not been determined, because all methods have different calculation functions, which prevent taking an average of the scores. Hence, in order to observe the relationships of methods and make an obvious choice, Spearman’s ranks correlation coefficient test has been used for each of the characteristics and the total score separately.

1.5 Thesis Outline

This thesis consists of 5 main chapters. The first chapter is the introduction which presents the research problem, research aim and objectives, methodology, thesis outline, conclusion and suggestion.

Chapter 2 presents "Understandings of smart cities" on the basis of literature review. Smart cities are held in a holistic approach in this chapter. Historical background of smart cities, synonym terms of smart cities, the definitions of smart cities in the literature, criticizing the concept of smart cities, explanation of people factor and human capital, components and features of smart cities, different ranking and evaluation approaches, importance of ranking will be held respectively in this chapter.

Chapter 3 is the methodology, which is based upon indicator-based approach. Multi Criteria Decision 4 suitable analysis (MCDA) methods are chosen to be used for selection, ranking, and sorting. Thematic maps in Turkey are created in ArcGIS 10.2 software. Finally, in order to observe the relationships of methods and make an obvious choice, Spearman's ranks correlation coefficient test is used for each of the categories and the total score separately.

Chapter 4 is the main chapter where case study analysis is presented. In this chapter, implication of evaluation process is applied on Turkish cities. Moreover, four different multi-criteria decision analysis methods will be held including GRA, TOPSIS, SAW, and PROMETHEE. Thematic maps are created and evaluated after the analysis process, using ArcGIS 10.2 software. Then, Spearman Correlation will be used to choose a suitable method for the final evaluation.

Chapter 5 is the final chapter where the thesis is concluded and related suggestions and policies are made**.**

CHAPTER 2

UNDERSTANDINGS OF SMART CITIES

A number of explanations regarding smart cities have been made in order to understand what smart cities are. Most of them are basically interested in the ICT infrastructure of smart cities, ignoring the holistic approaches.

In this chapter, smart cities will be discussed in a holistic perspective. In the first part of the chapter, historical background of smart cities will be examined. Secondly, terms such as intelligent, knowledge, creative, ubiquitous, and digital, which are generally used as synonyms of smart cities, will be discussed. In the third part, definitions of smart cities in literature will be discussed in order to make the concept clear. Fourthly, deficiencies of definitions will be criticized, which generally focus on the people factor and human capital. To emphasize the importance of the people factor and human capital, the fifth part of the chapter will debate this issue. The sixth part will include components and features of smart cities. Those examples that there is consensus on conducted by scientists will be given in this part as well. Different ranking and evaluation approaches, and some studies conducted by scientists will be examined in the seventh part of the chapter. Finally, importance of ranking will be held in order to attract attention to city rankings.

2.1 Evolution of Smart Cities

Rapid increase in population make cities to become more complex systems and also cause depletion of natural resources as time passes. Researches show that urbanization rates have increased day by day, from 34% in 1960, to 54% in 2015 (WHO). In Turkey, this rate was 32% in 1960 and reached as 73% in 2015 (World Bank). In 2050, 66 % of the world population is expected to be urban, whereas only 34 % will be rural (UN, 2014) (see figure 1). In other words, every 2 out of 3 people will live in urban areas. Consequently, cities will encounter more complicated problems. This means that “the world” has to make bigger efforts to deal with complex problems of future cities, especially regarding depletion of resources.

Improvements in the cities have been closely associated with the changes in externalities, even from the beginning of early settlements. The rise of modern cities stems from the industrial revolution, which represents one of the most dramatic changes over the history of settlements. These changes have led to significant problems in urban areas such as, rapid urbanization, congestion, bad air quality, depletion of resources, and so on. Different theories have been suggested with regards to the negative effects of the industrial era in the beginning of 20^{th} century. For example, the “Garden City” theory, suggested by Ebenezer Howard, in order to solve loss of “Green” as well as the transportation problems in the city. Also, the concept of “Industrial City”, proposing the concept of zoning which segregates residential and industrial areas, was put forward by Tony Garnier to work out rapid industrialization problems.

These transformation processes have basically being summarized in the US President’s Council of Advisory on Science and Technology Report (PCAST, 2016). According to the report, cities are under the fourth stage of modern transformational change, embodied by technological innovation. “S*team engine*” was the first stage of transformation while “*electrical grid and reliable mass transit*” (e.g. subway systems) constitutes the second stage. The third was the “*personal automobile*”, which lead to rapid suburbanization, with finding out Fordist production type and assembly line. With the continuation of growing cities, urbanization, the fourth stage, “*new physical and digital technologies*” will be offered for cities to overcome increasing demands (PCAST, 2016).

As a result, the rapid increases in the population and rapid urbanization have caused urban sprawl in most of the metropolitan areas, especially in North America. To overcome the problems of urban sprawl, approaches such as, the “*New Urbanism Movement*” and “*Smart Growth*” have been suggested. In fact, American Planning

Association (APA) stated in 1990 that the concept of New Urbanism leads to that of Smart Growth (Sağ, 2011). Many scientists have conducted studies concerning the problems of traffic congestions, urban sprawl, and air pollution, and decided that these complex problems can not to be solved with traditional solutions (Sağ, 2011). They require alternative physical and methodological approaches which relate to the economic, environmental, and social aspects of planning. Therefore, these terms are not against urban development, but rather an approach that supports sustainable urban development (Steward, 2005).

Additionally, Cocchia (2014), in his article "*Smart and Digital City: A Systematic Literature Review*", states that the roots of smart cities are based on the last quarter of the 20th century. He investigated 705 articles concerning smart and digital cities and suggests that the concept of smart cities have begun to be written since 1993. According to him, the term has 5 breaking points; *Kyoto Protocol* in 1997, widespread internet usage in 2000s, *Kyoto Protocol entered in force* in 2005, *the IBM Smart Planet concept* and *the Covenant of Mayors* in 2008, and *Europe 2020 Strategy* approved in 2010.

Firstly, *Kyoto Protocol*, whose main purpose is to limit CO2 emissions and to protect environment, makes countries to take policies and measures to decrease emissions of greenhouse gases by concentrating on smart technologies. The role of *Kyoto Protocol* in driving countries and cities to design and apply environmental policies is also one of the main drivers of interest about the Smart City topic (Cocchia, 2014). Secondly, in 2000s, internet usage spreads more and more all over the world, not only in academic context and business but also in daily life. In that time, ICT infrastructure, internet-based networked applications, open platforms, e-services regarding healthcare, energy, education, environmental management, transportation, mobility and public safety are the factors that speed up the process of smart cities. Thirdly, in 2005, the fact that *Kyoto Protocol entered in force* has fostered the development of smart strategies all over the world, focused on the environment safeguard. Fourthly, *the IBM Smart Planet concept* that is the way to compete in the "smart" era, to have a good quality of life and to improve the city, and *the Covenant of Mayors* which aims to reduction of CO_2 emissions and to spread the Smart City concept in 2008 are two important events for smart cities.

Finally, *Europe 2020 Strategy* offers three main goals; *smart growth* investing in education, research and innovation areas; *sustainable growth* investing in technologies and resources low-carbon economy; *inclusive growth* giving a strong emphasis on job creation and poverty reduction. Each European country commits to carry out smart or digital initiatives in its own major cities by achieving these goals. This makes the concept of both smart city and digital city widespread and as a result the research studies about them (Cocchia, 2014).

Meanwhile, due to the fact that technology has inevitably begun to be incorporated into cities heavily, technology based approaches such as, intelligent, knowledge, creative, ubiquitous, digital, virtual or ubiquitous cyberville, electronic communities, flexi city, information city, MESH city, elicity, teletopia, wired city, and so on have emerged from scientists. But, most of the technology based approaches handle the subject insufficiently and inconsistently by taking in hand only one side of smartness (Albino, Berardi, & Dangelico, 2015). This has revealed that a new approach that is consistent and inclusionary is needed; "Smart City".

2.2 Analogous Terms with "Smart Cities"

As mentioned above, the term "smart city" is an inconsistent and fuzzy concept and is open to the manipulation of many technology firms and policy makers. Albino et al. (2015) states the situation as approaches come from the top-down and company driven actions are taken when creating smart cities. Moreover, usage of similar terms like digital, intelligent, knowledge, creative, ubiquitous, virtual or ubiquitous cyberville, electronic communities, flexicity, information city, MESH city, elicity, teletopia, wired city, and so on also leads to confusion concerning smart cities. In fact, since these terms often represent the more specific and less inclusive city models, the term smart cities encompasses these terms. The most frequent ones of the terms will be discussed in detail below.

2.2.1 Digital City

A "digital city" refers to virtual reconstructions of the cities (Hollands, 2008). Ishida (2002) explains the digital city as *"... a connected community that combines broadband communications infrastructure to meet the needs of governments, citizens, and business"*. The main purpose of the digital city is to create an environment to share information, collaborate and corporate experience for inhabitants in all places (Abid, 2014; Albino et al., 2015). Therefore, unlike a smart city, a digital city totally depends on the virtual world where the relationships, social interactions, and daily activities are carried out in virtual interfaces.

2.2.2 Intelligent City

Intelligent city probably is the most commonly used term instead of smart cities, which result in confusion. According to Albino et al (2015), intelligent city is the cross point of the knowledge society and the digital city. Intelligent city uses information technology consciously in order to transform life and work (Komninos, Pallot, & Schaffers, 2013).

Different from digital cities, intelligent cities use information technology for the physical environment. That is, urbanization process, city development, demand of inhabitants is in the concern of intelligent city (Abid, 2014). Hence, every digital city is not necessarily an intelligent city; however, every intelligent city has digital components (Albino et al., 2015). Most of the cities today use intelligent technology not only for their transportation infrastructure but also for their natural environment and resources like energy (as smart grid) and water (as smart water usage). However, in both of these two concepts, the people component is still missing as opposed to smart cities.

2.2.3 Knowledge City

The knowledge city that emerges from the discussion of smart city is defined by Edvinsson (2006, p. 6) as "*the city designed intentionally to encourage nutrition knowled*ge". The knowledge city is basically based on the idea of increasing accessibility of information technology. Therefore, the notion of knowledge-based city is encouraged by the advancement of cloud technologies used for urban monitoring systems (Albino et al., 2015). Cloud and sensors of urban environments gains importance in knowledge based cities.

2.2.4 Creative City

Creative city, which was developed by Charles Landry in the 80s, consists of people, economy, and built environment. According to Yencken (1988) "…*creative cities must be efficient and fair, a creative city must also be one that is committed to fostering creativity among its citizens and to providing emotionally satisfying places and experiences for them*". Landry (2013) also emphasized notion of Florida's 3 T's that are tolerance, technology, and talent, which creates creative cultural industries and cultural economies of creative cities. Creative cities in general open doors and present the ground for someone to create wealth and improve visual environment.

2.2.5 Ubiquitous City

Ubiquitous city or U-city focuses on the notion of the city being present everywhere. According to Albino et al (2015), ubiquitous city is the extension of digital city by increasing the accessibility rate of informational technology in the virtual world. Yigitcanlar (2015) define U-city as "… *a city wired with smart urban technologies and coupled with sustainable design principles aiming at creating a unique city type that is an innovative city for a utopian future*". U-city offers a usage of abundant computing devices for all components of the cities such as buildings, roads, bridges, and landscapes (Abid, 2014). Therefore, the city represents the environment where any citizen can get any information and service anywhere and at anytime through any device (Albino et al., 2015).

2.3 Definition of Smart Cities

The term "smart city" has been a fashionable term used in academia, technology developers, and urban politics in the last few decades. Despite being so famous, it is a fuzzy concept and is used in a sense that is not always consistent, which means that it has neither a single block of meaning nor a one-size-fit-all definition (Albino et al., 2015). To crown it all, some scientists and technology firms utilize evoking terms as synonyms.

The root of the term is based on the last quarter of the 20th century (Cocchia, 2014). At the same period, approaches of "*New Urbanism Movement*" and "*Smart Growth*", American Planning Association (APA) stated (Sağ, 2011). In addition, in those times, the focus was the use of ICT in cities infrastructure. However, the focus of technology-dependent city, so-called smart city is undergoes heavy criticism even today (Albino, et al., 2015).

In order to refute the notion that the only way to be a smart city is the ICT and to make a holistic definition, various academicians and urban scientists have studied overwhelmingly. According to Giffinger (2007, p. 4), smart city is "… *a well performing city built on the smart combination of endowments and activities of self-decisive, independent, and aware citizens…*". According to him, a smart city should have the combination of smart environment, smart governance, smart mobility, smart economy, smart people, and smart living.

Batty et al. (2012, p. 481) define smart city as "… *a city in which ICT is merged with traditional infrastructures, coordinated and integrated using new digital technologies".* According to them, the city can only be smart by integrating intelligent functions in or der to improve the efficiency, equity, sustainability, and quality of life in cities (Batty, et al., 2012).

Caragliu and Del Bo (2012, p. 100) define the term of smart city as the city *"... when investments in human and social capital and traditional (transport), and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resource, through participatory governance.*"

Abid (2014, p. 15) defines the term of "smart city" as *"... a developed urban area that produces a sustainable economic development and creates an optimal place for people to live by increasing the quality of life, through highly enhancement of multiple key areas; governance, economy, people, environment, mobility, and built environment.*

Enhancement of these key areas can be achieved through human capital and infrastructure for information and communication technology." He generally focused his study on assessing smart cities by dividing smart cities into two major components; soft and hard components. According to him, while soft components include governance, economy, people, and environment; hard components consist of mobility and smart environment (Abid, 2014).

Albino et al. (2015) brought the definitions of smart cities togerher in Table 1;

Table 1 Definitions of smart cities (Albino, et al., 2015).

Definitions	Sources
"Smart city as a high-tech intensive and advanced city that connects people, information and city elements using new technologies in order to create a sustainable, greener city, competitive and innovative commerce, and an increased life quality."	Bakıcı et al. (2012)
"Being a smart city means using all available technology and resources in an intelligent and coordinated manner to develop urban centers that are at once integrated, habitable, and sustainable."	Barrionuevo et al. (2012)
"A city is smart when investments in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and a high quality of life, with a wise management of natural resources, through participatory governance."	Caragliu et al. (2011)
"Smart cities will take advantage of communications and sensor capabilities sewn into the cities' infrastructures to optimize electrical, transportation, and other logistical operations supporting daily life, thereby improving the quality of life for everyone."	Chen (2010)
"Two main streams of research ideas: 1) smart cities should do everything related to governance and economy using new thinking paradigms and 2) smart cities are all about networks of sensors, smart devices, real-time data, and ICT integration in every aspect of human life."	Cretu (2012)
"Smart community – a community which makes a conscious decision to aggressively deploy technology as a catalyst to solving its social and business needs – will undoubtedly focus on building its high-speed broadband infrastructures, but the real opportunity is in rebuilding and renewing a sense of place, and in the process a sense of civic pride. [. . .] Smart communities are not, at their core, exercises in the deployment and use of technology, but in the promotion of economic development, job growth, and an increased quality of life. In other words, technological propagation of smart communities isn't an end in itself, but only a means to reinventing cities for a new economy and society with clear and compelling community benefit."	Eger (2009)
"A smart city is based on intelligent exchanges of information that flow between its many different subsystems. This flow of information is analyzed and translated into citizen and commercial services. The city will act on this information flow to make its wider ecosystem more resource efficient and sustainable. The information exchange is based on a smart governance operating framework designed to make cities sustainable."	Gartner (2011)
"A city well performing in a forward-looking way in economy, people, governance, mobility, environment, and living, built on the smart combination of endowments and activities of self-decisive, independent and aware citizens. Smart city generally refers to the search and identification of intelligent solutions which allow modern cities to enhance the quality of the services provided to citizens."	Giffinger et al. (2007)
"A smart city, according to ICLEI, is a city that is prepared to provide conditions for a healthy and happy community under the challenging conditions that global, environmental, economic and social trends may bring."	Guan (2012)
"A city that monitors and integrates conditions of all of its critical infrastructures, including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings, can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens."	Hall (2000)
"A city connecting the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city."	Harrison et al. (2010)
"(Smart) cities as territories with high capacity for learning and innovation, which is built-in the creativity of their population, their institutions of knowledge creation, and their digital infrastructure for communication and knowledge management."	Komninos (2011)
"Smart cities are the result of knowledge-intensive and creative strategies aiming at enhancing the socio-economic, ecological, logistic and competitive performance of cities. Such smart cities are based on a promising mix of human capital (e.g. skilled labor force), infrastructural capital (e.g. high-tech communication facilities), social capital (e.g. intense and open network linkages) and entrepreneurial capital (e.g. creative and risk-taking business activities)."	Kourtit and Nijkamp (2012)
"Smart cities have high productivity as they have a relatively high share of highly educated people, knowledge-intensive jobs, output-oriented planning systems, creative activities and sustainability-oriented initiatives."	Kourtit et al. (2012)

Table 1 (Continued)

Definitions	Sources
"Smart city [refers to] a local entity – a district, city, region or small country –which takes a holistic approach to employ[ing] information technologies with real-time analysis that encourages sustainable economic development."	IDA (2012)
"A community of average technology size, interconnected and sustainable, comfortable, attractive and secure."	Lazaroiu and Roscia (2012)
"The application of information and communications technology (ICT) with their effects on human capital/education, social and relational capital, and environmental issues is often indicated by the notion of smart city."	Lombardi et al. (2012)
"A smart city infuses information into its physical infrastructure to improve conveniences, facilitate mobility, add efficiencies, conserve energy, improve the quality of air and water, identify problems and fix them quickly, recover rapidly from disasters, collect data to make better decisions, deploy resources effectively, and share data to enable collaboration across entities and domains."	Nam and Pardo (2011)
"Creative or smart city experiments [. . .] aimed at nurturing a creative economy through investment in quality of life which in turn attracts knowledge workers to live and work in smart cities. The nexus of competitive advantage has [. . .] shifted to those regions that can generate, retain, and attract the best talent."	Thite (2011)
"Smart cities of the future will need sustainable urban development policies where all residents, including the poor, can live well and the attraction of the towns and cities is preserved. [. . .] Smart cities are cities that have a high quality of life; those that pursue sustainable economic development through investments in human and social capital, and traditional and modern communications infrastructure (transport and information communication technology); and manage natural resources through participatory policies. Smart cities should also be sustainable, converging economic, social, and environmental goals."	Thuzar (2011)
"A smart city is understood as a certain intellectual ability that addresses several innovative socio-technical and socio-economic aspects of growth. These aspects lead to smart city conceptions as "green" referring to urban infrastructure for environment protection and reduction of CO2 emission, "interconnected" related to revolution of broadband economy, "intelligent" declaring the capacity to produce added value information from the processing of city's real-time data from sensors and activators, whereas the terms "innovating", "knowledge" cities interchangeably refer to the city's ability to raise innovation based on knowledgeable and creative human capital."	Zygiaris (2013)
"The use of Smart Computing technologies to make the critical infrastructure components and services of a city—which include city administration, education, healthcare, public safety, real estate, transportation, and utilities—more intelligent, interconnected, and efficient."	Washburn et al. (2010)

As seen in the table 1, there is no consensus about the definition of smart cities. Most of the definitions focus only on one side of smart cities such as ICT, social aspects, or environmental aspects. However, the common notion of the term emphasizes the human and social factor as smart people of smart cities with the combination of ICT infrastructure. Accordingly, many criticisms focus on the exclusion of the human factor of smart cities.

2.4 Criticisms about Smart Cities

As mentioned above, the term smart city can be easily manipulated by politicians and technology firms convincing that it relates to ICT alone. However, most academicians are opposed to such approaches. The most famous criticism about smart cities was made by Hollands in 2008.

In his article, “*Will the real smart city please stand up? Intelligent, progressive or entrepreneurial?”*, he firstly criticizes the complexity of the definitions (Hollands, 2008). The literature has appeared to be bombarded with the most of the relative new city terms such as intelligent, innovative, wired, digital, creative and cultural, relating with the technological informational transformation with change of economic, political, and socio-cultural. Due to the usage of common assumptions, separating the terms from each other is very difficult, so these terms are often confused with each other. In addition to this, hype and such similar terms for the purpose of place marketing manipulates the term as opposed to actual situation of the area such as workable and effective IT policies. In fact, the reality and the image is the main difference of actual smart cities and the cities lauding themselves as a smart city (Hollands, 2008). Moreover, introducing the smart city as an almost positive and uncritical thing leads to false retrieval for city development. According to Hollands (2008), the smart city label does not always come with good and positive meanings in all respects, for example, some smart city definitions refer to the city as technological-dependent and ignorant towards the people.

Second criticism of Hollands (2008) is on self-designated smart cities that emphasize themselves as business-led urban developments. In essence, many self- designated smart cities define themselves as “business-led” or “business-friendly” cities, which imply industrial and technological smartness. This makes the smart cities market-led smart cities (Hollands, 2008). Of course, these types of approaches may only be one of the aspects of smart cities. The main criticism here is that “*technological smart city becomes a smokescreen for ushering in the business-dominated informational city*” (Hollands, 2008, p. 311).

The third criticism is the role of information and communication technology (ICT) in urban development. While the impact of ICT on smart cities cannot be denied, it is considered that they have to be more than just broadband networks. Likewise, the technology factor can only be an enabler, but not a critical factor in order to define smart cities (Paquet, 2001). The human factor is generally ignored in the technology based aspect. Hollands (2008) explains this by giving an example of Lima, a city in South

America. He states that although there was a big telecommunication diffusion in 90s, less than half of the city inhabitants use the phone and solely 7% of dwellers have access to internet. In contrast to blindly believing that information technologies will automatically transform and improve a city, Hollands (2008) believes that the smart city movement must be initiated with human capital investments.

The fourth criticism is, according to Hollands (2008), smart cities can bring about not only economical polarization, but also can lead to a separation between creative, well-educated people and the technology illiterate, unskilled local poorer population socially, culturally, and spatially. This may arise as an urban gentrification in this regard. According to Chatterton and Hollands' gentrification study conducted in 2003, the factor behind the social polarization and gentrification in UK is based on the changes of urban economy including, IT and services employment in cities (Hollands, 2008).

In the most general sense, criticism on smart cities is mainly gathered around the human capital, rather than the ICT factor alone. In fact, according to Roller and Waverman (2001), without mentioning the concept of "smartness", it has not been possible to tie up ICT, economy, and human capital since the beginning of the digital era (see also Caragliu, Del Bo, & Nijcamp, 2011). In addition to this, Glaeser and Berry (2006) and Berry and Glaeser (2005) indicated that educated labor force is directly proportional to rapid urban growth rates. According to them, without investing on the human capital and education, smart cities cannot be defined well (Berry & Glaeser, 2005).

2.5 Human Capital Emphasis in Conceptualizations of the Smart City

Caragliu, Del Bo and Nijcamp (2011) deal with the smart city concept in a slightly different way. According to them, the term smart city cannot be limited to the quality of ICT infrastructure, or technology, but human capital investment has much more meaning for this concept. They drew attention to human capital – educated labor – by using Florida's term "Creative Class" in competition of cities (Caragliu et al., 2011).

According to them, a city can only be smart when investment in human and social capital and traditional (transport) and modern (ICT) communication infrastructure fuel sustainable economic growth and high quality of life, with a wise management of natural resources through participatory governance (Caragliu et al., 2011). Florida employs three concepts, i.e. technology, talent, tolerance (3Ts), to define the Creative City. The application of knowledge base approach in defining the creative city refers specifically to the existence of a creative class, particularly in metropolitan areas (Florida, 2002).

Berry and Glaeser (2005) also concentrated on human capital and skilled workforce. According to them, it can be said that a higher education level of people or higher level of human capital has led to the attraction of more skilled people. That is, if entrepreneurs are willing to employ another skilled people, this may create an agglomeration economy where skilled people want to be around each other (Berry & Glaeser, 2005).

Glaeser and Berry (2006) have similarly focused on the proportion of educated workforce as a smartness indicator of cities. They assumed that skilled workforce indicate higher rates of population growth and income. In their study, educated or skilled workforces agglomerates same specific areas in smart cities such as, technopoles, and technoparks; hence, the gap between smart cities and the other cities grows.

In addition, Albino et al. (2015) believe that the label of smart city should not be restricted by technology; rather, it should consist of two different kinds of domains; soft domains including education, culture, policies; and hard domains including energy grids, water management, buildings etc. which leads to no general agreement about this term.

Yiğitcanlar (2015) also states that smart city model is the potential model for cities in the information and knowledge era, although it is under a deep exploration and investigation process. According to him, smart city, not the concept only that integrates ICT into the city, aims to provide citizens with a higher level of sustainable living and democratic governance through the process of social-technological innovation and political and socio-economic governance.

Nam and Pardo (2011) have tried to conceptualize smart cities by discussing its concepts and success factors. They investigate smart cities in 3 dimensions; technology, people, and community. These three dimensions, or conceptual variants, are mutually connected with substantial confusion in definitions and complicated usages rather than independent from each other. In their article, it was found that smart cities have organic connections between technology, human, and institutional components, emphasizing the social factors of smart cities. They advocated that instead of believing IT itself can transform and develop cities; investment on people, which leads to improvements in interaction and participation is the major factor for the smartness of the cities.

2.6 Components and Characteristics of Smart Cities

The components and characteristics of smart cities are one of the important issues that have been debated among researchers. Many academicians and researchers like Giffinger, Komninos, Cohen, and so on focus mainly on this subject for different purposes. For example, while Giffinger and Cohen used the components of the smart cities for the ranking purpose, others used it in order to define a framework for the term.

2.6.1 Giffinger's Approach

Giffinger et al. (2007) firstly define four main components of smart cities; industry, education, participation, and technical infrastructure. The characteristics have since been broadened according to literature and round-table discussion which are likely to be relevant: economy, people, governance, mobility, environment, and living.

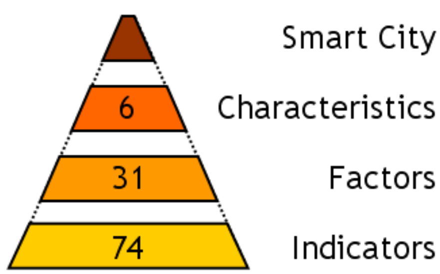


Figure 2 Giffinger's Description of Smart City (2007)

These 6 characteristics are divided into 31 relevant factors, which reflect the most important respects of the smart cities (see figure 2). Finally, these factors are separated into 74 relevant indicators in order to rank medium-sized smart cities of Europe (Giffinger, Kramar, & Haindl, 2010). The characteristics defined by Giffinger and his colleagues gain importance, and have been accepted and used commonly due to being one of the first approaches in evaluating smart cities in a holistic perspective.

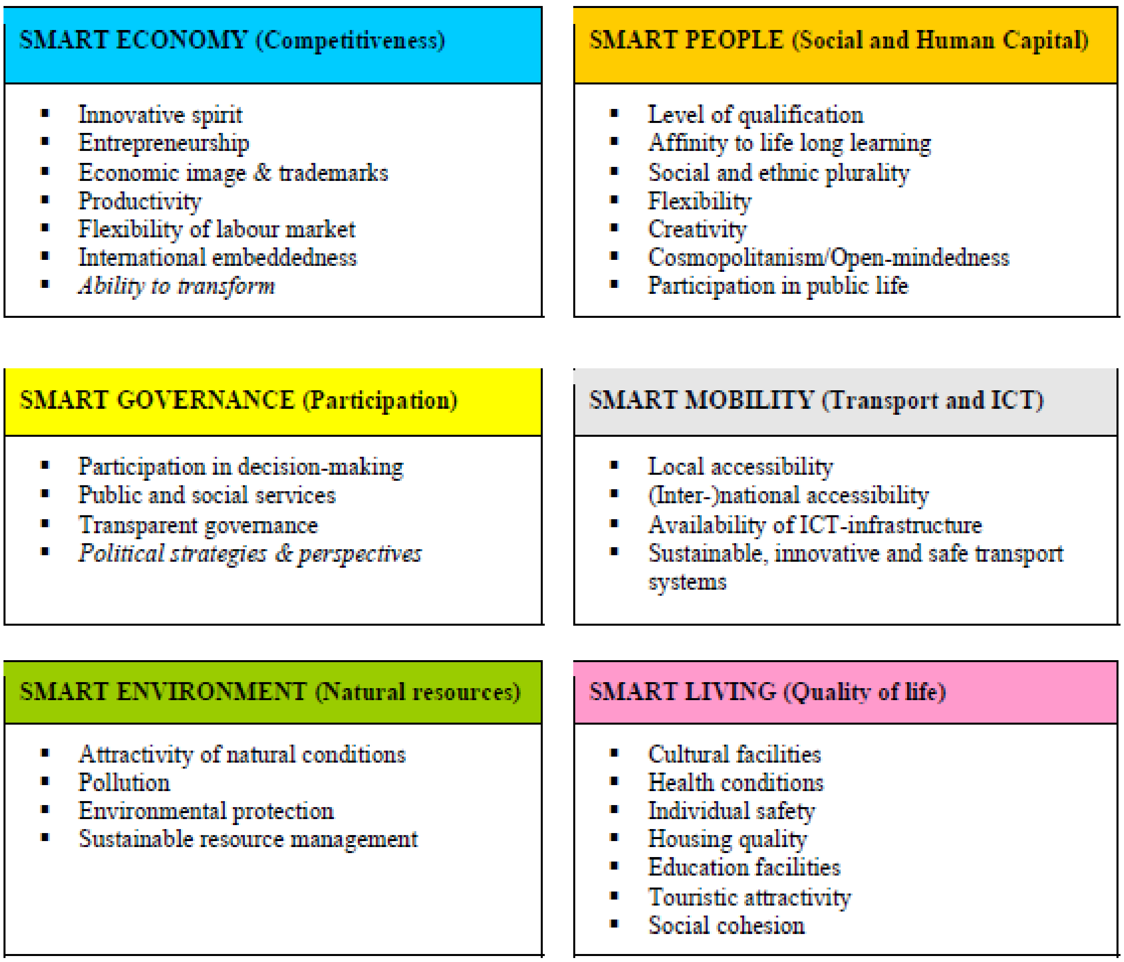


Figure 3 Lists of Giffinger's Characteristics and Factors (2007)

Smart Economy

Smart economy consists of 7 factors; innovative spirit, entrepreneurship, economic image and trademarks, productivity, flexibility of labor market, international embeddedness, and ability to transform (Giffinger, et. al., 2010) (see figure 3). In the light of e-business and e-commerce, the term aims to increase productivity, ICT-enabled and advanced manufacturing and delivery of services, ICT-enabled innovation as well as new products, new services and business models (EU, 2014).

Smart People

Smart people, which consist of 7 factors; level of qualification, affinity to lifelong learning, social and ethnic plurality, flexibility, creativity, cosmopolitanism/open-mindedness and participation in public life (Giffinger, et. al., 2010), means that e-skills, working in ICT-enabled working, having access to education and training, human resources and capacity management, within an inclusive society that improves creativity and fosters innovation (EU, 2014) (see figure 3).

Smart Governance

Giffinger et al. (2010) divided smart governance into 4 factors; participation in decision-making, public and social services, transparent governance and political strategies, and perspectives (see figure 3). It means joined up within-city and across-city governance, including services and interactions within link and integrates public, private, civil organizations so the city can function efficiently and effectively as one organism. It also includes ICT and e-government in participatory decision making and co-created e-services (EU, 2014).

Smart Mobility

Smart mobility consists of 4 factors; local accessibility, inter-national accessibility, availability of ICT-infrastructure, sustainable, innovative and safe transport systems (Giffinger, et. al., 2010), means that ICT supported and integrated transport and logistics systems. It aims to save time and commuting efficiency, save costs and reduce CO2 emissions, as well as to network transport managers to improve services and provide feedback to citizens (EU, 2014) (see figure 3).

Smart Environment

Giffinger, et. al. (2010), discuss smart environment into 4 main factors; attractivity of natural conditions, pollution, environmental protection and sustainable resource management (see figure 3). It consist of renewable smart environment policies, ICT-enabled energy grids, metering, pollution control and monitoring, renovation of buildings and amenities, green buildings, green urban planning (EU, 2014).

Smart Living

Giffinger et al. (2010) states that smart living term consist of 7 factors like cultural facilities, health conditions, individual safety, housing quality, education facilities, touristic attractivity and social cohesion (see figure 3). The term is explained in the EU report (2014) as the combination of ICT-based life styles, behavior and consumption. It is linked to the high levels of social cohesion and social capital, incorporating with the high quality of housing and accommodation (EU, 2014).

2.6.2 Cohen's (Smart City Council) Approach

Cohen (2014) has used the smart city wheel in order to rank smartest cities since 2012. Like Giffinger et al., Cohen's smart city approach consists of 6 main characteristics, which are; smart economy, smart environment, smart government, smart living, smart mobility, and smart people (see figure 4). Every characteristics of the Cohen's wheel is comprised of 3 main working areas. In Cohen's wheel, there are 62 indicators in order to evaluate smart cities (Ercoşkun, 2016). 16 indicators out of 62 are directly related to the new sustainable cities ISO standard (ISO 37120). According to Cohen's wheel, the center of the wheel consists of smart city and its 6 components, whereas going out of wheel is comprised of 18 working areas and 62 indicators.

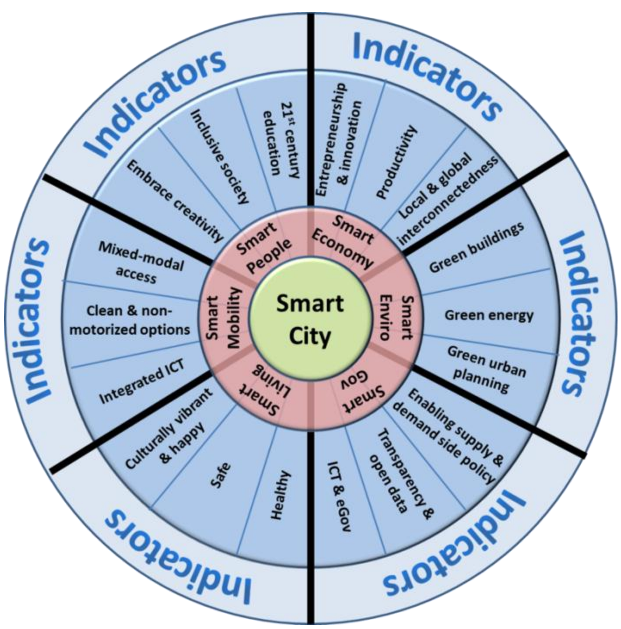


Figure 4 Cohen's Smart City Wheel (2014)

2.6.3 Mohanty and Colleagues Approach

According to Mohanty, Choppali, and Kougianos (2016), the smart city has 8 components; infrastructure, building, transportation, energy, health care, technology, governance, education, and citizen. They also describe 4 different attributes, 4 diversified core themes and 3 infrastructures of smart cities other than characteristics (see figure 5).

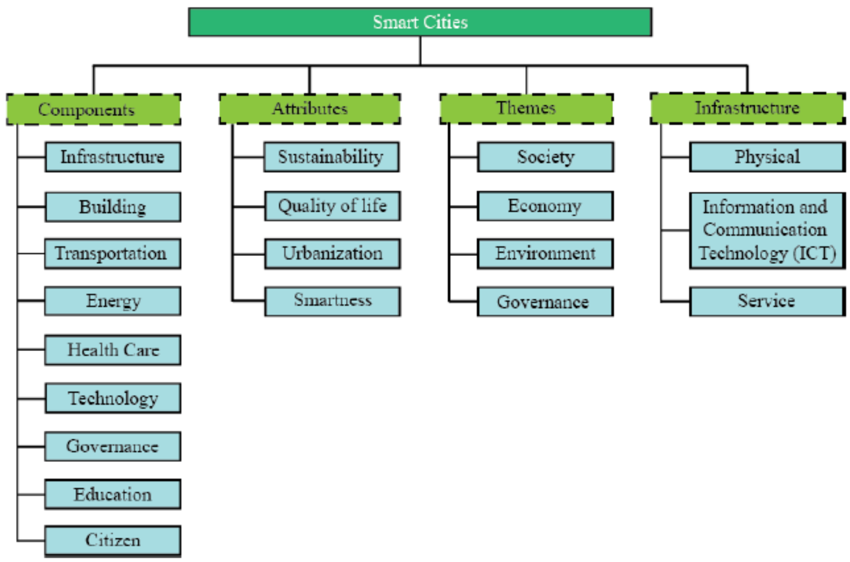


Figure 5 Mohanty and His Colleagues' Components and Characteristics of Smart Cities (2016)

In smart infrastructure and building, the author means anything that is physical, electrical and digital can be considered as smart infrastructure. Yet, in this context, it refers to infrastructure and building connected heavily with ICT infrastructure such as, fiber optics, Wi-Fi networks, smart homes, and so on. Likewise, unlike traditional transportation, smart transportation implies Intelligent Transportation Systems (ITS), which connects various types of different communication and navigation systems. Smart energy systems state the model of "internet energy" like smart grids, smart storage, and smart consumption. Another one is smart healthcare, which utilizes the ICT cloud to connect all smart medicine and living areas to each other. According to the authors, in order to design, implement and operate, smart technology is the key component of smart cities. Most of the features of smart cities depend on the use of the technology, so smart technology is one of the core factors of smart cities (Mohanty, Choppali, & Kougianos, 2016).

2.6.4 Caragliu and Del Bo Approach

Caragliu and Del Bo used the 6 axis of the smart cities in order to evaluate the connection between smart policies and smart cities. The six components are human capital, social capital, transport infrastructure, ICT infrastructure, natural resources, and e-government. Each component has at least 4 indicators, 28 indicators in total are used to evaluate this relationship (Caragliu & Del Bo, 2012).

The components used in the evaluation of Caragliu and Del Bo are important due to them giving significance to people factors and social capital. The human capital encompasses formal education, a functional/industrial component, and the position of the city within the urban hierarchy (Caragliu & Del Bo, 2012). The social capital, in this case, refers to the political action of the citizens, safety factors of the cities such as, crime and burglary rates, and so on.

2.6.5 IBM's Approach

IBM smarter planet initiative indicates three of the main components of smart cities; planning and management, human, and infrastructure. While smart planning and management are interested in the public safety, smarter buildings and urban planning, government and agency administration; infrastructure consists of energy and water, environment and transportation. The third, human factor, refers to social programs, healthcare, and education (Wiig, 2015).

Figure 6 IBM Smart City Components (IBM)

2.6.6 Verification (Classification) of Components

There are many more classifications of smart city characteristics and components. Yet, Albino et al. (2015) bring these characteristics of smart cities together in a table (see table 2). The table includes the different researchers' approaches upon smart cities including Mahizhnan, Giffinger, Eger, Thuzar, Nam and Pardo, Barrionuevo, Kourit and Nijkamp, and Chourabi, and so on. While creating the components of smart cities, some scientists were mainly interested in the ICT or IoT factors, basically the technology of smart cities; others focused on the holistic perspective of smart cities including the human capital.

Table 2 Key dimensions of smart cities created by Albino et al (2015)

Key dimensions of a smart city	Source
IT education IT infrastructure IT economy quality of life	Mahizhnan (1999)
economy mobility environment people governance	Giffinger et al. (2007)
technology economic development job growth increased quality of life	Eger (2009)
quality of life sustainable economic development management of natural resources through participatory policies convergence of economic, social, and environmental goals	Thuzar (2011)
economic socio-political issues of the city economic-technical-social issues of the environment interconnection instrumentation integration applications innovations	Nam and Pardo (2011)
economic (GDP, sector strength, international transactions, foreign investment) human (talent, innovation, creativity, education) social (traditions, habits, religions, families) environmental (energy policies, waste and water management, landscape) institutional (civic engagement, administrative authority, elections)	Barrionuevo et al. (2012)
human capital (e.g. skilled labor force) infrastructural capital (e.g. high-tech communication facilities) social capital (e.g. intense and open network linkages) entrepreneurial capital (e.g. creative and risk-taking business activities)	Kourtit and Nijkamp (2012)
management and organizations technology governance policy context people and communities economy built infrastructure natural environment	Chourabi et al. (2102)

Like Albino et al., Abid (2014) also classified 4 main approaches which define the characteristics of smart cities (see table 3).

Table 3 Combination of smart cities adopted by Abid (2014)

2007 Giffinger		2009 IBM		2013 Telefónica		2014 Meeting of the Minds	
Smart Economy	• Innovative spirit • Entrepreneurship • Economic image & trademarks • Productivity • Flexibility of labor market • International embeddedness • Ability to transform	Planning and Management	• Public safety • Smarter Buildings and Urban Planning • Government and Agency Administration.	Smart Mobility	• Smart Parking • Fleet Management • Intelligent Transport System • Traffic Management • Community Biking • Electric Vehicles Infrastructure • Smart Taxi	Soft Infrastructure	• Regulations • Education • Laws • Policies • Human capital
Smart People	• Level of qualification • Affinity to life-long learning • Social and ethnic plurality • Flexibility • Creativity • Cosmopolitanism/ Open-mindedness • Participation in public life			Energy and Environment	• Smart Building • Smart Grid and Smart Meters • Smart Urban Lighting • Waste Management • Watering Management • Noise Detection		
Smart Governance	• Participation in decision-making • Public and social services • Transparent governance • Political strategies & perspectives	Infrastructure	• Energy and water • Environment • Transportation	City Economy	• NFC Services • Digital Signage • E-Tourism • Connected Retailer	Hard Infrastructure	• Built Environment • Mobility • Utilities • Energy • Water • Grids
Smart Mobility	• Local accessibility • (Inter-)national accessibility • Availability of ICT-infrastructure • Sustainable, innovative and safe transport systems			City Management	• Smart City Dashboard • Smart City Operations Center • City Maintenance		
Smart Environment	• Attractivity of natural conditions • Pollution • Environmental protection • Sustainable resource management	Human	• Social Programs • Healthcare • Education	Security and e-Health	• Video Surveillance • Tele-Health and Tele-Care • Emergency Management	Technology	The bridge between soft infrastructure and hard infrastructure
Smart Living	• Cultural facilities • Health conditions • Individual safety • Housing quality • Education facilities • Touristic attractivity • Social cohesion						

Giffinger and his colleagues' holistic point of view attracted the most attention, although each researcher categorized indicators and criteria under different characteristics. In fact, characteristics of smart cities analyzed similarly, yet researcher uses different names that imply similar meanings. To illustrate, while IBM uses human as one of the characteristics of smart cities, Giffinger uses smart people and smart living as similar meanings.

2.7 Evaluation of Smart Cities

The questions, is the city smart city or not and how can smartness of the cities be understood, and to what extend the city is smart; could not be inadequately answered by scientists because there is not a delineation regarding smart cities. But, most scientists conducted studies about ranking and evaluating smart cities by comparing with each other.

In literature, Giffinger, Lombardi, Caragliu, Lazaroiu, Leydesdorff, Ercoskun have tried to rank, assess, and measure smartness performance of smart cities with their colleagues since nearly a decade.

2.7.1 Giffinger's Evaluation Model

Rudolf Giffinger, an expert in analytical research of urban and regional development in Vienna University of Technology, has been ranking European smart cities since 2007. As mentioned above, he and his team defined 6 main characteristics, 31 factors and 74 indicators in order to evaluate the process. To limit their sample sizes, they chose a group of medium-sized European cities (Giffinger et al., 2010) according to;

- The population being between 100.000 and 500.000 inhabitants,
- Having at least one university,
- Having catchment area of 1.500.000 inhabitants.

After these selection criteria, 256 cities remained as the potentially ranked group. But, due to the difficulties of accessibility and lack of information, solely 70 cities were included in the ranking process.

After the selection process, they calculated the smartness of the cities with z-score;

$$z = \frac{x-\mu}{\sigma} \tag{1}$$

where; μ is mean, and σ denotes standard deviation.

With z-transformation all values are ranging from “0” to “1”, which allow them to compare values. Because of the missing values, they did not sum the total values, instead, average values of the standardized values were used.

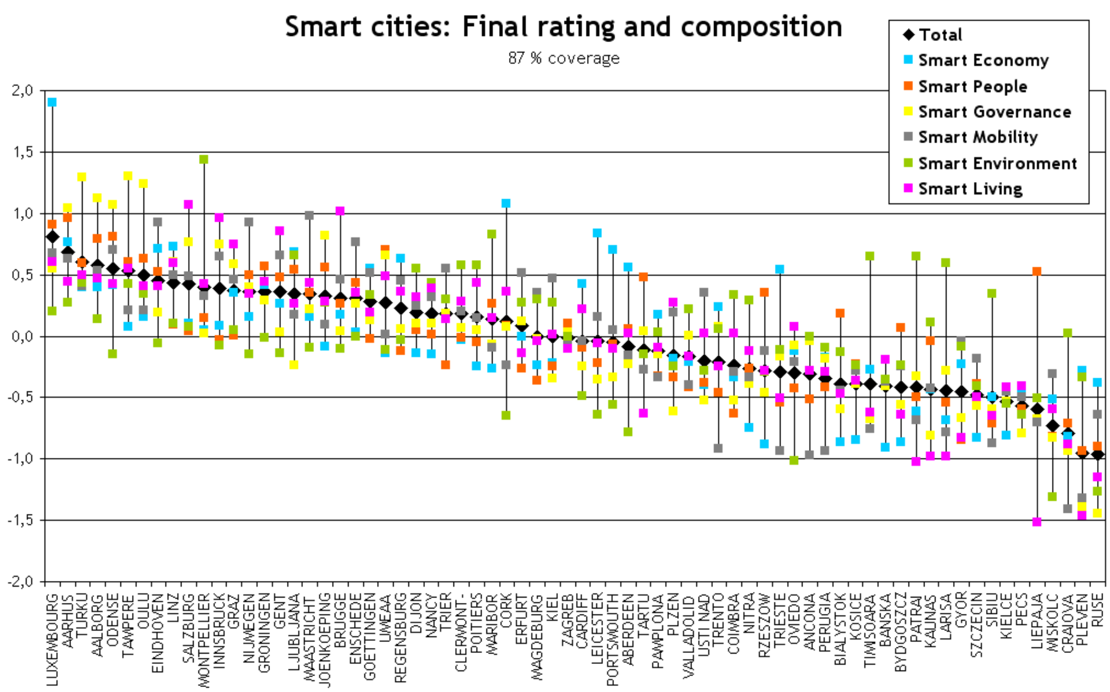


Figure 7 Final ratings and composition (Giffinger et al., 2010)

The average results show that the smartest city among 70 medium sized of European cities is Luxemburg, whereas the worst city is Ruse (see figure 7). They, finally, clustered cities divided by two, which is winning cities, with positive values of 37 cities; and loosing cities, with negative values of 28 cities. 5 of these cities have very interesting and heterogeneous results and 1 extraordinary city “Luxembourg” ranked first in European smart cities.

2.7.2 Caragliu, Del Bo's and Policy Evaluation Model

Caragliu and Del Bo, in their study "*Do Smart Cities Invest in Smarter Policies? Learning from the Past, Planning for the Future*", try to measure the relationships between urban smartness and smart urban policies (2012). Their aim was to fill the gap between them. In order to define and test policy score of the cities, they used the equation below;

$$policy_{score_i} = \alpha + \beta smartness_i + \gamma Z_i + \varepsilon_i \qquad (2)$$

where i indicates the cities, while Z is a matrix of relevant controls.

Urban smartness indicators of the study include 6 axis and 24 indicators. For each axis, the values are reduced by means of Principle Component Analysis (PCA). After that, the policy scores are tested with the heteroskedastic-robust ordinary least squares estimates. The score indicates the relationship and correlation between smart city policy intensity and urban smartness. The final scores show that London is the first city with the score of 11.7 points and Aalborg is the last with 2.5 points.

2.7.3 Lazaroiu and Roscia's Fuzzy Logic Evaluation Model

Lazaroiu and Roscia (2012) used the fuzzy logic model in order to evaluate Italian smart cities in their article, "*Definition methodology for the smart cities model*". Their model includes 18 indicators. Firstly, the weights of the indicators are decided according to the judges' expressions. After weights of the indicators are assembled, decision matrix of fuzzy logic is indicated. Then, defuzzification process is applied in order to calculate cities scores.

Classification with fuzzy weights	
Pavia	0.68
Bergamo	0.63
Como	0.62
Salerno	0.6
Cremona	0.56
Rome	0.56
Rieti	0.50
Naples	0.47
Foggia	0.47
Milan	0.43

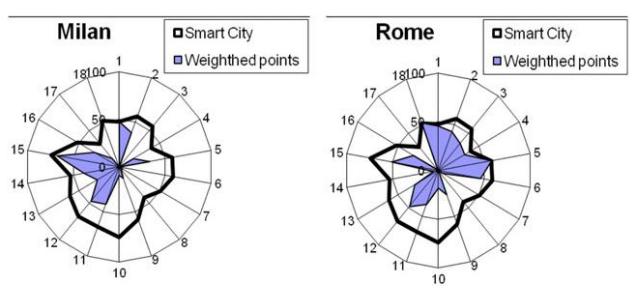


Figure 8 Smart city indices and smart city conditions (Lazaroiu & Roscia, 2012)

In the study, the smart city reference is stated, shown by black line and closeness of the cities are observed, indicated with blue area. According to the scores, in figure 8, it is indicated that fuzzy logic test score represents the Pavia is the smartest city in Italy, whereas Milan is the worst in terms of smartness.

2.7.4 Lombardi and His Colleagues' Triple Helix Model for Evaluation

Lombardi et al. (2012) used Triple Helix Model to evaluate performance of smart cities. They used the term of revised triple helix (as four helices) by adapting civil society with university, government, and industry. Their clusters which were used for calculating the relationship between triple helix were smart governance, smart economy, smart human capital, smart living, and smart environment. They add their study ANP (Analytic Network Process) analysis in order to identify relationship between smart city components and actors.

In the evaluation model, four helices and four policy visions adapted from "Urban Europe" (see figure 9); Connected City (smart logistic and sustainable mobility), Entrepreneurial City (economic vitality), Liveable City (ecological sustainability), and Pioneer City (social participation and social capital) were identified (Lombardi et al.,2012). These policy visions of smart cities are adapted from "Urban Europe" Joint Programme Initiatives by Nijcamp and Kourtik, which are connected city (smart logistic and sustainable mobility), entrepreneurial city (economic vitality), liveable city (ecological sustainability) and the pioneer city (social participation and social capital).

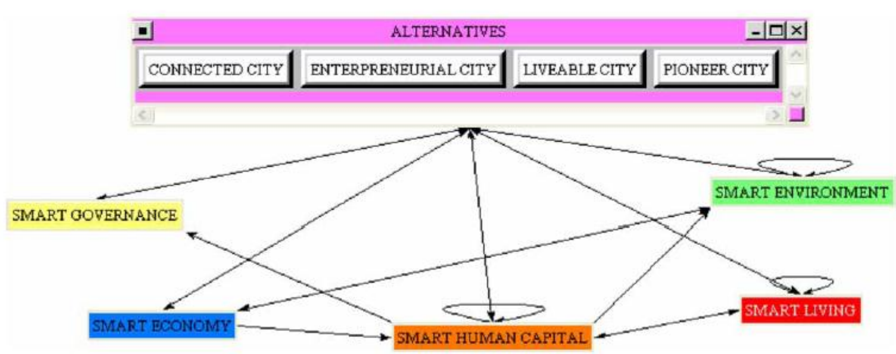


Figure 9 Civil Society subnetwork (Lombardi et al., 2012)

The final results of the study are;

- Entrepreneurial City (48%),
- Pioneer City (20%)
- Livable City (17%)
- Connected City (13%).

The model shows that the Entrepreneurial City has higher priority in all sectors considered in the model; universities, government, industry, and civil society.

2.7.5 Ercoskun Evaluation as Turkish Case

Ercoskun (2016) studied Turkish smart cities. In her article "*Ultimate ICT Network in Turkey For Smart Cities*", she investigated Turkish ICT infrastructure with thematic maps created in GIS software. She generally focused on the holistic perspective of smart cities, yet her evaluation is based on ICT network infrastructure of Turkey.

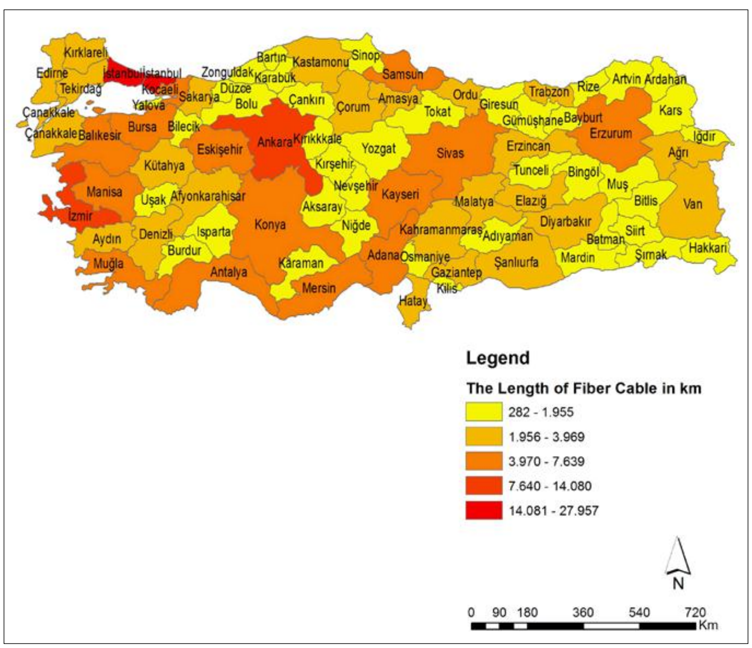


Figure 10 Lengths of the fiber cable in Turkey (Ercoşkun, 2016)

To illustrate, one of the maps created by Ercoskun is length of the fiber cables infrastructure in Turkey (see figure 10). This can be one of the indicators of smart cities under the roof of infrastructure. The study is positive as the fact that it is the first study of Turkish cities, but negative due to the ignoring people and human capital factor of smart cities. This can lead to misunderstanding of the smart cities as a whole by putting ICT infrastructure forward.

2.8 Benefits and Limits of Ranking of (Smart) Cities

Ranking of cities guides cities in many different areas, such as policy and urban growth. In addition, it will have more public attention with the dissemination of relevant results. According to Schönert (2003), ranking cities leads to the following assets below (Giffinger et al., 2010);

- Drawing public attention to major issues,
- Stimulating the board discussion
- Forcing regional actors by making their decisions transparent and comprehensible
- Making positive characteristics public outside the city itself,
- Initiating learning effects of local actors.

However, it also has some handicaps;

- (Sometimes) neglects the complex interrelations and causalities,
- Mainly focuses on the final results,
- May threaten long term strategic decisions,
- Strengthens existing stereotypes,
- May be ignored by the badly ranked cities.

According to Fertner et al. (2007), it is important to distinguish 3 factors by ranking cities; objectivity, methodology, and dissemination. According to them, the characteristics of ranking with respect to these 3 factors are;

- It should produce applicable results rather than just overall results,
- It is excessively taken into consideration by “winners”, while ignored by “losers”,

- Final results are the main concern of the public attention, not the methodology process.
- Even cities themselves may not use the results to evaluate their strengths and weaknesses for their future activities (Fertner, Giffinger, Kramar, & Meijers, 2007).

In the light of the literature framework, ranking and evaluation approaches concerning smart cities, adaptation of the criteria (indicators) for Turkish cities and methods that are used in the thesis are explained in Chapter 3.

CHAPTER 3

METHODOLOGY

In this research, an indicator-based approach is used to evaluate the smartness performance of Turkish cities in a holistic perspective. In recent years, many politicians, urban managers, technology developers, and international agencies are increasingly concerning about establishing a means to monitor, assess and evaluate the smartness performance of cities. To illustrate, technology firms like IBM, Sisco and Siemens are try to define and evaluate smartness performance of cities in order to encourage cities to insert technology to their infrastructure to achieve smartness requirements. There are many different indicator based approaches for smart cities like Giffinger's approach, Cohen's approach, and Caragliu and Del Bo's approach but there is no consensus in literature. However, the fact that these approaches are generally focusing on European cities has led to debate on the necessity of the smartness performance of Turkish cities.

In this research, smartness performance of Turkish cities is discussed and they are ranked by using Multi Criteria Decision Analysis (MCDA) methods. Thereby, all of 81 provinces of Turkey represent alternatives of the study. Although there are a number of MCDA methods, which can be used for choice, ranking and sorting, only suitable 4 ranking methods are selected. In order to evaluate and rank, categorical and continuous variables are both preferred. These variables has normalized and evaluated according to these methods individually. Each city has scored separately based on these variables and sum of the scores has given the cities total score in each methods.

According to these scores, smart cities' thematic maps in Turkey are created in ArcGIS 10.2 software. The maps give the author clues about the aggregations, concentrations, directions and locations of smarter and less smart cities of Turkey. These maps are also created for each characteristic of the smart cities to observe changes of the smartness of cities.

However, after these analyses, the obvious ranks of the cities are not determined because all methods have different calculation functions, which is not allow to take average scores. Hence, in order to observe the relationships between these methods, and to make an obvious choice, Spearman's rank correlation coefficient test is used for each character and the total score separately.

3.1 Determination of Criteria List

3.1.1 Giffinger's Frameworks

Giffinger, Kramar and Haindl have been studying to rank European cities since 2007. They started to discuss how smart cities can be ranked according to particular criteria. Giffinger et al. (2010) thought that the term 'smart city' can easily be manipulated and is not used in a holistic approach; rather, most examples take into consideration one specific part of the term. In their first study, he and his colleagues decide to evaluate the term 'smart city' by dividing six main characteristics; economy, people, governance, mobility, environment and living for the medium sized European cities. These six major characteristics are divided into 31 relevant factors that indicate the most important aspects of every smart characteristic. Finally, these factors are composed of 74 indicators to operationalize the relevant factors (Giffinger et al., 2010).

In Giffinger and his colleagues' study, 65% of indicators are defined in local level, while 15% of them are of regional level and 20% of them are in national level (2010). Compared to other methods, cities are defined as medium-sized cities according to their population, location (in Europe), the number of university (at least one university), and their catchment area in their study.

According to Giffinger et al. (2010), characteristics, factors and indicators are summarized as follows;

Table 4 Smart City Characteristics, Factors, and Indicators (Giffinger et al, 2010)

	factor	indicator	year	level
Smart Economy	Innovative spirit	R&D expenditure in % of GDP	2003	regional
		Employment rate in knowledge-intensive sectors	2004	regional
		Patent applications per inhabitant	2003	regional
	Entrepreneurship	Self-employment rate	2001	local
		New businesses registered	2001	local
	Economic image & trademarks	Importance as decision-making centre (HQ etc.)	2007	regional
	Productivity	GDP per employed person	2001	local
	Flexibility of labour market	Unemployment rate	2005	regional
		Proportion in part-time employment	2001	local
	International embeddedness	Companies with HQ in the city quoted on national stock market	2001	local
		Air transport of passengers	2003	regional
		Air transport of freight	2003	regional
Smart People	Level of qualification	Importance as knowledge centre (top research centres, top universities etc.)	2007	regional
		Population qualified at levels 5-6 ISCED	2001	local
		Foreign language skills	2005	national
	Affinity to life long learning	Book loans per resident	2001	local
		Participation in life-long-learning in %	2005	regional
		Participation in language courses	2005	national
	Social and ethnic plurality	Share of foreigners	2001	local
		Share of nationals born abroad	2001	local
	Flexibility	Perception of getting a new job	2006	national
	Creativity	Share of people working in creative industries	2002	national
	Cosmopolitanism/ Open-mindedness	Voters turnout at European elections	2001	local
		Immigration-friendly environment (attitude towards immigration)	2006	national
		Knowledge about the EU	2006	national
	Participation in public life	Voters turnout at city elections	2001	local
		Participation in voluntary work	2004	national
Smart Governance	Participation in decision-making	City representatives per resident	2001	local
		Political activity of inhabitants	2004	national
		Importance of politics for inhabitants	2006	national
		Share of female city representatives	2001	local
	Public and social services	Expenditure of the municipal per resident in PPS	2001	local
		Share of children in day care	2001	local
		Satisfaction with quality of schools	2005	national
	Transparent governance	Satisfaction with transparency of bureaucracy	2005	national
		Satisfaction with fight against corruption	2005	national
Smart Mobility	Local accessibility	Public transport network per inhabitant	2001	local
		Satisfaction with access to public transport	2004	national
		Satisfaction with quality of public transport	2004	national
	(Inter-)national accessibility	International accessibility	2001	regional
	Availability of ICT-infrastructure	Computers in households	2006	national
		Broadband internet access in households	2006	national
	Sustainable, innovative and safe transport systems	Green mobility share (non-motorized individual traffic)	2001	local
		Traffic safety	2001	local
		Use of economical cars	2006	national
Smart Environment	Attractivity of natural conditions	Sunshine hours	2001	local
		Green space share	2001	local
	Pollution	Summer smog (Ozon)	2001	local
		Particulate matter	2001	local
		Fatal chronic lower respiratory diseases per inhabitant	2004	regional
	Environmental protection	Individual efforts on protecting nature	2004	national
		Opinion on nature protection	2006	national
	Sustainable resource management	Efficient use of water (use per GDP)	2001	local
		Efficient use of electricity (use per GDP)	2001	local
Smart Living	Cultural facilities	Cinema attendance per inhabitant	2001	local
		Museums visits per inhabitant	2001	local
		Theatre attendance per inhabitant	2001	local
	Health conditions	Life expectancy	2001	local
		Hospital beds per inhabitant	2001	local
		Doctors per inhabitant	2001	local
		Satisfaction with quality of health system	2004	national
	Individual safety	Crime rate	2001	local
		Death rate by assault	2001-03	regional
		Satisfaction with personal safety	2004	national
	Housing quality	Share of housing fulfilling minimal standards	2001	local
		Average living area per inhabitant	2001	local
		Satisfaction with personal housing situation	2004	national
	Education facilities	Students per inhabitant	2001	local
		Satisfaction with access to educational system	2004	national
		Satisfaction with quality of educational system	2004	national
	Touristic attractivity	Importance as tourist location (overnights, sights)	2007	regional
		Overnights per year per resident	2001	local
	Social cohesion	Perception on personal risk of poverty	2006	national
		Poverty rate	2005	national

3.1.2 Cohen's (Smart City Council) Framework

Smart City Council ranking criteria has been developed by Council Advisor Body Cohen since 2011 and conducted annually. In this year, these criteria are determined in a more broad sense (Smart City Council, n.d). He used 16 indicators from ISO37120 "Sustainable development of communities - Indicators for city services and quality of life standards" in his approach. Like Giffinger indicator lists, Cohen's indicator list consists of 6 main characteristics. Each characteristic is broken down three separate factors, that is, 18 factors in total. These factors consist of 47 indicators and finally, they include 62 sub-indicators. The characteristics, factors, indicators, and sub-indicators are shown in table 5.

Table 5 Smart City Council Characteristics, Factors, Indicators and Sub-Indicators (Cohen, 2014)

Ch	Factors	Sub-Factors	Indicators
Environment	**Smart Buildings**	Sustainability-certified Buildings	Number of LEED or BREAM sustainability certified buildings in the city (Note: if your city uses another standard please indicate)
		Smart homes	% of commercial and industrial buildings with smart meters
			% of commercial buildings with a building automation system
			% of homes (multi-family & single-family) w/ smart meters
	Resources Management	Energy	% of total energy derived from renewable sources (ISO 37120: 7.4) Total residential energy use per capita (in kWh/yr) (ISO 37120: 7.1)
			% of municipal grid meeting all of following requirements for smart grid (1. 2-way communication; 2.) Automated control systems for addressing system outages 3.) real-time information for customers; 4.) Permits distributed generation; 5.) Supports net metering
		Carbon Footprint	Greenhouse gas emissioned measured in tonnes per capita (ISO 37120: 8.3)
		Air quality	Fine Particular matter 2.5 concentration (µg/m3) (ISO 37120: 8.1)
		Waste Generation	% of city's solid waste that is recycled (ISO 37120: 16.2) Total collected municipal solid waste city per capita (in kg) (ISO 37120: 16.3)
		Water consumption	% of commercial buildings with smart water meters Total water consumption per capita (litres/day) (ISO 37120: 21.5)
	Sustainable Urban Planning	Climate resilience planning	Does your city have a public climate resilience strategy/plan in place? (Y/N) If yes provide link.
		Density	Population weighted density (average densities of the separate census tracts that make up a metro)
		Green Space per capita	Green areas per 100,000 (in m2) (ISO 37120: 19.1)
Mobility	**Efficient Transport**	Clean-energy Transport	Kilometers of bicycle paths and lanes per 100,000 (ISO 37120: 18.7)
			# of shared bicycles per capita
			# of shared vehicles per capita
			# of EV charging stations within the city
	Multi-modal Access	Public Transport	Annual # of public transport trips per capita (ISO 37120: 18.3)
			% non-motorized transport trips of total transport
			Integrated fare system for public transport
	Technology Infrastructure	Smart cards	% of total revenue from public transit obtained via unified smart card systems
		Access to real-time information	Presence of demand-based pricing (e.g. congestion pricing, variably priced toll lanes, variably priced parking spaces). Y/N
			% of traffic lights connected to real-time traffic management system
			# of public transit services that offer real time information to the public: 1 point for each transit category up to 5 total points (bus, regional train, metro, rapid transit system (e.g. BRT, tram), and sharing modes (e.g. bikesharing, carsharing)
			Availability of multi-modal transit app with at least 3 services integrated (Y/N)
Government	**Online services**	Online Procedures	% of government services that can be accessed by citizens via web or mobile phone
		Electronic Benefits Payments	Existence of electronic benefit payments (e.g. social security) to citizens (Y/N)
	Infrastructure	Wi-Fi Coverage	Number of Wi-Fi hotspots per km2
		Broadband coverage	% of commercial and residential users with internet download speeds of at least 2 Mbit/s
			% of commercial and residential users with internet download speeds of at least 1 gigabit/s
		Sensor Coverage	# of infrastructure components with installed sensors 1 point for each: traffic, public transit demand, parking, air quality, waste, H2O, public lighting
		Integrated health + safety operations	# of services integrated in a singular operations center leveraging real-time data. 1 point for each: ambulance, emergency/disaster response, fire, police, weather, transit, air quality
	Open Government	Open Data	Open data use
		Open Apps	# of mobile apps available (iPhone) based on open data
		Privacy	Existence of official citywide privacy policy to protect confidential citizen data
Economy	**Entrepreneurship & Innovation**	New startups	Number of new opportunity-based startups/year
		R + D	% GDP invested in R&D in private sector
		Employment levels	% of persons in full-time employment (ISO 37120: 5.4)
		Innovation	Innovation cities index
	Productivity	GRP per capita	Gross Regional Product per capita (in US$, except in EU, in Euros)
	Local and Global Connection	Exports	% of GRP based on technology exports
		International Events Hold	Number of international congresses and fairs attendees.
People	**Inclusion**	Internet-connected Households	% of Internet-connected households
		Smart phone penetration	% of residents with smartphone access
		Civic engagement	# of civic engagement activities offered by the municipality last year
			Voter participation in last municipal election (% of eligible voters) (ISO 37120: 11.1)
	Education	Secondary Education	% of students completing secondary education (ISO 37120: 6.3)
		University Graduates	Number of higher education degrees per 100,000 inhabitants (ISO 37120: 6.7)
	Creativity	Foreign-born immigrants	% of population born in a foreign country
		Urban Living Lab	# of officially registered ENOLL living labs
		Creative Industry Jobs	Percentage of labor force (LF) engaged in creative industries
Living	**Culture and Well-being**	Life Conditions	Percentage of inhabitants with housing deficiency in any of the following 5 areas (potable water, sanitation, overcrowding, deficient material quality, or lacking electricity)
		Gini Index	Gini coefficient of inequality
		Quality of life ranking	Mercer ranking in most recent quality of life survey
		Investment in Culture	% of municipal budget allocated to culture
	Safety	Crime	Violent crime rate per 100,000 population (ISO 37120: 14.5)
		Smart Crime Prevention	# technologies in use to assist with crime prevention, 1 point for each of the following: live streaming video cameras, taxi apps, predictive crime software technologies
	Health	Single health history	% of residents w/ single, unified health histories facilitating patient and health provider access to complete medical records
		Life Expectancy	Average life expectancy (ISO 37120: 12.1)

3.1.3 Caragliu and Del Bo's Frameworks

Caragliu and Del Bo (2015) investigated smart cities' indicators in their article, *"Do Smart Cities Invest in Smarter Policies? Learning From the Past, Planning for the Future"*, in order to measure connections between smartness policies and smart implementations. Like Giffinger's and Cohen's analysis, Caragliu and Del Bo's analysis is consists of 6 main dimensions; human capital, social capital, transport infrastructure, ICTs, natural resources, and E-government. These dimensions divided into four individual indicators. Hence, Caragliu and Del Bo used to 24 criteria for their study. These dimensions and criteria are shown in table 6;

Table 6 Caragliu and Del Bo's (2015) Six Axes of the Smart City Definitions

Urban Smartness Axis	**Indicators**
Human Capital	Proportion of population aged 15–64 years qualified at tertiary level (ISCED 5–6) living in urban audit cities—Percentage
	Students in tertiary education (ISCED 5–6) living in urban audit cities—number of students per 1000 inhabitants
	Proportion of employment in financial intermediation business activities
	Proportion of employment public administration health education
	Number of companies with headquarters in the city quoted on the national stock market
Social Capital	Car thefts per 1,000 population
	Burglaries per 1,000 population
	Crimes per 1,000 population
	Number of elected city representatives
Transport Infrastructure	Length of public transport network per inhabitant
	Share of restricted bus lanes from public transport network
	Number of buses (or bus equivalents) operating in the public transport per 1,000 population
	Number of stops of public transport per 1,000 population
ICT infrastructure	Percentage of families with Internet access at home
	Number of local units producing ICT products
	Number of local units producing ICT-related services
	Number of local units producing web content
Natural Resources	Proportion of solid waste arising within the boundary processed by recycling
	Proportion of the area in green space
	Green space (in m2) to which the public has access, per capita
	Annual average concentration of PM10
	Annual average concentration of NO2
E-government	Percentage of Internet users who interacted via Internet with the public authorities in the last 12 months (Country data)
	Percentage of Internet users who sent filled forms to public authorities in the last 12 months (Country data)
	Number of administrative forms available for download from official website
	Number of administrative forms which can be submitted electronically

3.1.4 Adaptation of Criteria for Turkish Cities

These all approach above are used different criteria according to their study. The factors that shape criteria or indicator list are varying due to data accessibility, availability, the scope of the study, situation or condition of the cities which is selected by authors, and so on. For example, in the research project of Giffinger et al. (2007), *Smart Cities Ranking of European medium-sized cities*, indicators are determined according to city population size, data avaliability in Espon 1.1.1 study, Urban Audit (CORE) local 35, Espon 1.4.3 project (FUA level), Espon 1.2.1 project (NUTS3 level), Eurostat database (NUTS3 level), Eurostat database (NUTS2 level), Eurostat database (NUTS0 level), Various Eurobarometer special surveys (NUTS0 level), and Study on creative industries in Europe (NUTS0 level). In the present study, data is collected in 15 different institutions and several statistical database like ESPON, Urban Audit, EuroStat, MevkaStat,Corine (OSB), YOKstat, TUIK and so on.

In the thesis, besides the indicators in these three approaches, various sustainable city indicators, SEGE analysis indicators, Quality of Life indicators of TUIK analysis are adopted according to Turkish context. The author decided to bring all the outputs of approaches together. As a result of this, 122 criteria were identified in order to rank Turkish smart cities. However, data availability and "state of emergency" situation in Turkey lead to limit these indicators. Ultimately, 6 Axis, 21 factors, and 75 criteria is determined in order to rank Turkish smart cities. These are summarized in table 7 below;

Table 7 6 axis, 21 factors, and 75 criteria to rank Turkish cities based on smartness levels

Ch	Factors	No	Indicators	Yr	Source
ENVIRONMENT	**Energy Usage**	**C1**	Percentage of renewable energy (%) (ISO 37120: 7.4)	2017	Enerji Atlası
		C2	Energy generation / Energy consumption (%)	2017	Enerji Atlası
		C3	Total residential energy use per capita (in kWh/yr) (ISO 37120: 7.1)	2012	TUIK
	Pollution	**C4**	Total collected municipal solid waste city per capita (in kg/p) (ISO 37120: 16.3)	2014	TUIK
		C5	Amount of Particulate Matter 10 concentration (ISO 37120: 8.1) (µg / m^3)	2016	CSB
		C6	Amount of Nitrogen Dioxide (NO2) concentration (µg / m^3)	2016	TUIK
		C7	Amount of Sulphur Dioxide (SO2) concentration (µg / m^3)	2016	CSB
		C8	Water pollution priority ranking (sig. level.)	2014	CSB
		C9	Noise pollution rate (%)	2015	TUIK

Table 7 (Continued)

Ch	Factors	No	Indicators	Yr	Source
ENVIRONMENT	Sustainability	C10	Number of LEED, DGNB or BREEAM sustainability certified buildings	2017	LEED, BREAM Web Site
		C11	Built environment per person (m^2)	2012	OSB
		C12	People density (in built environment - p/ha)	2012	OSB
		C13	Municipal environmental expenditures per person (tl)	2015	TUIK
		C14	Green areas (Forest) per capita (m^3)(ISO 37120: 19.1)	2015	OGM
		C15	Satisfaction rate with green strategies of municipality (%)	2013	TUIK
		C16	Forest area per km^2 (%)	2015	TUIK
	Water Usage	C17	Amount of discharged daily wastewater per person in municipalities (l / person-day)	2014	TUIK
		C18	Percentage of people served by the wastewater treatment plant (%)	2014	TUIK
		C19	Rate of people served by municipal water service (%)	2014	TUIK
		C20	Amount of water treated (1000 m^3 / yr)	2014	TUIK
		C21	Total water consumption per capita (l /day) (ISO 37120: 21.5)	2014	TUIK
		C22	Sewerage and municipal water access rate (%)	2015	TUIK
TRANSPORTATION & INFRASTRUCTURE	Accessibility	C23	Airport access rate (%)	2015	TUIK
		C24	Railway per ha (m)	2015	OSB
		C25	Availability of High Speed Train (y / n) (#)	2017	TCDD
	Internet Subscriptions	C26	Fixed broadband subscriptions rate (%)	2015	BTK
		C27	Number of mobile broadband subscriptions rate (%)	2015	BTK
		C28	Internet subscribers rate (%)	2015	BTK
		C29	Mobile phone subscribers rate (%)	2015	BTK
	Technological Infrastructure	C30	The length of fiber cable per person (m)	2015	BTK
		C31	Number of municipal mobile applications (#)	2017	Android Play Store
	Transportation	C32	Number of cars per 1000 inhabitant (‰)	2014	TUIK
		C33	Number of traffic accidents per 100,000 people	2014	EGM
		C34	Satisfaction rate with public transport services (%)	2015	TUIK
GOVERNANCE	Civic Engagement	C35	Civil Participation Index (#)	2015	TUIK
		C36	Rate of membership to political parties (%)	2015	TUIK
		C37	Voter turnout at local administrations (%) (ISO 37120: 11.1)	2015	TUIK
		C38	Percentage of persons interested in union/association activities (%)	2015	TUIK
	Representatives & Equity	C39	Number of parliament members per 100.000 people	2014	TBB
		C40	Female representative ratio (%)	2014	TBB
ECONOMY	Entrepreneurship & Business	C41	Percentage of engineers employed in the industry (%)	2013	BSTB
		C42	Number of companies (HQ) in the city (#)	2015	BSTB
		C43	Unemployment Rate (%)	2015	TUIK
		C44	Employment Rate (%)	2015	TUIK
		C45	Number of entrepreneurs (with Techno Capital Support) (#)	2013	BSTB
	Innovation	C46	Number of companies with R & D unit (#)	2013	BSTB
		C47	Number of R & D centers (#)	2013	BSTB
		C48	Number of technopoles in the city (#)	2013	BSTB
		C49	Innovative City Index (#)	2015	MevkaSta
		C50	Number of patent application s (#)	2015	MevkaSta
	Local and Global Connections	C51	Number of airline passengers / population (#)	2015	UDHB
		C52	Air freight carrying amount / population (kg)	2015	UDHB
	Productivity	C53	GDP per capita (#)	2014	TUIK
		C54	Export / Import (tl)	2017	TUIK

Table 7 (Continued)

Ch	Factors	No	Indicators	Yr	Source
PEOPLE	Brain Power	C55	Number of academic staff per 100.000 people	2016	YOK
		C56	Working in creative industries (#)	2015	BSTB
	Education	C57	Percentage of BSc graduates (* 1000) (ISO 37120: 6.3)	2015	TUIK
		C58	Percentage of MSc Graduates (* 1000) (ISO 37120: 6.7)	2015	TUIK
		C59	Percentage of PhD graduates (* 1000)	2015	TUIK
		C60	Percentage of students in university (* 1000)	2015	YOK
LIVING	Culture & Well Being	C61	Life Satisfaction Rate (%)	2015	TUIK
		C62	Percentage of cinema and theater audience (%)	2015	TUIK
	Health	C63	Number of hospital beds per 100 000 people	2012	TUIK
		C64	Number of doctors per 100,000 people	2012	TUIK
		C65	Rate of satisfaction with public health services (%)	2015	TUIK
	Housing	C66	Rate of non-kitchen households (%)	2011	TUIK
		C67	Rate of bathroom in households (%)	2011	TUIK
		C68	Number of rooms per person (#)	2015	TUIK
		C69	Rate of availability of toilet in the house (%)	2015	TUIK
		C70	Proportion of people experiencing problems in quality of housing (%)	2015	TUIK
	Safety	C71	Violent crime rate (in 1.000.000 people) (ISO 37120: 14.5) (%)	2015	TUIK
		C72	Safety satisfaction level at night (%)	2015	TUIK
	Working & Income Condition	C73	GINI regional coefficient (2014 - 2015) (tl)	2015	TUIK
		C74	Average daily earnings (tl)	2015	TUIK
		C75	Satisfaction rate of job (%)	2015	TUIK

These all criteria are subjected to 81 provinces of Turkey and decision matrix is created according to these criteria. Then, these criteria weights are determined according to factors. Each axis that creates smart cities is considered to be *equal weights*. Similarly, each factor that is subset of the each axis is considered to be *equal* in order to make an objective evaluation, and each indicator that creates each factor is thought to be *equal weights*. (e.g the weight of criterion 1 (C1) is determined as (((100/6)/4)/3) = 1.39%.)

3.2 Multi Criteria Decision Analysis

Multi Criteria Decision Analysis is a useful tool which can be applied to solve many complex problems. It is the most applicable when the solution is needed to be chosen, sorted and ranked among the alternatives (Turan, 2015). Its allegedly root is stand on Benjamin Franklin's (1706-1790) simple paper systems used for deciding important issues (MCDM Society). Additionally, Condorcet, Cantor, Edgeworth and Pareto are also thought to be leading scientists of MCDA with many contributions (Turan, 2015).

However, modern MCDA and its software started to emerge about 50 years ago and with the recent developments, it has a very widespread use in many areas ranging from economy, industry, agriculture, to planning (Tzeng & Huang, 2011).

Yıldırım and Önder (2015) define the MCDA as problems where the best alternative is selected from possible solution sets where more than one criterion is optimized. To them, MCDA process is consists of two major parts;

1. Decision Analysis / Utility Theory
2. Multi-Purpose Math Programming

3.2.1 Multi Criteria Decision Making (MCDM)

Multi criteria decision making processes are comprised of five main components;

1. Define the nature of the problem,
2. Construct a hierarchy systems for its evaluation,
3. Select the appropriate evaluation model,
4. Obtain the relative weights and performance score of each criteria with respect to each alternative,
5. Determine the best alternative (Tzeng & Huang, 2011).

In addition, multi criteria decision making problems can be investigated in three main categories (Vassilev, Genova, & Vassileva, 2005);

1. Problems of multi criteria choice
2. Problems of multi criteria rankings
3. Problems of multi criteria sorting

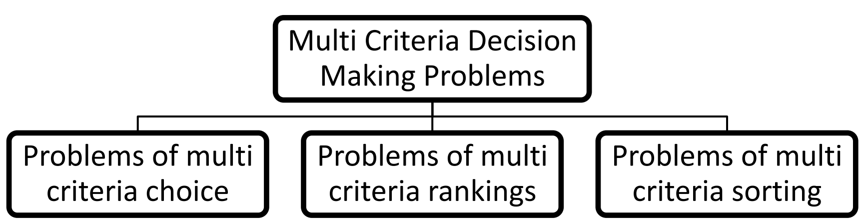


Figure 11 Multi Criteria Decision Making Problems (Turan, 2015)

Today, many techniques and software are developed in order to find answer to these problems that classified under the categories of choice, ranking and sorting. In table 8, it is indicated methods developed according to the categories.

Table 8 MCDA Methods Developed to Overcome Problems and Methods (Turan, 2015)

Choice Problems	Ranking Problems	Sorting Problems
AHP	**PROMETHEE**	AHP
ANP	ELECTRE	ANP
MAUT/UTA	**GRA**	MAUT/UTA
MACBETH	**TOPSIS**	MACBETH
PROMETHEE	**SAW**	**PROMETHEE**
ELECTRE	UTADIS	ELECTRE
TOPSIS	Flow Sort	**TOPSIS**
GRA	VIKOR	SMARTS
SAW	MOORA	
VIKOR		
MOORA		
DEMATEL		
PAPRICA		

As mentioned before, in the thesis Grey Relational Analysis (GRA), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Simple Additive Weighting (SAW), and Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) methods will be used to rank Turkish cities in the light of smart city criteria because of that these methods are perfectly suited to research. Some of other methods such as ELECTRE and VIKOR are applied for the study, yet definitive result could not be obtained in these methods due to the fact that dataset of the study is too large for the ranking.

3.2.2 Grey Relational Analysis (GRA)

One of the methods which will be used in order to evaluate smart city performances of Turkish cities is Grey Relational Analysis (GRA), which is based on Grey System Theory, introduced by Deng Julong in 1982 (Julong, 1989).

Grey System Theory can be referred in the event of lack and inadequate information such as structure message, operation mechanism and behavior document. Grey System involves three parts: Known, which white relations; totally unknown, which is black relations; and the incomplete information, which is grey relations (Liu & Lin, 2011).

Table 9 Comparison of White, Grey and, Black Systems (Liu & Lin, 2011)

	White	**Grey**	**Black**
From information	Completely known	Incomplete	Unknown
From appearance	Clear	Blurred	Dark
From processes	Old	Changing	New
From properties	Order	Multivariate	Chaotic
From methods	Confirmation	Change for better	Negation
From attitude	Rigorous	Tolerant	Letting go
From the outcomes	Unique solution	Multi-solution	No solution

The major aim of Grey System applications is to bridge the gap between social science and natural science. Hence, this system brings important solutions to interdisciplinary problems. The scope of Grey System applications is very broad like agriculture, ecology, economy, meteorology, medicine, history, geography, industry, earthquake, geology, hydrology, irrigation strategy, military affairs, sports, traffic, management, material science, environment, planning, biological protection, judicial system and so on (Julong, 1989).

Grey Relational Analysis as one of the Multi Criteria Decision Making methods can be applied to problems that have some complex and inadequate information, criteria and factors. Hence, it is easy to use MCDM problems alone and together with other methods as a hybrid model (Yıldırım, 2015).

Grey relational analysis is basically measure grey relations of the factors with the reference factors. Whence, the reference factors should be determined in order to measure grey relations. The degree of effect between the factors gives the degree of grey relations.

The reasons to use grey relational analysis for the study are; suitability for ranking, applicability of small data sets, a common usage area, ease of use, no need to be extra and specific software programs, and so on (Tzeng & Huang, 2011).

Grey Rational Analysis procedures are summarized as follows (Tzeng & Huang, 2011);

1- Step 1: Generate the referential series of $x_0 = (x_0(1), x_0(2), \ldots, x_0(j), \ldots, x_0(n))$ with j entities, and x_i is the compared series of$(x_i(1), x_i(2), \ldots, x_i(j), \ldots, x_i(n)$, where$i = 1,2,3, \ldots, m$.. The compared series x_i can be represented in a matrix form:

$$x_i = \begin{bmatrix} x_1(1) & x_1(2) & \cdots & x_1(n) \\ x_2(1) & x_1(2) & \cdots & x_2(n) \\ \vdots & \vdots & \ddots & \vdots \\ x_n(1) & x_n(2) & \cdots & x_n(n) \end{bmatrix}. \tag{3}$$

2- Step 2: Normalize the data set. The data can be useful in three types; larger-is-better, smaller-is-better and nominal-is-better.

For larger-is-better transformation, $x_i(j)$ can be transformed to $x_i^*(j)$;

$$x_i^*(j) = \frac{x_i(j) - \min_j x_i(j)}{\max_j x_i(j) - \min_j x_i(j)} \tag{4}$$

where $\max_j x_i(j)$ is the maximum value of entity j and $\min_j x_i(j)$ is the minimum value of entity$j$.

For smaller-is-better;

$$x_i^*(j) = \frac{\max_j x_i(j) - x_i(j)}{\max_j x_i(j) - \min_j x_i(j)} \tag{5}$$

For nominal is the better, if the target value is $x_{0b}(j)$and $\max_j x_i(j) \geq x_{0b}(j) \geq \min_j x_i(j)$, then the formula;

$$x_i^*(j) = \frac{|x_i(j) - x_{0b}(j)\,|}{\max_j x_i(j) - \min_j x_i(j)} \tag{6}$$

Similarly, referential series of x_0 should be normalized as well by using these formulation 2-4. Therefore, after the normalization process is done, the matrix shown in Eq.(3) can be revised as;

$$x_i^* = \begin{bmatrix} x_1^*(1) & x_1^*(2) & \cdots & x_1^*(n) \\ x_2^*(1) & x_2^*(2) & \cdots & x_2^*(n) \\ \vdots & \vdots & \ddots & \vdots \\ x_n^*(1) & x_n^*(2) & \cdots & x_n^*(n) \end{bmatrix} \tag{7}$$

3- Step 3: Compute the distance of $\Delta_{0i}(j)$, the absolute value of difference between x_0^* and x_i^* at the j-th point. So, the formula is;

$$\Delta_{0i}(j) = |x_0^*(j) - x_i^*(j)| \tag{8}$$

$$= \begin{bmatrix} \Delta_{01}(1) & \Delta_{01}(2) & \cdots & \Delta_{01}(n) \\ \Delta_{02}(1) & \Delta_{02}(2) & \cdots & \Delta_{02}(n) \\ \vdots & \vdots & \ddots & \vdots \\ \Delta_{0m}(1) & \Delta_{0m}(2) & \cdots & \Delta_{0m}(n) \end{bmatrix} \tag{9}$$

4- Step 4: Apply grey relational equation to compute grey relational coefficient $r_{0i}(j)$using the following equation:

$$\gamma_{0i\,(j)} = \frac{\Delta_{min} + \xi\Delta_{max}}{\Delta_{0i}(j) + \xi\Delta_{max}}, \tag{10}$$

where $\Delta_{max} = \max_i \max_j \Delta_{0i}(j)$, $\Delta_{min} = \min_i \min_j \Delta_{0i}(j)$, and $\Delta \in [0,1]$.

5- Step 5: Compute the degree of grey coefficient$\Gamma_{\ 0i}$. If the weights (W_i) of criteria are determined, the degree of grey coefficient $\Gamma_{\ 0i}$ is computed as:

$$\Gamma_{\ 0i} = \sum_{j=1}^{n} [W_i(j) \times \Gamma_{\ 0i}(j)]. \tag{11}$$

For decision-making processes, if any alternative has the highest Γ_{0i} value, then it is the significant alternative. Therefore, the priorities of alternatives can be ranked in accordance with Γ_{0i} values.

3.2.3 Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)

TOPSIS, one of the MDCM methods, was initiated by Hwang and Yoon (1981) to determine the best alternative based on the concepts of the compromise solution (Tzeng & Huang, 2011). The fundamental of TOPSIS based on the best solution which is the one that has *the shortest distance* to the ideal solution and *the furthest distance* from the anti-ideal solution (Hwang & Yoon, 1981). To illustrate, in figure 12, alternative A is closer to ideal solution than alternative B and also further from the anti-ideal solution, so alternative A is the better solution than alternative B according to TOPSIS.

The main purpose to use TOPSIS for the thesis is the fact that TOPSIS takes into consideration both ideal and anti-ideal solution, that it is one of the ranking methods, that it is not needed to be extra software, that it is easy in calculation and so on.

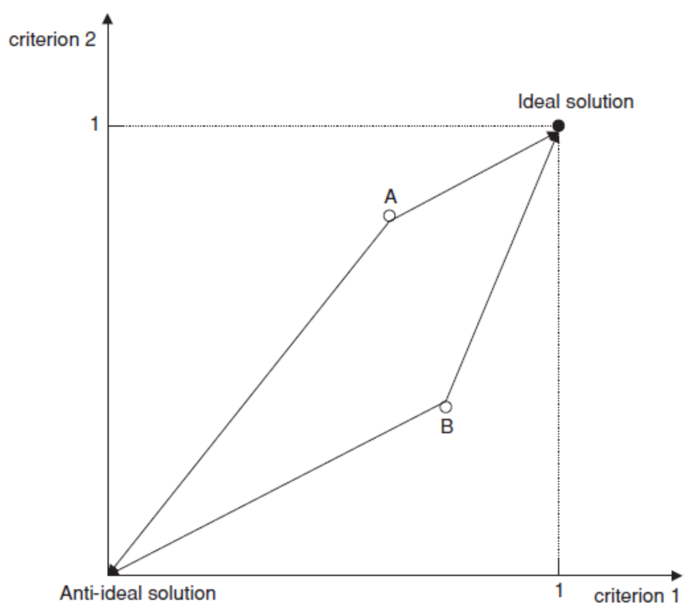


Figure 12 TOPSIS Method

TOPSIS procedures can be explained as follow (Tzeng & Huang, 2011);

1- Step 1: Decide the data matrix and normalize data by using;

$$r_{ij} = x_{ij} \Big/ \sqrt{\sum_{i=1}^{m} x_{ij}^2}, \qquad (12)$$

where $i = 1,2, \dots, m$ and $j = 1,2, \dots, n$, from the basic matrix of

$$D = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1j} & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2j} & x_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{i1} & x_{i2} & \dots & x_{ij} & x_{in} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \dots & x_{mj} & x_{mn} \end{bmatrix}. \qquad (13)$$

The rows represent the alternatives, and the columns represent the criteria.

2- Step 2: Decide the weights of $w_j = [w_1, w_2, \dots, w_n]$ and the total weights of criteria equal to 1.

3- Step 3: Determine the ideal solution (A^*) and negative ideal solution (A^-) for each alternative. The formulas are;

$$A^* = \left\{ \max_i V_{ij} \middle| j \in J \; or \; \left(\min_i V_{ij} \middle| j \in J' \right) | i = 1,2,3, \dots, m \right\}$$
$$= \{V_1^*, V_2^*, \dots, V_j^*, \dots, V_n^*\}. \qquad (14)$$

and

$$A^- = \left\{ \min_i V_{ij} \middle| j \in J \; or \; \left(\max_i V_{ij} \middle| j \in J' \right) | i = 1,2,3, \dots, m \right\}$$
$$= \{V_1^-, V_2^-, \dots, V_j^-, \dots, V_n^-\}. \qquad (15)$$

4- Step 4: Compute the separate measures of S_i^* and S_i^- by following formulas:

$$S_i^* = \sqrt{\sum_{j=1}^{n} (V_{ij} - V_j^*)^2} \qquad (16)$$

and

$$S_i^- = \sqrt{\sum_{j=1}^{n}(V_{ij} - V_j^-)^2}. \tag{17}$$

5- Step 5: Calculate the relative closeness to ideal solutions (C_i^*) using by;

$$C_i^* = \frac{S_i^-}{S_i^* + S_i^-} \tag{18}$$

6- Step 6: Rank the alternatives by descending order of C_i^*. The alternative with the largest C_i^*value is the best alternative, while the alternative with the smallest C_i^* value is the worst.

3.2.4 Simple Additive Weighting (SAW)

SAW method, which is firstly utilized by Churchman and Ackoff (1954) to deal with a portfolio selection problem also known as Weighted Sum Model (WSM) in the literature (Karaatlı, Ömürbek, Budak, & Dağ, 2015). According to Tzeng and Huang (2011), SAW method is probably the best known, widely used and most popular method in MCDM problems due to its simplicity. To SAW method, the best alternative can be derived by the following equation:

$$A^* = \{u_i(x) | \max_i u_i(x) \,|i = 1,2, \dots, n\} \tag{19}$$

Or the gaps of alternatives can be improved to build a new best alternative A^* for achieving aspired/desired levels in each criterion. Also,

$$u_i(x) = \sum_{j=1}^{n} w_j r_{ij}(x) \tag{20}$$

where $u_i(x)$ denotes the utility of the ith alternative and $i = 1,2, \dots, n$; w_j denotes the weights of the jth criterion; $r_{ij}(x)$ is the normalized preferred ratings of the ith alternative with respect to the jth criterion for all commensurable units; and all criteria are assumed to be independent. In addition, the normalized preferred ratings ($r_{ij}(x)$) of the ith alternative with respect to the jth criterion can be defined by:

$$r_{ij} = \frac{x_{ij}}{\max_i X_{ij}} \; i = 1, \dots, m; j = 1, \dots, n \text{ (for the benefit criteria)} \tag{21}$$

$$r_{ij} = \frac{\min_i x_{ij}}{x_{ij}} \; i = 1, \dots, m; j = 1, \dots, n \text{ (for the cost of the criteria).} \tag{22}$$

Therefore, the synthesized performance is;

$$P_i = \sum_{j=1}^{m} w_j r_{ij} \tag{23}$$

where P_i is a synthesizing performance value of the ith alternative; w_j denotes the weights of the jth criterion; r_{ij} is the normalized preferred ratings of the ith alternative with respect to the jth criterion for becoming the commensurable units; and the criteria are assumed to be independent of each other. If the units of the performance matrix are the commensurable units, we do not need to transfer the data matrix into the normalized preferred rating scales (Tzeng & Huang, 2011).

The main purpose to use SAW method for the theses is its simplicity and popularity to make ranking among alternatives.

3.2.5 Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE)

The PROMETHEE method, initiated by Jean-Pierre Brans in 1982, is based on mutual comparison of each alternative pair with respect to each of the selected criteria (Tzeng & Huang, 2011). In order to perform alternative ranking by the PROMETHEE method, it is necessary to define preference function $P(a, b)$ for alternatives a and b after defining the criteria. Alternatives a and b are evaluated according to the criteria functions. It is considered that alternative a is better than alternative b according to criterion f, if $f(a) > f(b)$. The decision maker has possibility to assign the preference to one of the alternatives on the basis of such comparison. The preference can take values on the scale from 0 to 1, and relation combinations are possible to represent using following relations (Tzeng & Huang, 2011):

$P(a, b) = 0$ no preferences, indifference,

$P(a, b) \approx 0$ weak preference $k(a) > k(b)$,

$P(a, b) \approx 1$ strong preference $k(a) >> k(b)$,

$P(a, b) = 1$ strict preference $k(a) >>> k(b)$.

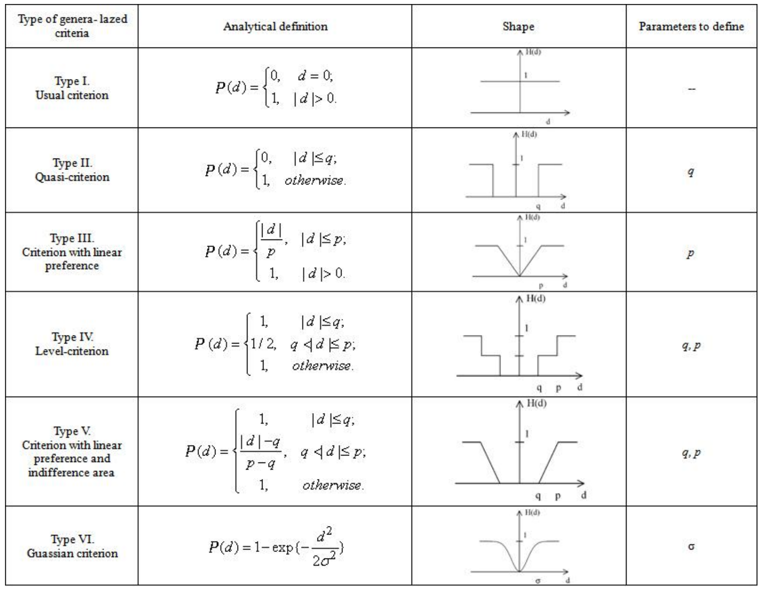
Higher preference is defined by higher value from the given interval. This means that, for each criterion, the decision maker considers certain preference function. In figure 13, 6 generalized criteria and 6 preference functions $P(d)$are given. All 6 generalized criteria are possible to illustrate via linear functions, that is, they are obtained by choosing the highest 4 points inside criteria space of the given criterion. In figure 13, besides criteria functions, the parameters for chosen points within criteria space, which is illustrated in x-axis, are given, and the level of preference is given in y-axis P. In the four-level criterion, instead of value $P(d) = 1/2$, it is possible to give any value 0 < $P(d)$ < 1 (Tzeng & Huang, 2011).

In figure 13, the following denotation is used: m – indifference limit, n – strong preference limit, q – approximate value between m and n for Gaus criterion.

After defining the type of general criterion, it is necessary to determine the value of function preference of action a in relation to action b for each criterion, and calculate the index of preferences (IP) of action a in relation to action b. Each pair of actions is in set$A$. The index preference is calculated in the following way (Tzeng & Huang, 2011);

$$IP(a, b) = \sum_j^n W_j P_j(a, b), b \sum W_j = 1, \quad (24)$$

where $W_j$is the weight of the criterion “j”.



Type of genera- lazed criteria	Analytical definition	Shape	Parameters to define
Type I. Usual criterion	$P(d)=\begin{cases}0, & d=0;\\ 1, & \mid d\mid>0.\end{cases}$		--
Type II. Quasi-criterion	$P(d)=\begin{cases}0, & \mid d\mid\le q;\\ 1, & otherwise.\end{cases}$		q
Type III. Criterion with linear preference	$P(d)=\begin{cases}\frac{\mid d\mid}{p}, & \mid d\mid\le p;\\ 1, & \mid d\mid>0.\end{cases}$		p
Type IV. Level-criterion	$P(d)=\begin{cases}1, & \mid d\mid\le q;\\ 1/2, & q<\mid d\mid\le p;\\ 1, & otherwise.\end{cases}$		q, p
Type V. Criterion with linear preference and indifference area	$P(d)=\begin{cases}1, & \mid d\mid\le q;\\ \frac{\mid d\mid-q}{p-q}, & q<\mid d\mid\le p;\\ 1, & otherwise.\end{cases}$		q, p
Type VI. Guassian criterion	$P(d)=1-\exp(-\frac{d^2}{2\sigma^2})$		σ

Figure 13 PROMETHEE Preference Functions (Yıldırım, 2015)

After determining index preference $IP\ (a, b)$, it is finally possible to calculate alternative flaw index $T\ (a)$, whose value represents the significance of the alternative. According to this index, the final decision about adequacy of one alternative from the set of alternatives is made. It is determined as: P

$$T\ (a) = \frac{\sum_{x\in A} IP(a,x)}{i-1} \tag{25}$$

The selection of criteria to be used in the decision process needs to be done carefully so that the majority of the chosen criteria define the problem at hand adequately and in accordance with the decision maker's given requests. In this way, the influence of experience and subjective evaluation of the decision maker during selection of generalized criteria is maximally reduced.

The reason to use PROMETHEE for the thesis is to select suitable functions for the different factors in order to compare each alternative by pair-wise comparison. This leads to evaluate every two alternative one by one. Although the method is more complex than the other ones, it is one of the most effective ranking methods.

3.2.6 Spearman's Rank Correlation Coefficient

Charles Spearman (1904) in the article of "*The proof and measurement of association between two things"* defines the Spearman Correlation coefficient as discovering the strength of a link between two sets of data, which is denoted by σ (rho) or as r_s. It uses monotonic function in order to evaluate relationships between two variables.

The Spearman Coefficient as a distribution-free test makes no assumption about the shape of distribution. The correlation coefficient can ranging from -1 to +1, while -1 represents the negative perfect correlation, +1 indicates the positive perfect correlation. (Lehman, O'Rourke, Hatcher, & Stephanski, 2005)

In order to calculate Spearman correlation coefficient, firstly, for n sample, the n raw scores X_i, Y_i should be converted to the ranks $r_s = \rho_{rg_X,rg_Y} = \frac{cov\,(rg_X,rg_Y)}{\sigma_{rg_X}\sigma_{rg_Y}}$

where,

- ρ denotes the Pearson correlation coefficient,
- $cov\,(rg_X, rg_Y)$ is the covariance of the rank variables,
- σ_{rg_X} and σ_{rg_Y} are the standard deviations of the rank variables.

If all variables are distinct integers, the formula below is used;

- $r_s = 1 - \frac{6\sum d_i^2}{n(n^2-1)}$ (26)

where,

- n is the number of observations,
- $d_i = rg(X_i) - rg(Y_i)$ is the difference of two ranks.

The guide for interpreting the score of correlation coefficient is below (Lehman et al., 2005);

- ±1.00 = perfect correlation

- ±0.80 = strong correlation
- ±0.50 = moderate correlation
- ±0.20 = weak correlation
- ±0 = no correlation

3.2.7 Research Methodology

In the thesis, the studies firstly focus on the concept of smart cities in a holistic perspective. Some of the researchers and the academicians who interest the term closely to make the concept clear are the guidance of the first part of the thesis. In the light of these researches and their studies, the purpose of the thesis is set as ranking and evaluation of smartness performance of Turkish cities.

For this purpose, 6 characteristics, 21 factors and 75 criteria are determined with regard to earlier studies. According to these indicators are collected from 15 different institutions, several statistical programs like, EuroStat, MevkaStat, YOKstat, TUIK, and so on. After data collection, 4 suitable Multi Criteria Decision Making methods which are GRA, TOPSIS, SAW and PROMETHEE are used to measure smartness performance of Turkish cities. These methods are applied for each characteristic separately. According to results of the methods, thematic maps are created in ArcGIS 10.2 in order to monitor aggregations, concentration, directions and locations of the smart cities in Turkey. In addition, Spearman’s rank correlation coefficient test is used in order to measure closeness of the results due to the fact that each method calculates the smartness performance independently. After these analyses, one of the methods that has the highest correlation coefficient determines the final rank of the cities.

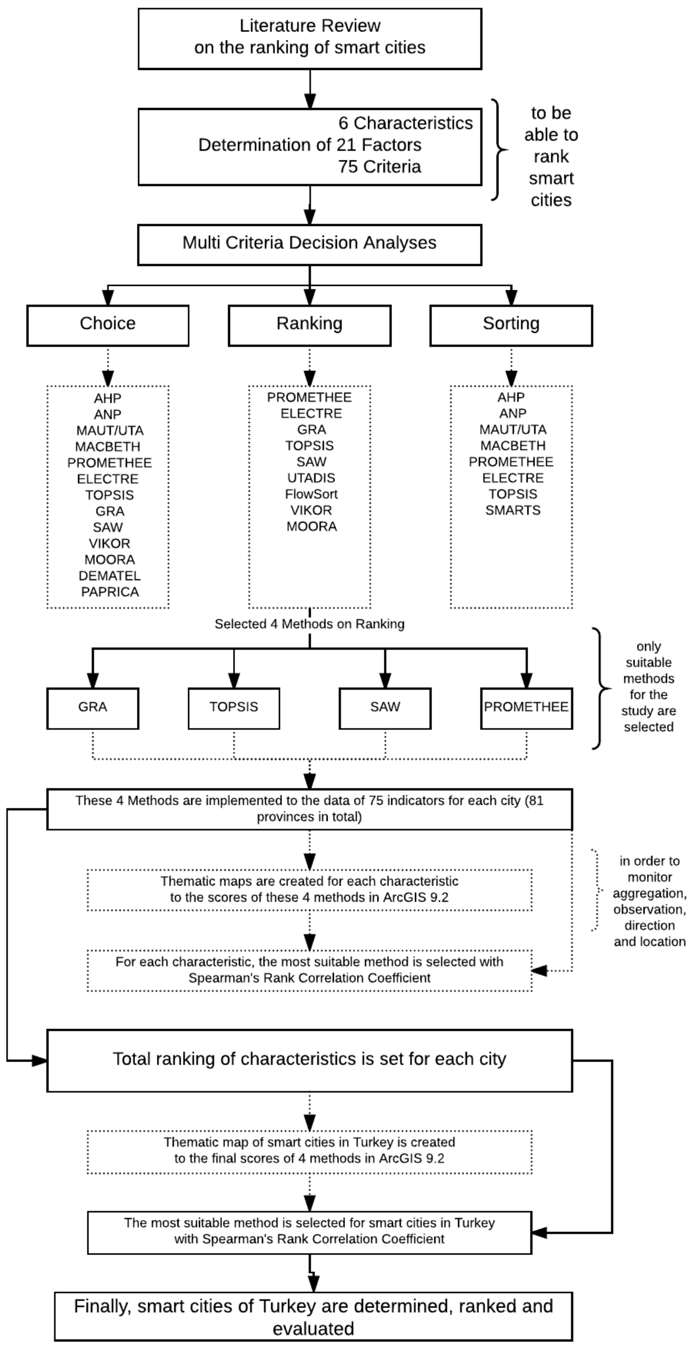


Figure 14 Evaluation process of the thesis

Similarly, total scores of the cities that are taken from each method individually are subjected to same process. Finally, after these processes, smartness performance of Turkish cities is determined (see figure 14). According to the final scores, the cities are ranked and evaluated.

CHAPTER 4

THE EVALUATION OF SMARTNESS PERFORMANCE OF TURKISH CITIES

In this research, 6 characteristics, 21 factors and 75 indicators are used to evaluate the smartness performance of Turkish cities. These 6 characteristics have equal weights, in order to calculate final score. Similarly, each factor of the characteristics has the same weights, and the indicators that form each factor are the same.

The study has 81 alternatives, which are represented by Turkish cities. In table 10, these alternatives and their basic features like statistical and geographical regions, codes, populations and areas are indicated. According to table 10, Turkish cities have 12 statistical regions in NUTS 1 level and 27 sub-regions in NUTS 2 level. But, there are 7 geographical regions in Turkey. Although the capital city is Ankara with the population of 5.346.518 people, the biggest city in Turkey is İstanbul with the population of 14.804.116 people in 2016 (TUIK).

Table 10 Features of 81 provinces of Turkey as alternatives of the study (Regions, Populations, Area and so on.)

NUTS 1	NUTS 2	NUTS 3	Province	Geographical Region	Code	Population	Area (km^2)
TR1	TR10	TR100	İstanbul	Marmara	34	14804116	13844
TR2	TR21	TR211	Tekirdağ	Marmara	59	972875	7337
TR2	TR21	TR212	Edirne	Marmara	22	401701	14016
TR2	TR21	TR213	Kırklareli	Marmara	39	351684	11099
TR2	TR22	TR221	Balıkesir	Marmara	10	1196176	7659
TR2	TR22	TR222	Çanakkale	Marmara	17	519793	5628
TR3	TR31	TR310	İzmir	Aegean	35	4223545	25632
TR3	TR32	TR321	Aydın	Aegean	9	1068260	20177
TR3	TR32	TR322	Denizli	Aegean	20	1005687	4934
TR3	TR32	TR323	Muğla	Aegean	48	923773	7393
TR3	TR33	TR331	Manisa	Aegean	45	1396945	8116
TR3	TR33	TR332	Afyonkarahisar	Aegean	3	714523	14583
TR3	TR33	TR333	Kütahya	Aegean	43	573642	2330
TR3	TR33	TR334	Uşak	Aegean	64	358736	4477
TR4	TR41	TR411	Bursa	Marmara	16	2901396	3746
TR4	TR41	TR412	Eskişehir	Aegean	26	844842	4179
TR4	TR41	TR413	Bilecik	Marmara	11	218297	8004
TR4	TR42	TR421	Kocaeli	Marmara	41	1830772	8294

Table 10 (Continued)

NUTS 1	NUTS 2	NUTS 3	Province	Geographical Region	Code	Population	Area (km^2)
TR4	TR42	TR422	Sakarya	Marmara	54	976948	8313
TR4	TR42	TR423	Düzce	Black Sea	81	370371	7175
TR4	TR42	TR424	Bolu	Black Sea	14	299896	10813
TR4	TR42	TR425	Yalova	Marmara	77	241665	9817
TR5	TR51	TR510	Ankara	Central Anatolia	6	5346518	7542
TR5	TR52	TR521	Konya	Central Anatolia	42	2161303	12428
TR5	TR52	TR522	Karaman	Central Anatolia	70	245610	12134
TR6	TR61	TR611	Antalya	Mediterranean	7	2328555	15168
TR6	TR61	TR612	Isparta	Mediterranean	32	427324	2492
TR6	TR61	TR613	Burdur	Mediterranean	15	261401	6145
TR6	TR62	TR621	Adana	Mediterranean	1	2201670	9383
TR6	TR62	TR622	Mersin	Mediterranean	33	1773852	11815
TR6	TR63	TR631	Hatay	Mediterranean	31	1555165	25006
TR6	TR63	TR632	Kahramanmaraş	Mediterranean	46	1112634	13960
TR6	TR63	TR633	Osmaniye	Mediterranean	80	522175	6803
TR7	TR71	TR711	Kırıkkale	Central Anatolia	71	277984	7025
TR7	TR71	TR712	Aksaray	Central Anatolia	68	396673	6668
TR7	TR71	TR713	Niğde	Central Anatolia	51	351468	7095
TR7	TR71	TR714	Nevşehir	Central Anatolia	50	290895	5524
TR7	TR71	TR715	Kırşehir	Central Anatolia	40	229975	3664
TR7	TR72	TR721	Kayseri	Central Anatolia	38	1358980	8946
TR7	TR72	TR722	Sivas	Central Anatolia	58	621224	5461
TR7	TR72	TR723	Yozgat	Central Anatolia	66	421041	11891
TR8	TR81	TR811	Zonguldak	Black Sea	67	597524	14520
TR8	TR81	TR812	Karabük	Black Sea	78	242347	4142
TR8	TR81	TR813	Bartın	Black Sea	74	192389	8678
TR8	TR82	TR821	Kastamonu	Black Sea	37	376945	10193
TR8	TR82	TR822	Çankırı	Central Anatolia	18	183880	13064
TR8	TR82	TR823	Sinop	Black Sea	57	205478	16970
TR8	TR83	TR831	Samsun	Black Sea	55	1295927	4791
TR8	TR83	TR832	Tokat	Black Sea	60	602662	6459
TR8	TR83	TR833	Çorum	Black Sea	19	527863	6584
TR8	TR83	TR834	Amasya	Black Sea	5	326351	1412
TR9	TR90	TR901	Trabzon	Black Sea	61	779379	3397
TR9	TR90	TR902	Ordu	Black Sea	52	750588	40838
TR9	TR90	TR903	Giresun	Black Sea	28	444467	11634
TR9	TR90	TR904	Rize	Black Sea	53	331048	12259
TR9	TR90	TR905	Artvin	Black Sea	8	168068	13339
TR9	TR90	TR906	Gümüşhane	Black Sea	29	172034	8780
TRA	TRA1	TRA11	Erzurum	Eastern Anatolia	25	762021	16010
TRA	TRA1	TRA12	Erzincan	Eastern Anatolia	24	226032	12654
TRA	TRA1	TRA13	Bayburt	Black Sea	69	90154	8650
TRA	TRA2	TRA21	Ağrı	Eastern Anatolia	4	542255	5485
TRA	TRA2	TRA22	Kars	Eastern Anatolia	36	289786	7234
TRA	TRA2	TRA23	Iğdır	Eastern Anatolia	76	192785	5861
TRA	TRA2	TRA24	Ardahan	Eastern Anatolia	75	98335	3320
TRB	TRB1	TRB11	Malatya	Eastern Anatolia	44	781305	3835
TRB	TRB1	TRB12	Elazığ	Eastern Anatolia	23	578789	4824
TRB	TRB1	TRB13	Bingöl	Eastern Anatolia	12	269560	9725
TRB	TRB1	TRB14	Tunceli	Eastern Anatolia	62	82193	5717
TRB	TRB2	TRB21	Van	Eastern Anatolia	65	1100190	5717
TRB	TRB2	TRB22	Muş	Eastern Anatolia	49	406501	28164
TRB	TRB2	TRB23	Bitlis	Eastern Anatolia	13	341225	19242
TRB	TRB2	TRB24	Hakkari	Eastern Anatolia	30	267813	7078
TRC	TRC1	TRC11	Gaziantep	Southeast Anatolia	27	1974244	6190
TRC	TRC1	TRC12	Adıyaman	Southeast Anatolia	2	610484	10042
TRC	TRC1	TRC13	Kilis	Southeast Anatolia	79	130825	4628
TRC	TRC2	TRC21	Şanlıurfa	Southeast Anatolia	63	1940627	7582
TRC	TRC2	TRC22	Diyarbakır	Southeast Anatolia	21	1673119	5555
TRC	TRC3	TRC31	Mardin	Southeast Anatolia	47	796237	20921
TRC	TRC3	TRC32	Batman	Southeast Anatolia	72	576899	798
TRC	TRC3	TRC33	Şırnak	Southeast Anatolia	73	483788	13690
TRC	TRC3	TRC34	Siirt	Southeast Anatolia	56	322664	3342

The basic aim of the study is to evaluate and rank the smartness of Turkish cities. Thanks to technological improvements in the world, the cities are under the process of change as being a smart city. The study not only will evaluate the smartness of the cities but also will create a discussion board concerning the smartness of Turkish cities. These debates are sadly controversial in the way of catching the level of contemporary civilizations.

4.1 Characteristics of Smart Cities

4.1.1 Smart Environment

Main purpose of the smart environment is to evaluate environmental performance of smart cities. In a holistic perspective, environmental smartness is one of the important points of the smart cities because it aims to protect the natural environment, which means that the more environmental-sensitive the city is, the smarter it becomes.

For evaluation, four different factors are used in the study; energy use, pollution, sustainability, and water use. These factors are separated in 22 criteria and treated by 81 province of Turkey. These indicators and their weights are listed below in table 11;

Table 11 Lists of Environmental Factors and Indicators

Ch.	Factors	No	Indıcators	Weights
ENVIRONMENT	Energy Usage	C1	Percentage of the renewable energy (%) (ISO 37120: 7.4) 2017	1.39%
		C2	Energy generation / Energy consumption (%) 2017	1.39%
		C3	Total residential energy use per capita (in kWh/yr) (ISO 37120: 7.1) 2012	1.39%
	Pollution	C4	Total collected municipal solid waste per capita (in kg) (ISO 37120: 16.3) 2014	0.69%
		C5	Amount of Particulate Matter 10 concentration (ISO 37120: 8.1) (µg / m3) 2016	0.69%
		C6	Amount of Nitrogen Dioxide (NO2) concentration (µg / m3) 2016	0.69%
		C7	Amount of Sulphur Dioxide (SO2) concentration (µg / m3) 2016	0.69%
		C8	Water pollution priority ranking 2014	0.69%
		C9	Noise pollution rate 2015	0.69%
	Sustainability	C10	The number of LEED, DGNB, and BREEAM sustainability certified buildings	0.60%
		C11	Built environment per person (m2) 2012	0.60%
		C12	People density (in built environment - p/ha) 2012	0.60%
		C13	Municipal environmental expenditures per person (tl) 2015	0.60%

Table 11 (continued)

<table>
<tr><td rowspan="9">ENVIRONMENT</td><td rowspan="3">Sustainability</td><td>C14</td><td>Green areas (forests) per capita (m3)(ISO 37120: 19.1) 2015</td><td>0.60%</td></tr>
<tr><td>C15</td><td>Satisfaction rate with green strategies of municipality (%) 2013</td><td>0.60%</td></tr>
<tr><td>C16</td><td>Forest area per km^2 (%) 2015</td><td>0.60%</td></tr>
<tr><td rowspan="6">Water Usage</td><td>C17</td><td>Amount of discharged daily wastewater per person (Lt / Person-Day) 2014</td><td>0.69%</td></tr>
<tr><td>C18</td><td>Percentage of people served by wastewater treatment plant 2014</td><td>0.69%</td></tr>
<tr><td>C19</td><td>Rate of people served by municipal water service 2014</td><td>0.69%</td></tr>
<tr><td>C20</td><td>Amount of water treated (1000 m3 / yr) 2014</td><td>0.69%</td></tr>
<tr><td>C21</td><td>Total water consumption per capita (lt/day) (ISO 37120: 21.5) 2014</td><td>0.69%</td></tr>
<tr><td>C22</td><td>Sewerage and municipal water access rate 2015</td><td>0.69%</td></tr>
</table>

Energy Usage

The factor of energy usage is composed of 3 indicators. These are; percentage of the renewable energy (C1), percentage of the energy generation over energy consumption (C2) and total residential energy use per capita (C3). It is expected that criterion 1 and criterion 2 should have the higher values, while criterion 3 should have the lower values for the smart energy usage.

Table 12 Energy Usage Data

<table>
<tr><td colspan="7">Ideal Values of Energy Usage</td></tr>
<tr><td></td><td>C1 – (max)</td><td>Value (%)</td><td>C2 – (max)</td><td>Value (%)</td><td>C3– (min)</td><td>Value (kWh/yr)</td></tr>
<tr><td>1</td><td>Edirne</td><td>100</td><td>Artvin</td><td>939</td><td>Ağrı</td><td>532</td></tr>
<tr><td>2</td><td>Kocaeli</td><td>100</td><td>Sakarya</td><td>580</td><td>Hakkari</td><td>624</td></tr>
<tr><td>3</td><td>Afyonkarahisar</td><td>94.2</td><td>Gümüşhane</td><td>556</td><td>Şırnak</td><td>646</td></tr>
<tr><td>4</td><td>Aydın</td><td>79.9</td><td>Kırklareli</td><td>493</td><td>Bingöl</td><td>647</td></tr>
<tr><td>5</td><td>Uşak</td><td>68.7</td><td>Elazığ</td><td>476</td><td>Iğdır</td><td>676</td></tr>
<tr><td colspan="7">Worst Values of Energy Usage</td></tr>
<tr><td></td><td>C1</td><td>Value (%)</td><td>C2</td><td>Value (%)</td><td>C3</td><td>Value (kWh/yr)</td></tr>
<tr><td>81</td><td rowspan="5">25 Provinces are not use renewable energy</td><td rowspan="5">0</td><td>Ağrı</td><td>0</td><td>Çanakkale</td><td>8565</td></tr>
<tr><td>80</td><td>Bitlis</td><td>0.38</td><td>Kocaeli</td><td>7268</td></tr>
<tr><td>79</td><td>Mersin</td><td>1</td><td>Tekirdağ</td><td>6850</td></tr>
<tr><td>78</td><td>Çankırı</td><td>4</td><td>Bilecik</td><td>5862</td></tr>
<tr><td>77</td><td>Bartın</td><td>4</td><td>Kırklareli</td><td>5486</td></tr>
</table>

It is shown the best 5 values of the cities in table 12. According to the table 12, Edirne, Kocaeli, Afyonkarahisar, Aydın and Uşak are the cities that have the highest scores for the use of renewable energy respectively, whereas 25 provinces do not use renewable energy like Ağrı, Çankırı, Batman, Kayseri, and so on. Remarkably, all the energy produced in Edirne and Kocaeli is supplied from renewable energy.

Artvin, Sakarya, Gümüşhane, Kırklareli, and Elazığ are the best cities in terms of percentage of energy generation over energy consumption, yet Ağrı, Bitlis, Mersin Çankırı, and Bartın are the worst cities on the same issue.

Unlike these two criteria, the minimum value of total residential energy use per capita is the best option. Thus, Ağrı, Hakkari, Şırnak, Bingöl, and Iğdır have the best values, as opposed to Çanakkale, Kocaeli, Tekirdağ, Bilecik, and Kırklareli. The values indicate that the top 5 cities consume 1600 times less energy than the least 5 cities (see table 12).

<u>Pollution</u>

One of the main environmental aspects of smart cities is pollution element. The element consists of 6 main indicators. No doubt, smart cities must eliminate air pollution, pollution in physical environment, noise pollution, and must produce less solid waste. Total collected municipal solid waste per capita (in kg) (C4), amount of particulate matter 10 concentration (C5), amount of nitrogen dioxide (NO_2) concentration (C6), amount of sulphur dioxide (SO_2) concentration (C7), water pollution priority ranking (C8), and noise pollution rate (C9) are the main components of the pollution element. In pollution element, criteria 4, 5, 6, 7, and 9 are assumed to have lower values, whereas criterion 8 should have higher values for the smartness matter.

Table 13 Pollution Data

Optimum Values of Pollution												
	C4 - (min)	Vl (kg)	C5 - (min)	Vl (µg /m^3)	C6 - (min)	Vl(µg / m^3)	C7- (min)	Vl(µg / m^3).	C8 - (max)	Vl (rank)	C9- (min)	Vl (%)
1	Trabzon	0.67	There are 11 cities whose PM10 values is the best	0	There are 61 cities whose NO2 conc. values is the best	0	There are 12 cities whose SO2 conc. values is the best	0	Karaman	5	Kütahya	6.36
2	Hakkari	0.72							Iğdır	5	Afyonka.	6.48
3	Hatay	0.72							Antalya	5	Uşak	6.89
4	Bitlis	0.78							Ankara	5	Niğde	7.14
5	Ordu	0.8							Sivas	5	Ardahan	8.15
Worst Values of Pollution												
	C4	Vl (kg)	C5	Vl(µg / m^3)	C6	Vl(µg / m^3)	C7	Vl(µg / m^3).	C8	Vl (rank)	C9	Vl (%)
81	Edirne	1.81	Iğdır	106	Giresun	54	Edirne	99	There are 31 cities having water pollution problem	1	İstanbul	33.75
80	Muğla	1.73	Düzce	92	Ankara	43.75	Yozgat	35			Antalya	28.65
79	Kastamonu	1.72	Siirt	91	Amasya	41.75	Tekirdağ	30			İzmir	26.99
78	Ardahan	1.68	Erzincan	84	Çorum	34.33	Çanakkale	23			Ankara	26.98
77	Bolu	1.67	Afyon-karahisa.	82	Tokat	33.75	Afyon-karahisar	20			Diyarbakır	26.63

To table 13, Trabzon, Hakkari, Hatay, Bitlis and Ordu are the least solid waste producing cities, while the most solid waste producing cities are Edirne, Muğla, Kastamonu, Ardahan, and Bolu.

Air quality measurements indicate that PM10, NO_2, SO_2 concentrations are not a problem for 11, 61 and 12 cities respectively. However, 5 cities that are suffered from PM10 concentration are Iğdır, Düzce, Siirt, Erzincan and Afyonkarahisar. Likewise, Giresun, Ankara, Amasya, Çorum and Tokat have NO_2 concentration problems as seen the cities that take the highest values. The result of SO_2 concentration of Edirne is remarkable that it is reaching 99 $\mu g/m^3$ as the highest value. In addition to this, water pollution is a major problem for 5 cities in Turkey, while 31 of them have a priority for water pollution. Finally, 15 cities in Turkey have less than 10% of noise pollution, whereas 9 of them have 25% and above noise pollution (see table 13).

Sustainability

Sustainability factor, as one of the factors of environmental aspect, composed of 7 main criteria, which are the number of sustainability certified buildings (C10), built environment per person (C11), people density (C12), municipal environmental expenditures per person (C13), green area per capita (C14), satisfaction rate with green strategies of the municipalities (C15), and forest area per km^2 (C16).

Table 14 Sustainability Data

Optimum Values of Sustainability														
	C10 - (max)	Vl (#)	C11 - (min)	Vl (m^2)	C12- (max)	Vl (p/ha)	C13- (max)	Vl (TL)	C14- (max)	Vl (m^3)	C15- (max)	Vl (%)	C16- (max)	Vl (%)
1	İstanbul	262	Rize	54	Rize	187	Bayburt	427	Kastamonu	398	Kastamonu	90	Karabük	70
2	Kocaeli	19	Trabzon	58	Trabzon	172	Kocaeli	376	Artvin	343	Manisa	86	Zonguldak	69
3	Ankara	14	Giresun	63	Giresun	160	Muğla	368	Bolu	324	Isparta	84	Kastamonu	68
4	İzmir	13	Hakkari	78	Hakkari	129	Bursa	361	Sinop	261	Bolu	82	Muğla	66
5	Antalya	8	İstanbul	82	İstanbul	122	Antalya	338	Karabük	212	Sinop	81	Sinop	62
Worst Values of Sustainability														
	C10	Vl (#)	C11	Vl (m^2)	C12	Vl (p/ha)	C13	Vl (TL)	C14	Vl (m^3)	C15	Vl (%)	C16	Vl (%)
81	There are any sustainable certified building in 54 cities	0	Ardahan	564	Ardahan	18	Şırnak	22	Iğdır	0.00	Kilis	28	Iğdır	0
80			Kırşehir	523	Kırşehir	19	Bingöl	30	Ağrı	0.02	Muş	32	Şanlıurfa	0.47
79			Aksaray	500	Aksaray	20	Muş	33	Şanlıurfa	0.03	Siirt	34	Ağrı	0.53
78			Yozgat	433	Yozgat	23	Iğdır	54	Aksaray	0.14	Hakkari	34	Nevşehir	1.29
77			Kars	416	Kars	24	Erzincan	55	Nevşehir	0.16	Batman	36	Van	1.35

In the sustainable factor, all criteria should take higher values except criterion 11 (C11). Unsurprisingly, İstanbul has the best score in terms of the number of sustainable certified buildings as 262, whereas 54 cities of Turkey do not have any sustainable certified buildings (see table 14). Besides, built environment per person is 564 m^2 in Ardahan, which means the most sprawled city in Turkey; however, in Rize, the area is only 54 m^2, which is the most compact city in Turkey. Trabzon, Giresun, Hakkari, and İstanbul are the other compact cities in Turkey with 58, 63, 78, and 82 m^2 respectively. Likewise, in human density, the result is exactly similar. The most densely populated city is Rize with 187 p/ha in built environment, while Ardahan is 18 p/ha. In addition, municipal environmental expenditure per person shows that Bayburt is surprisingly attracts the attention with 427 Tl per person. Yet, the municipality that allocates the least fund for environmental expenditure from the budget is Şırnak.

The city having the largest forest area per person is Kastamonu with 398 m^3 per person, while Iğdır has not any forest wealth surprisingly. Likewise, satisfaction rate of the municipality's green strategies in Kastamonu is about 90%, yet green area satisfaction rate in Kilis is 28%. The forest area per km^2 is 70% in Karabük, that is followed by Zonguldak, Kastamonu, Muğla, and Sinop with 69%, 68%, 66%, and 62% respectively, whereas the forest area per km^2 in Iğdır is about 0, followed by Şanlıurfa, Ağrı, Nevşehir, and Van with the number of 0.47%, 0.53%, 1.29%, and 1.35% respectively (see table 14).

Water Usage

Water Usage factor has six different indicators. These indicators are; amount of discharged daily wastewater per person (C17), percentage of people served by the wastewater treatment plant (C18), rate of people served by municipal water service (C19), amount of water treated (C20), total water consumption per capita (C21), and sewerage and municipal water access rate (C22).

Water usage element represents the water accessibility and water usage rates of the cities in general. It is expected that the rate of water usage (C21) should has least values, whereas the rate of water accessibility should has highest values (C22).

Table 15 Water Usage Data

Optimum Values of Water Usage												
	C17 - (max)	Vl (l/p)	C18- (max)	Vl(%)	C19- (max)	Vl(%)	C20- (max)	Vl (m^3)	C21 - (min)	Vl (l)	C22- (max)	Vl (%)
1	Yalova	398	Kocaeli	98	9 cities serve 100% of drinking water network.	100	İstanbul	951497	Hakkari	119	İstanbul	100
2	Muğla	361	İstanbul	98			Ankara	380075	Diyarbakır	125	Erzurum	100
3	Düzce	322	Gaziantep	94			İzmir	201707	Bursa	125	Bursa	100
4	Bolu	306	Ankara	93			Adana	137836	Aksaray	135	Kocaeli	99
5	Sakarya	239	İzmir	93			Kocaeli	137548	Kilis	138	Ankara	97
Worst Values of Water Usage												
	C17	Vl (l/p)	C18	Vl %)	C19	Vl(%)	C20	Vl (m^3)	C21	Vl (l)	C22	Vl (%)
81	Şırnak	70	None of the population can benefit from the wastewater treatment plant in 15 cities.	0	Ardahan	36	24 cities have not waste water treatment plant	0	Bitlis	427	Ardahan	31
80	Iğdır	71			Kars	45			Ardahan	422	Hakkari	36
79	Aksaray	77			Bartın	46			Kars	414	Muş	42
78	Mardin	77			Muş	51			Yalova	381	Kars	42
77	Çankırı	79			Iğdır	52			Muğla	347	Iğdır	46

In table 15, it is easily noticed that the amount of discharged daily wastewater per person in Yalova, Muğla, Düzce, Bolu, and Sakarya is 398, 361, 322, 306 and 239 lt per person respectively. However, in Şırnak, Iğdır, Aksaray, Mardin and Çankırı, this number is decreased 70, 71, 77, 77 and 79 lt per person respectively. Additionally, the rate of population that is served wastewater treatment plant is 98% in Kocaeli and İstanbul; however, in 15 cities, none of the population can benefit from the wastewater treatment plant. Moreover, the rate of people served by municipal water service is 100% in 9 Turkish cities, whereas the rate is only 36% in Ardahan.

The amount of water treated in İstanbul in a day is 951497 liters, but 24 cities do surprisingly not have wastewater treatment systems. Besides, minimum water is consumed in Hakkari with 119 liters per person, yet it is Bitlis, the city has the higher amount of water consumption per person with 427 liters. Finally, İstanbul, Erzurum and Bursa have the highest accessibility rate of sewerage and municipal water with 100%, while Ardahan has the lowest accessibility rate of sewerage and municipal water with only 31%.

4.1.2 Evaluation of Smart Environment

Smart environment has totally 4 factors and 22 indicators. In the light of these factors and indicators, smart environments are ranked with 4 different MCDA methods separately; GRA, TOPSIS, SAW and PROMETHEE (see Appendix A for calculations).

Table 16 Ranking of Smart Environment according to GRA, TOPSIS, SAW, and PROMETHEE methods

Cities	GRA	TOPSIS	SAW	PRO.	Cities	GRA	TOPSIS	SAW	PRO.
Adana	7	3	5	6	Kahramanmaraş	45	68	51	71
Adıyaman	55	75	69	76	Karabük	44	56	28	34
Afyonkarahisar	17	7	10	8	Karaman	40	69	47	49
Ağrı	51	22	77	60	Kars	71	41	81	73
Aksaray	62	38	70	55	Kastamonu	12	27	31	50
Amasya	77	57	62	56	Kayseri	27	72	50	61
Ankara	11	14	8	11	Kırıkkale	38	26	45	36
Antalya	9	46	11	17	Kırklareli	67	6	16	9
Ardahan	78	23	74	45	Kırşehir	70	76	73	62
Artvin	4	2	9	5	Kilis	34	17	23	14
Aydın	5	10	6	7	Kocaeli	3	4	2	2
Balıkesir	26	9	4	3	Konya	35	44	21	21
Bartın	69	81	76	79	Kütahya	15	40	36	30
Batman	50	48	57	58	Malatya	8	20	20	32
Bayburt	48	45	67	70	Manisa	14	66	37	68
Bilecik	76	49	48	46	Mardin	41	37	64	47
Bingöl	47	16	39	19	Mersin	29	64	41	59
Bitlis	33	13	44	31	Muğla	36	29	19	18
Bolu	16	42	35	48	Muş	53	55	80	77
Burdur	65	65	55	35	Nevşehir	73	78	75	64
Bursa	23	52	12	27	Niğde	58	25	56	29
Çanakkale	81	21	32	15	Ordu	42	63	42	72
Çankırı	75	80	79	80	Osmaniye	72	73	58	51
Çorum	74	74	60	63	Rize	13	33	25	25
Denizli	21	58	18	41	Sakarya	31	8	7	13
Diyarbakır	6	31	15	40	Samsun	63	35	34	39
Düzce	61	77	61	57	Siirt	52	53	49	52
Edirne	66	5	30	10	Sinop	56	19	27	23
Elazığ	37	18	59	42	Sivas	57	39	33	16
Erzincan	68	54	68	53	Şanlıurfa	30	71	71	81
Erzurum	20	60	53	75	Şırnak	19	28	52	67
Eskişehir	2	51	13	20	Tekirdağ	80	67	66	69
Gaziantep	28	61	38	44	Tokat	49	43	17	24
Giresun	60	30	26	22	Trabzon	18	47	24	33
Gümüşhane	39	11	29	26	Tunceli	43	34	43	37
Hakkari	10	24	54	66	Uşak	32	15	14	12
Hatay	54	70	63	65	Van	24	59	65	74
Iğdır	64	36	72	54	Yalova	25	12	3	4
Isparta	46	62	40	43	Yozgat	79	79	78	78
İstanbul	1	1	1	1	Zonguldak	59	32	46	38
İzmir	22	50	22	28					

As seen in table 16 and figure 15, İstanbul has the highest scores in 4 different MCDA methods separately, thus the city has the smartest environment among 81 provinces in Turkey. In order to calculate smartness score of the cities, it is considered that each factor has the same weights, and the criteria that constitute factors are similarly the same weights.

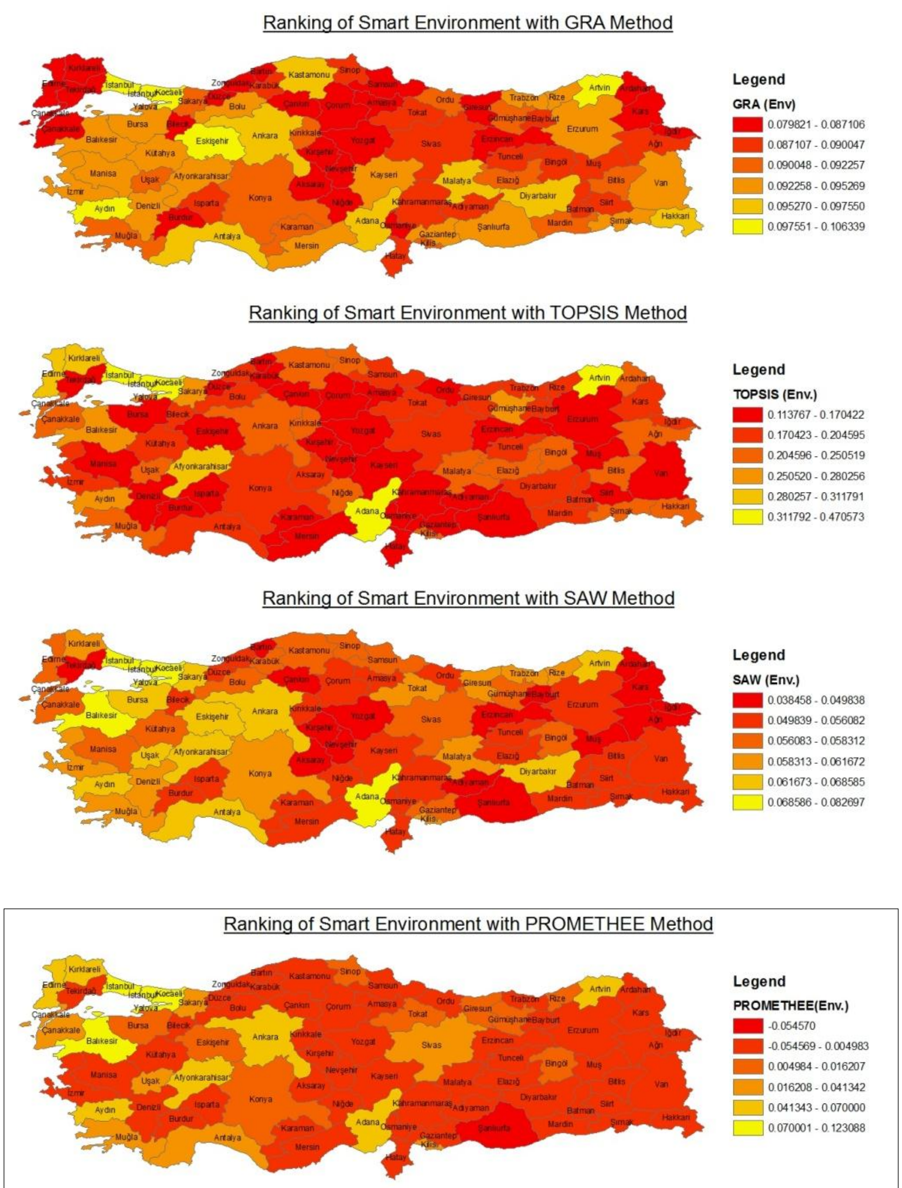


Figure 15 Ranking of Smarter Environment in Turkish Cities with GRA, TOPSIS, SAW, and PROMETHEE Methods

It is clearly understood in the maps that İstanbul and its surroundings raise to the prominence in smarter environment by taking the highest score. However, cities with lowest scores a bit complicated. In fact, although aggregation of less smarter cities can be noticed as central and east regions of Turkey, it should be decided to choose one of the ranking methods that are used in the thesis. Hence, Spearman's correlation test is used to define the relationship between MCDA methods in smart environments.

According to Spearman's correlation coefficients, it is indicated that the methods have positive correlations. Actually, except from correlation coefficient 4 to 1 which is 0.391, all methods have strong positive correlation. The table shows that the most preferable method that has the highest Spearman rank correlation coefficient (see Appendix A) is PROMETHEE method. SAW, GRA, and TOPSIS are the other preferable methods respectively for smart environment, after PROMETHEE (see table 17).

Table 17 Spearman's Ranking Correlation Coefficient for Smart Environment

			ENV_GRA	ENV_TOPSIS	ENV_SAW	ENV_PROMETHEE
Spearman's rho	ENV_GRA	Correlation Coefficient	1,000	,390**	,662**	,391**
		Sig. (2-tailed)	.	,000	,000	,000
		N	81	81	81	81
	ENV_TOPSIS	Correlation Coefficient	,390**	1,000	,613**	,770**
		Sig. (2-tailed)	,000	.	,000	,000
		N	81	81	81	81
	ENV_SAW	Correlation Coefficient	,662**	,613**	1,000	**,861****
		Sig. (2-tailed)	,000	,000	.	,000
		N	81	81	81	81
	ENV_PROMETHEE	Correlation Coefficient	,391**	,770**	,861**	1,000
		Sig. (2-tailed)	,000	,000	,000	.
		N	81	81	81	81
**. Correlation is significant at the 0.01 level (2-tailed).						
1-PROMETHEE, 2-SAW, 3-GRA, 4-TOPSIS						

Therefore, according to PROMETHEE method, İstanbul as having the highest score is followed by Kocaeli, Balıkesir, Yalova, and Artvin. It can be inferred from the maps, these cities are the most careful cities for the environment by taking the cautions with technology. Also these cities are the most respectful cities for nature and natural resources, and the lowest waste and garbage generators. On the contrary, Şanlıurfa, Çankırı, Bartın, Yozgat, and Muş are the least smart cities in Turkey. It can be noticed that managers of these cities are paying less attention to environmental protection and sustainability.

4.1.3 Smart Transportation and Infrastructure

Smart transport and smart infrastructure is stated as one of the smart city attributes in order to assess accessibility, internet usage, technological infrastructure, and transportation performances of smart cities. Indeed, smart city manipulations are focusing on the smart transportation and infrastructure policies and implementations. Especially, many technology firms are solely focusing on smart infrastructure policies. However, in literature, this attribute are handled in a more inclusive way. Because of that, the attribute is investigated in 4 main factors and 12 different indicators (see table 18).

Table 18 Lists of Smart Transportation and Infrastructure Factors and Indicators

TRANSPORTATION & INFRASTRUCTURE	**Accessibility**	**C23**	Airport access rate (%) 2015	1.39%
		C24	Railway per hectare (m) 2015	1.39%
		C25	Availability of High Speed Train 2017	1.39%
	Internet Subscriptions	**C26**	Fixed broadband subscriptions rate (%) 2015	1.04%
		C27	Mobile broadband subscriptions rate (%) 2015	1.04%
		C28	Internet subscribers rate (%) 2015	1.04%
		C29	Mobile phone subscribers rate (%)	1.04%
	Technological Infrastructure	**C30**	The length of fiber cable per person (m)2015	2.08%
		C31	Number of municipal mobile applications 2017	2.08%
	Transportation	**C32**	Number of cars per 1000 inhabitants 2014	1.39%
		C33	Number of traffic accidents per 100,000 people (2014)	1.39%
		C34	Satisfaction rate with public transport services (%) 2015	1.39%

Accessibility

The factor of accessibility is composed of 3 main criteria which are; airport access rate (C23), railway per hectare (m) (C24), and availability of high speed train (C25). According to results, İstanbul has the best accessible rate of airport with 9874.834. Unfortunately, 10 Turkish cities have not easy access of the airport. Besides that, the longest railway per person is in Kastamonu about 94 meters, whereas 23 cities have not any railway in their city border. In addition to this, just 6 cities in Turkey have High-Speed Train stations which are İstanbul, Ankara, Eskişehir, Konya, Bilecik, and Sakarya (see table 19).

Table 19 Accessibility Data

Optimum Values of Accessibility						
	C23 - (max)	Value (%)	C24 - (max)	Value (m)	C25 - (max)	Value (#)
1	İstanbul	9874.834	Kastamonu	94.6924	6 cities has High-Speed Train station	0
2	Adana	7449.762	Bingöl	61.56611		
3	İzmir	3890.321	Sivas	58.66978		
4	Trabzon	3694.167	Çankırı	49.66223		
5	Diyarbakır	3543.684	Karabük	41.67605		
Worst Values of Accessibility						
	C23	Value (%)	C24	Value (m)	C25	Value (#)
81	10 cities has not easy accessibility of airport	0	23 cities has not any railway in their borders	0	75 cities has not any High-Speed Train station	0
80						
79						
78						
77						

Internet Subscriptions

Fixed broadband subscriptions rate (C26), mobile broadband subscriptions rate (C27), internet subscribers rate (C28), mobile phone subscribers rate (C29) are the indicators of internet subscriptions factor. These indicators basically represent the information of internet access and usage rates in the cities.

Table 20 Internet Subscription Data

Optimum Values of Internet Subscription								
	C26 - (max)	Value (%)	C27 - (max)	Value (%)	C28 - (max)	Value (%)	C29 - (max)	Value (%)
1	İstanbul	0.185005	İstanbul	0.684561	Ankara	17.66356	Şanlıurfa	2.588436
2	Ankara	0.18225	Amasya	0.613458	İstanbul	17.62955	Sivas	2.472623
3	İzmir	0.173888	Kilis	0.611588	İzmir	16.50399	Kırıkkale	1.763737
4	Yalova	0.167869	Aksaray	0.569379	Yalova	15.97341	İstanbul	1.321203
5	Eskişehir	0.163745	Ankara	0.538531	Eskişehir	15.54535	Amasya	1.134256
Worst Values of Internet Subscription								
	C26	Value (%)	C27	Value (%)	C28	Value (%)	C29	Value (%)
81	Muş	0.023199	Muş	0.324879	Ağrı	2.163495	Siirt	0.107909
80	Ağrı	0.023636	Van	0.346078	Muş	2.198115	Şırnak	0.501616
79	Şanlıurfa	0.027799	Gümüşhane	0.350091	Van	2.596399	Sinop	0.505533
78	Van	0.028211	Bitlis	0.350334	Şanlıurfa	2.631461	Kırşehir	0.545849
77	Şırnak	0.029536	Diyarbakır	0.353646	Şırnak	2.672578	Muş	0.568165

For example, the rate of fixed broadband subscriptions is the highest in İstanbul, while the lowest in Muş. Similarly, mobile broadband subscriptions rate is also the highest value in İstanbul with nearly 68 percent of population. Yet, the lowest ratio is nearly 32% in Muş. In addition, internet subscriber's rate is about 18% in Ankara as the highest value, but the ratio is about 2% in Ağrı and Muş as the worst values. Also, mobile phone subscriber's rate is the highest in Şanlıurfa, yet it is the worst in Siirt (see table 20).

Technological Infrastructure

Technological infrastructure element consists of 2 major criteria; the length of fiber cable per person (C30) and the number of municipal mobile applications (C31). Unfortunately, data availability has negatively affected the number of technological infrastructure indicators. However, this is not an obstacle in order to evaluation of smartness of transportation and infrastructure.

It is seen in the table 21 that the longest fiber cable per person is in Erzincan with nearly 11 meters. Yet, it is only about 2 meters per person in Hatay and Şanlıurfa as the shortest length. According to the number of municipal mobile applications, Istanbul is the best city with 24 applications, but unfortunately 34 municipalities have not any mobile applications for their citizens.

Table 21 Technological Infrastructure Data

Optimum Values of Technological Infrastructure				
	C30 - (max)	Value (m)	C31 - (max)	Value (#)
1	Erzincan	10.67209	İstanbul	24
2	Tunceli	9.874994	Ankara	9
3	Bayburt	9.853596	İzmir	8
4	Ardahan	9.036418	Konya	8
5	Artvin	8.588228	Bursa	7
Worst Values of Technological Infrastructure				
	C30	Value (m)	C31	Value (#)
81	Hatay	1.776973	34 cities has not any mobile application	0
80	Şanlıurfa	1.804663		
79	Muş	2.135895		
78	İstanbul	2.158904		
77	Gaziantep	2.286426		

Transportation

The numbers of cars per 1000 inhabitants (C32), the number of traffic accidents per 100,000 people (C33), and satisfaction rate with public transport services (C34) are the indicators of transportation factor of transportation and infrastructure characteristic. In the present factor, traffic safety and public transportation satisfaction rate of the cities are going to be discussed. Although minimum values of accident rate and the number of cars are expected, maximum values of public transportation are anticipated as the best values.

Ankara has the best value in car ownership and traffic safety, but Şırnak and Tunceli has the worst values of them respectively. In addition, Karaman and Konya have the highest satisfaction rate of public transportation with about 78%, but Hakkari and Siirt have the least ratio with 23% and 30% respectively (see table 22).

Table 22 Transportation Data

Optimum Values of Transportation						
	C32 - (min)	Value (‰)	C33 - (min)	Value (per 100.000 p)	C34 - (max)	Value (%)
1	Şırnak	7	Tunceli	134	Karaman	78.81
2	Hakkari	8	Bayburt	140	Konya	78.06
3	Ağrı	18	Hakkari	151	Manisa	76.81
4	Muş	19	Kilis	201	Afyonkarahisar	74.24
5	Siirt	20	Iğdır	215	Sakarya	74.15
Worst Values of Transportation						
	C32	Value (‰)	C33	Value (per 100.000 p)	C34	Value (%)
81	Ankara	217	Ankara	33992	Hakkari	23.46
80	Muğla	177	İstanbul	33596	Siirt	30.73
79	Burdur	170	İzmir	19573	Kilis	35.21
78	Antalya	170	Bursa	9462	Muş	35.8
77	Eskişehir	157	Antalya	6552	Adıyaman	36.72

4.1.4 Evaluation of Smart Transportation and Infrastructure

Like in smart environment, in smart transportation and infrastructure, İstanbul is in the first place in all MCDA methods (see Appendices A and B). However, Hatay is the last city in smart transportation and infrastructure (see table 23).

Table 23 Ranking of Smart Transportation and Infrastructure according to GRA, TOPSIS, SAW, and PROMETHEE methods

Cities	GRA	TOPSIS	SAW	PRO.	Cities	GRA	TOPSIS	SAW	PRO.
Adana	42	7	22	7	Kahramanmaraş	80	76	78	35
Adıyaman	79	73	70	72	Karabük	19	21	17	30
Afyonkarahisar	32	69	64	61	Karaman	18	45	36	51
Ağrı	43	43	66	62	Kars	40	51	53	53
Aksaray	72	72	54	74	Kastamonu	11	4	12	11
Amasya	20	59	38	73	Kayseri	45	42	42	31
Ankara	7	2	2	2	Kırıkkale	46	41	25	46
Antalya	53	30	26	43	Kırklareli	14	35	19	63
Ardahan	16	20	15	34	Kırşehir	67	48	37	56
Artvin	10	22	13	47	Kilis	56	39	41	37
Aydın	59	77	65	77	Kocaeli	38	28	34	17
Balıkesir	27	46	43	26	Konya	8	3	10	6
Bartın	30	36	27	50	Kütahya	68	67	52	60
Batman	69	71	79	69	Malatya	47	40	51	23
Bayburt	13	15	7	12	Manisa	36	63	67	32
Bilecik	3	11	4	21	Mardin	64	55	74	54
Bingöl	25	14	23	20	Mersin	63	26	47	19
Bitlis	49	34	63	41	Muğla	34	47	24	57
Bolu	41	52	31	38	Muş	78	37	77	49
Burdur	75	64	49	76	Nevşehir	35	50	35	65
Bursa	33	18	29	18	Niğde	48	68	59	71
Çanakkale	17	33	18	52	Ordu	74	80	72	75
Çankırı	22	19	16	29	Osmaniye	77	61	73	25
Çorum	76	56	62	28	Rize	21	58	40	64
Denizli	58	49	46	27	Sakarya	5	13	14	14
Diyarbakır	65	29	75	40	Samsun	54	66	61	36
Düzce	73	79	60	81	Siirt	66	25	56	33
Edirne	15	16	11	13	Sinop	61	53	39	68
Elazığ	44	24	33	10	Sivas	6	10	6	3
Erzincan	4	17	9	15	Şanlıurfa	23	44	76	45
Erzurum	37	31	32	39	Şırnak	50	8	44	16
Eskişehir	2	9	3	4	Tekirdağ	39	65	48	70
Gaziantep	51	57	71	24	Tokat	60	74	69	59
Giresun	31	62	50	67	Trabzon	24	23	28	22
Gümüşhane	29	27	30	44	Tunceli	9	12	5	8
Hakkari	62	6	21	9	Uşak	52	70	58	66
Hatay	81	81	80	79	Van	57	54	81	55
Iğdır	70	38	55	48	Yalova	12	32	20	42
Isparta	28	60	45	58	Yozgat	71	78	68	78
İstanbul	1	1	1	1	Zonguldak	55	75	57	80
İzmir	26	5	8	5					

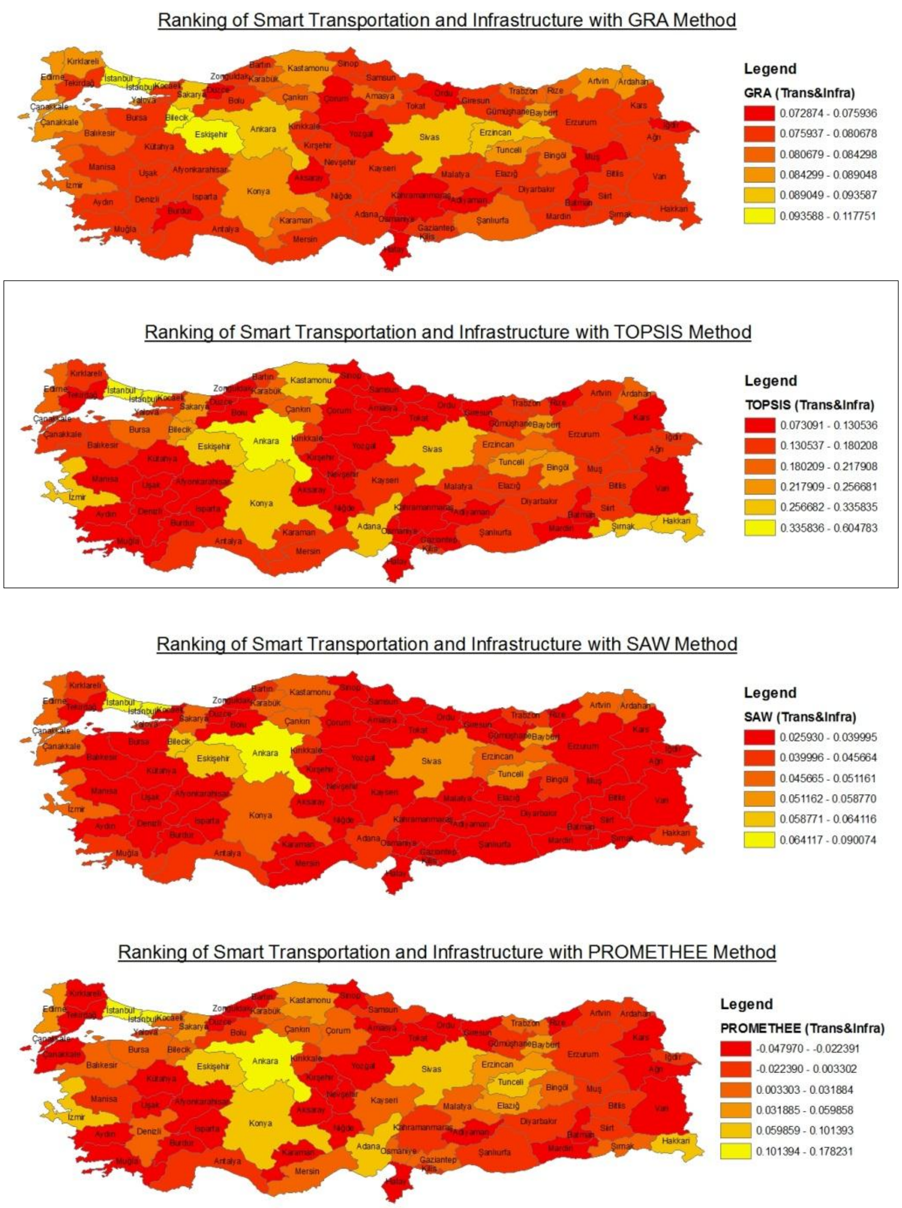


Figure 16 Ranking of Smarter Transportation and Infrastructure in Turkish Cities with GRA, TOPSIS, SAW, and PROMETHEE Methods

The maps clearly indicate that 3 main focal points are come into forefront, which are İstanbul, Ankara, Sivas, and their surroundings. Cities, has smarter transportation and infrastructure policies, are generally focusing on the central Turkey except İstanbul. Accordingly, it is clear that three dominant region of Turkey give the priority of smart transportation and infrastructure whereas the others have the lack of smarter transportation and infrastructure implementations (see figure 16).

However, the methods are also tested with Spearman's rank correlation methods according to the results. In smart transportation and infrastructure, the most preferable method is also TOPSIS method according to Spearman's rho, which is 0,839. The coefficients are indicated that all methods have positive correlation as well. Yet, the preference order of the methods is TOPSIS, PROMETHEE, SAW and GRA respectively (see Appendix A).

Table 24 Spearman's Ranking Correlation Coefficient in Smart Transportation and Infrastructure

Correlations						
			TRAN_GRA	TRA_TOPSIS	TRA_SAW	TRA_PRO.
Spearman's rho	TRANS_INF_GRA	Correlation Coefficient	1,000	,654**	,800**	,494**
		Sig. (2-tailed)	.	,000	,000	,000
		N	81	81	81	81
	TRANS_INF_TOPSIS	Correlation Coefficient	,654**	1,000	,794**	**,839****
		Sig. (2-tailed)	,000	.	,000	,000
		N	81	81	81	81
	TRANS_INF_SAW	Correlation Coefficient	,800**	,794**	1,000	,601**
		Sig. (2-tailed)	,000	,000	.	,000
		N	81	81	81	81
	TRANS_INF_PROMETHEE	Correlation Coefficient	,494**	,839**	,601**	1,000
		Sig. (2-tailed)	,000	,000	,000	.
		N	81	81	81	81
**. Correlation is significant at the 0.01 level (2-tailed).						
1-TOPSIS, 2-PROMETHEE, 3-SAW, 4-GRA						

Hence, the method shows that İstanbul takes the highest score, and it is followed by Ankara and Konya. Yet, Düzce, Ordu, Hatay take the least scores of smart transportation and infrastructure.

4.1.5 Smart Governance

The matter of governance is one of the important characteristics of smart cities due to its participatory decision making process for the city. Smart governance is focusing on 2 main factors and 6 criteria. These are mainly based on participation and -gender-equity. Unfortunately, smart governance criteria are affected negatively on accessibility and shortage of data. Yet, these 6 criteria will sort out smart governance of Turkish cities in general manner.

The factors and indicators of smart governance are listed as following (see table 25);

Table 25 List of Smart Governance Factors and Indicators

GOVERNANCE	Civic Engagement	C35	Civil participation index 2015	2.08%
		C36	Rate of membership to political parties (%) 2015	2.08%
		C37	Voter turnout at local administrations (%) 2015 (ISO 37120: 11.1)	2.08%
		C38	Percentage of persons interested in union/association activities (%) 2015	2.08%
	Representatives & Equity	C39	The number of parliament members per 100.000 people 2014	4.17%
		C40	Female representative ratio 2014	4.17%

Civic Engagement

Civic engagement is composed of 4 main criteria. These criteria are; civil participation index (C35), rate of membership to political parties (C36), voter turnout at local administrations (C37), and percentage of persons interested in union/association activities (C38).

Table 26 Civic Engagement Data

Optimum Values of Civic Engagement								
	C35 - (max)	Value	C36 - (max)	Value (%)	C37 - (max)	Value (%)	C38 - (max)	Value (%)
1	Sakarya	0.796696	Rize	34.72953	Manisa	93.1	Sakarya	22.08
2	Kocaeli	0.651214	Sivas	32.65437	Denizli	92.5	Kocaeli	13.19
3	Sivas	0.617855	Çorum	31.57389	Bilecik	92.4	Artvin	12.32
4	Çorum	0.572123	Tokat	27.89199	Burdur	92.2	Kars	10.35
5	Rize	0.571303	Kilis	27.73339	Afyonkarahisar	92	Tunceli	9.91
Worst Values of Civic Engagement								
	C35	Value	C36	Value (%)	C37	Value (%)	C38	Value (%)
81	Hakkari	0.101715	Hakkari	12.44412	Ağrı	77.1	Manisa	3.54
80	Ağrı	0.143343	Tunceli	14.96583	Hakkari	80.8	Şırnak	3.58
79	Muş	0.177305	Şırnak	15.38073	Van	81.7	Siirt	3.64
78	Van	0.188124	Van	15.99393	Muş	82	Bolu	3.87
77	Diyarbakır	0.20454	Bartın	16.45252	Diyarbakır	82	Gaziantep	3.98

Civil participation index shows that Sakarya has the highest rate regarding civic engagement with 79%, yet the least rate is in Hakkari with 10%. In addition, 34% of the population in Rize is a member of political parties, while the rate is only 12% in Hakkari. Additionally, Manisa experiences turnout rate of about 93% as the highest value, whereas it is experienced 77.1% in Ağrı as the lowest score. The rate of people who interest in union or association activities is the highest in Sakarya with 22 percent, yet the rate is about only 4% in Manisa, Şırnak, Siirt, Bolu, and Gaziantep (see table 26).

<u>Representatives and Equity</u>

Representative and -gender- equity factors are one of the important factors of smart governance. The factors are represented in two criteria, which are the number of parliament members per 100.000 people (C39) and female representative ratio (C40).

In representative rate, Erzincan is the heading city with 103 representatives per 100.000 people; however, in Istanbul, the number is solely 9. This means that while an assemblyman represents 1000 people in Erzincan, he represents 10.000 people in Istanbul. Unfortunately, the ratio of women representatives is very low in our country. The highest rate of women representatives is in Diyarbakır with 28%, but in Niğde, the ratio is just 2 (see table 27).

Table 27 Representatives and Equity Data

Optimum Values of Representatives and Equity				
	C39 - (max)	Value (per 100.000 p)	C40 - (max)	Value (%)
1	Erzincan	103.7414	Diyarbakır	0.283465
2	Tunceli	100.5467	Van	0.242525
3	Gümüşhane	91.55945	Mardin	0.231481
4	Yozgat	86.46199	Tunceli	0.218391
5	Niğde	84.03655	Hakkari	0.216981
Worst Values of Representatives and Equity				
	C39	Value (per 100.000 p)	C40	Value (%)
81	İstanbul	9.702986	Niğde	0.0208
80	Gaziantep	11.48473	Afyonkarahisar	0.0246
79	Ankara	11.5144	Sivas	0.0269
78	Adana	15.09978	Adıyaman	0.0272
77	Bursa	15.24642	Yozgat	0.0294

4.1.6 Evaluation of Smart Governance

In table 28, it is obviously seen that Tunceli has the smartest governance policies among 81 cities of Turkey, whereas Gaziantep takes the least score from smart governance policies.

Table 28 Ranking of Smart Governance according to GRA, TOPSIS, SAW, and PROMETHEE methods

Cities	GRA	TOPSIS	SAW	PRO.	Cities	GRA	TOPSIS	SAW	PRO.
Adana	69	64	69	77	Kahramanmaraş	45	67	59	68
Adıyaman	72	76	71	79	Karabük	20	35	14	33
Afyonkarahisar	8	26	22	18	Karaman	21	46	31	54
Ağrı	81	77	80	62	Kars	75	41	57	36
Aksaray	71	56	70	73	Kastamonu	40	34	28	34
Amasya	48	72	62	59	Kayseri	31	66	50	75
Ankara	33	29	45	58	Kırıkkale	50	63	54	65
Antalya	65	68	75	70	Kırklareli	7	5	5	17
Ardahan	66	45	46	53	Kırşehir	52	53	51	67
Artvin	15	12	6	21	Kilis	41	55	38	46
Aydın	51	39	56	38	Kocaeli	10	27	11	27
Balıkesir	43	48	53	41	Konya	47	75	64	72
Bartın	57	36	42	31	Kütahya	38	58	61	56
Batman	55	16	39	10	Malatya	76	79	76	76
Bayburt	59	37	47	57	Manisa	25	51	65	52
Bilecik	12	32	21	51	Mardin	39	8	27	6
Bingöl	62	47	35	42	Mersin	67	62	74	66
Bitlis	54	42	24	40	Muğla	29	24	25	24
Bolu	49	44	52	32	Muş	79	50	77	47
Burdur	17	31	30	29	Nevşehir	11	15	10	11
Bursa	27	18	36	16	Niğde	6	22	20	14
Çanakkale	22	21	17	23	Ordu	73	71	67	60
Çankırı	9	17	8	13	Osmaniye	64	80	78	80
Çorum	16	65	40	71	Rize	4	10	2	22
Denizli	28	60	58	50	Sakarya	1	13	4	4
Diyarbakır	5	2	13	2	Samsun	60	74	66	64
Düzce	37	43	43	35	Siirt	53	38	37	30
Edirne	44	33	34	26	Sinop	23	7	7	15
Elazığ	77	78	73	69	Sivas	14	59	32	78
Erzincan	3	4	3	3	Şanlıurfa	78	73	79	74
Erzurum	63	57	49	43	Şırnak	35	6	19	9
Eskişehir	58	61	68	55	Tekirdağ	30	25	33	25
Gaziantep	80	81	81	81	Tokat	13	30	12	48
Giresun	56	40	41	45	Trabzon	68	69	63	61
Gümüşhane	19	14	16	8	Tunceli	2	1	1	1
Hakkari	61	9	44	7	Uşak	42	54	55	39
Hatay	70	70	72	63	Van	34	3	23	5
Iğdır	74	52	60	37	Yalova	36	11	9	19
Isparta	46	49	48	49	Yozgat	18	20	18	12
İstanbul	24	23	26	44	Zonguldak	32	28	15	28
İzmir	26	19	29	20					

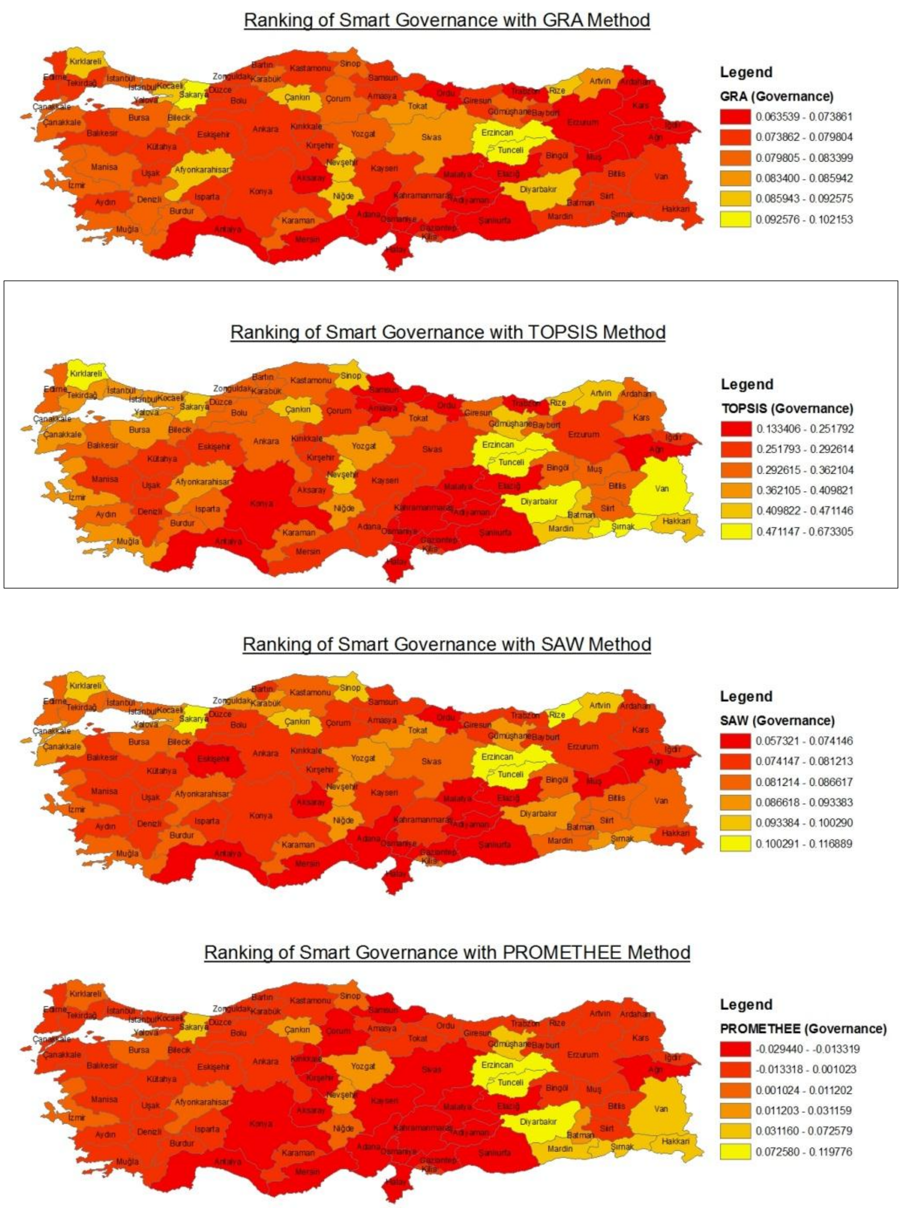


Figure 17 Ranking of Smarter Governance in Turkish Cities with GRA, TOPSIS, SAW, and PROMETHEE Methods

According to figure 17 smarter governance implementations of Turkish cities are mainly focusing on the southeast regions of Turkey. Although the region is the most cosmopolitan and has the most complex problems, the cities in the region have surprisingly highest scores in smart governance among Turkish cities. In order to define the rank of the cities clearly, Spearman’s correlation coefficient helps the study.

Spearman's rho shows that although all methods have positive correlation, the most preferable method is TOPSIS in smart governance with 0,924 (see table 29).

Table 29 Spearman's Ranking Correlation Coefficient in Smart Governance

Correlations						
			GOV_GRA	GOV_TOPSIS	GOV_SAW	GOV_PRO
Spearman's rho	GOVERN_GRA	Correlation Coefficient	1,000	,695**	,849**	,603**
		Sig. (2-tailed)	.	,000	,000	,000
		N	81	81	81	81
	GOVERN_TOPSIS	Correlation Coefficient	,695**	1,000	,879**	**,924****
		Sig. (2-tailed)	,000	.	,000	,000
		N	81	81	81	81
	GOVERN_SAW	Correlation Coefficient	,849**	,879**	1,000	,795**
		Sig. (2-tailed)	,000	,000	.	,000
		N	81	81	81	81
	GOVERN_PROMETHEE	Correlation Coefficient	,603**	,924**	,795**	1,000
		Sig. (2-tailed)	,000	,000	,000	.
		N	81	81	81	81
**. Correlation is significant at the 0.01 level (2-tailed).						
1-TOPSIS, 2-PROMETHEE, 3-SAW, 4-GRA						

According to TOPSIS ranking method, Tunceli and Diyarbakır come into prominence as the cities that have the smartest governance practice among Turkish cities. Table 29 shows that these cities are the most equal, participant and conscious cities in Turkey. However, Malatya, Osmaniye, and Gaziantep are the least conscious cities concerning equality and civic participation.

4.1.7 Smart Economy

Smart economy represents the intersection of economy and smart cities. The characteristic has 4 major factors and 14 criteria in order to evaluate and rank Turkish smart cities. The major factors of smart economies are entrepreneurship and business, innovation, local and global connections, and productivity of cities. The main purpose of the smart economy is to base economies of the cities mainly on technology and innovation without depletion of natural resources. Accordingly, employment conditions in industries, the number of HQ, the number of entrepreneurs, technology development areas such as technopoles and R&D, innovation index, the number of patent applications, smart connection decision (with airlines), GDP, and the ratio of export represent smart economies in order to observe smartness performance of Turkish cities economically (see table 30).

Table 30 Lists of Smart Economy Factors and Indicators

ECONOMY	Entrepreneurship & Business	C41	Percentage of engineers employed in the industry 2013	0.83%
		C42	Number of companies (HQ) in the city 2015	0.83%
		C43	Unemployment rate 2015	0.83%
		C44	Employment rate 2015	0.83%
		C45	Number of entrepreneurs(with Techno Capital Support) 2013	0.83%
	Innovation	C46	Number of companies with R & D unit 2013	0.83%
		C47	Number of R & D centers 2013	0.83%
		C48	Number of technopoles in the city 2013	0.83%
		C49	Innovative City Index 2015	0.83%
		C50	Patent application 2015	0.83%
	Local and Global Connections	C51	Number of airline passengers per person 2015	2.08%
		C52	Air freight carrying amount per person (kg) 2015	2.08%
	Productivity	C53	GDP per capita 2014	2.08%
		C54	Export / Import (tl) 2017	2.08%

Entrepreneurship & Business

Percentage of engineers employed in the industry (41), the number of companies (HQ) in the city (C42), unemployment rate (C43), employment rate (C44), and the number of entrepreneurs with techno capital support (C45) are the 5 major indicators of entrepreneurship and business factor (see table 31). Although unemployment rate is anticipated the lower values as the best value, the others are expected to be higher values.

According to table 31, Ankara, Ardahan, and Kocaeli have the highest rate of engineer employment with 8% while Sinop and Uşak have the lowest rate with 1%. 7 cities have missing data for criteria 41. In addition to this, İstanbul has 181 companies out of first 500 companies, while 32 cities have not any firms in first 500 companies in Turkey. Moreover, Karaman has the lowest value in unemployment rate with 4.2%. Ardahan has also the best in employment rate with 59.1%. However, Batman is the city that has not only the highest rate of unemployment rate, but also has the lowest rate of employment with 23.4% and 27.8% respectively. Additionally, the highest value in technological entrepreneurship belongs to Ankara with 472 people, whereas 45 cities have unfortunately not any attempts (see table 31).

Table 31 Entrepreneurship and Business Data

Optimum Values of Entrepreneurship and Business										
	C41- (max)	Vl (%)	C42 - (max)	Vl (#)	C43- (min)	Vl (%)	C44 - (max)	Vl (%)	C45-(max)	Vl (#)
1	Ankara	0.08	İstanbul	181	Karaman	4.2	Ardahan	59.1	Ankara	472
2	Ardahan	0.08	İzmir	38	Konya	4.7	Kars	55.5	İstanbul	228
3	Kocaeli	0.08	Kocaeli	32	Manisa	5.1	Burdur	54.9	Konya	45
4	Yalova	0.06	Bursa	29	Uşak	5.4	Bartın	54.9	İzmir	43
5	Eskişehir	0.05	Ankara	27	Afyonkarahisar	5.6	Iğdır	54.5	Kayseri	30
Worst Values of Entrepreneurship and Business										
	C41	Vl	C42	Vl	C43	Vl	C44	Vl	C45	Vl
81	Sinop	0.01	32 cities has not any firms in first 500	0	Batman	23.4	Batman	27.8	45 cities has not any technological entrepreneurs	0
80	Uşak	0.01			Mardin	20.6	Mardin	29.7		
79	Ağrı	0.02			Siirt	20.5	Siirt	29.8		
78	Bartın	0.02			Şırnak	20.1	Şırnak	30		
77	Burdur	0.02			Diyarbakır	18.7	Diyarbakır	30.2		

Innovation

Innovation factor consists of 5 main indicators; the number of companies with R & D unit (C46), the number of R & D centers (C47), the number of technopoles in the city (C48), innovative city index (C49), and patent application number (C50).

Table 32 Innovation Data

Optimum Values of Innovation										
	C46 - (max)	Value (#)	C47- (max)	Value (#)	C48- (max)	Value (#)	C49- (max)	Value	C50- (max)	Value (#)
1	İstanbul	1462	İstanbul	45	Ankara	7	İstanbul	24.01	İstanbul	2399
2	Ankara	471	Bursa	28	İstanbul	5	Ankara	14.03	Ankara	636
3	İzmir	434	Kocaeli	21	Kocaeli	4	Kocaeli	7.93	Bursa	440
4	Bursa	319	Ankara	18	İzmir	3	İzmir	6.93	İzmir	289
5	Kocaeli	318	İzmir	13	Şanlıurfa	1	Bursa	6.73	Kocaeli	209
Worst Values of Innovation										
	C46	Value (#)	C47	Value (#)	C48	Value (#)	C49	Value	C50	Value (#)
81	Hakkari	1	57 cities has not any R&D center	0	41 cities has not any Technopoles	0	Muş	-4.27	Muş	0
80	Nevşehir	1					Bitlis	-3.81	Ardahan	0
79	Ardahan	1					Ağrı	-3.73	Iğdır	0
78	Bayburt	2					Şanlıurfa	-3.2	Sinop	0
77	Iğdır	2					Ardahan	-3.15	Kars	1

It is clearly noticed in the table 32 that İstanbul and Ankara dominate the highest scores. Istanbul has the highest numbers in C46, C47, C49, and C50 with 1462, 45, 24.01 and 2399 respectively, whereas Ankara has the highest number of technopoles (C48) with 7. Unfortunately, 57 cities have not any R&D center; likewise, 47 cities have not any technopoles (see table 32).

Local and Global Connections

Number of airline passengers per capita (C51) and air freight carrying amount per capita (C52) are the two basic components of the local and global connection factor. The factor actually implies the airline usage.

Table 33 Local and Global Connection Data

Optimum Values of Local & Global Connection				
	C51 - (max)	Value (p)	C52 - (max)	Value (kg)
1	Antalya	12.53396	Antalya	156.7039
2	Muğla	9.08809	İstanbul	142.1895
3	İstanbul	6.102082	Muğla	105.2764
4	Trabzon	4.376268	Trabzon	40.06939
5	İzmir	2.921518	İzmir	32.29429
Worst Values of Local & Global Connection				
	C51	Value (p)	C52	Value (kg)
81	33cities have not any air passengers.	0	33 cities has not any air fright carryings	0
80				
79				
78				
77				

According to the table 33, airline usage per capita in a year is about 13 times per people, and the amount of air freight carrying per person is about 157 kg in Antalya. However, 33 cities do not use airlines not only for transportation needs but also their freight carrying needs, which mean they prefer traditional methods for their transportation needs.

Productivity

Productivity factor is represented by two main criteria in this study; one is GDP per capita (C53) and the other is import coverage ratio (export/import) (C54). According to the table 34, İstanbul is the first city with 43.316 Tl per person, while Ağrı is the last city with 8.499 TL per person. Moreover, import coverage ratio is surprisingly the highest in Rize with 33%, but the ratio is 0 in Bayburt, which means that Bayburt do not need to send any production to the abroad.

Table 34 Productivity Data

Optimum Values of Productivity				
	C53 - (max)	Value	C54 - (max)	Value
1	İstanbul	43316.47	Rize	33.50277
2	Kocaeli	42932.03	Trabzon	16.82385
3	Ankara	36305.79	Giresun	11.79583
4	Tekirdağ	32667.23	Mardin	10.66951
5	Bilecik	32521.48	Şırnak	8.121634
Worst Values of Productivity				
	C53	Value	C54	Value
81	Ağrı	8499.151	Bayburt	0
80	Şanlıurfa	9657.487	Kars	0.087157
79	Van	9842.935	Zonguldak	0.120355
78	Hakkari	11591.1	Erzurum	0.143925
77	Batman	11688.07	Tunceli	0.173634

4.1.8 Evaluation of Smart Economy

Smart economies of Turkey are calculated according to four major factors and 14 main criteria. The calculation and ranking process indicate that İstanbul is the first and Antalya is the second city in smart economy according to the results of all methods (see table 35). Siirt is unfortunately has the least smart economy to all methods. The results of four methods are transferred Turkey map in order to observe regions that have smarter economies of Turkey (see Appendix A).

Table 35 Ranking of Smart Economy according to GRA, TOPSIS, SAW, and PROMETHEE methods

Cities	GRA	TOPSIS	SAW	PRO.	Cities	GRA	TOPSIS	SAW	PRO.
Adana	52	12	12	10	Kahramanmaraş	72	71	69	59
Adıyaman	69	66	70	55	Karabük	45	58	45	61
Afyonkarahisar	33	33	73	70	Karaman	16	31	26	58
Ağrı	61	79	74	79	Kars	31	44	50	43
Aksaray	43	53	41	47	Kastamonu	56	65	54	73
Amasya	46	54	43	44	Kayseri	42	16	16	14
Ankara	3	5	3	3	Kırıkkale	54	43	38	33
Antalya	2	2	2	2	Kırklareli	21	34	28	46
Ardahan	7	17	23	18	Kırşehir	63	63	58	67
Artvin	41	48	39	48	Kilis	66	60	61	45
Aydın	38	41	40	39	Kocaeli	4	8	5	5
Balıkesir	28	38	27	32	Konya	17	22	11	17
Bartın	35	70	56	78	Kütahya	22	27	22	23
Batman	80	78	79	56	Malatya	48	40	35	26
Bayburt	58	73	65	75	Manisa	13	37	53	52
Bilecik	12	24	14	50	Mardin	75	11	60	19
Bingöl	57	72	64	65	Mersin	65	46	46	37
Bitlis	73	77	76	68	Muğla	5	4	4	4
Bolu	18	29	25	41	Muş	71	62	71	38
Burdur	20	47	33	62	Nevşehir	37	28	30	35
Bursa	8	9	9	9	Niğde	51	59	47	49
Çanakkale	25	39	59	64	Ordu	55	45	51	54
Çankırı	60	67	57	71	Osmaniye	79	80	78	77
Çorum	49	61	48	63	Rize	6	3	8	8
Denizli	14	30	15	34	Sakarya	24	23	19	22
Diyarbakır	76	35	63	20	Samsun	26	26	20	16
Düzce	30	42	34	42	Siirt	81	81	81	81
Edirne	34	50	36	53	Sinop	62	69	62	74
Elazığ	27	15	13	11	Sivas	47	13	18	12
Erzincan	23	25	24	27	Şanlıurfa	78	49	72	30
Erzurum	50	36	37	31	Şırnak	77	14	66	21
Eskişehir	15	18	10	15	Tekirdağ	11	20	31	40
Gaziantep	36	19	17	13	Tokat	59	64	55	51
Giresun	40	10	32	24	Trabzon	9	6	7	6
Gümüşhane	64	76	80	80	Tunceli	32	57	42	57
Hakkari	74	75	77	66	Uşak	29	56	44	76
Hatay	68	52	49	28	Van	70	55	67	36
Iğdır	44	51	75	60	Yalova	19	21	21	29
Isparta	39	32	29	25	Yozgat	67	74	68	72
İstanbul	1	1	1	1	Zonguldak	53	68	52	69
İzmir	10	7	6	7					

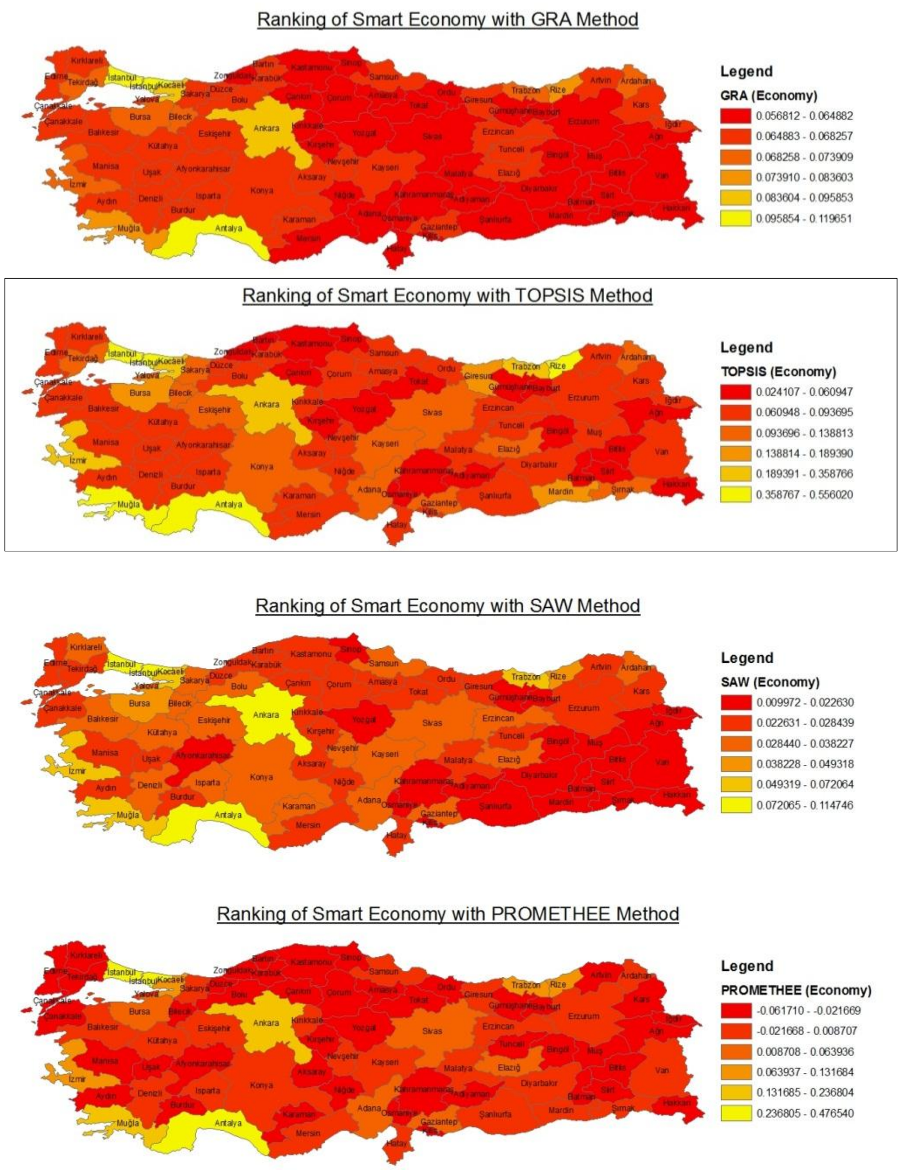


Figure 18 Ranking of Smart Economy in Turkish Cities with GRA, TOPSIS, SAW, and PROMETHEE Methods

The maps in the figure 18 show that smarter economies of Turkey are mainly focusing on the coastal cities of Mediterranean and Aegean regions except İstanbul and Ankara. Trabzon and Rize might also be included the group as having smarter economies. The cities with least smart economy are mainly focusing on the east part of Turkey (see figure 18), but due to the complexity of ranking of them, Spearman's rank correlation coefficient will also help the ranking of smart economies of Turkish cities (see table 36).

Table 36 Spearman's Ranking Correlation Coefficient in Smart Economy

			ECON_GRA	ECON_TOPSIS	ECON_SAW	ECON_PRO.
Spearman's rho	ECON_GRA	Correlation Coefficient	1,000	,718**	,841**	,500**
		Sig. (2-tailed)	.	,000	,000	,000
		N	81	81	81	81
	ECON_TOPSIS	Correlation Coefficient	,718**	1,000	,844**	**,885****
		Sig. (2-tailed)	,000	.	,000	,000
		N	81	81	81	81
	ECON_SAW	Correlation Coefficient	,841**	,844**	1,000	,773**
		Sig. (2-tailed)	,000	,000	.	,000
		N	81	81	81	81
	ECON_PROMETHEE	Correlation Coefficient	,500**	,885**	,773**	1,000
		Sig. (2-tailed)	,000	,000	,000	.
		N	81	81	81	81
**. Correlation is significant at the 0.01 level (2-tailed).						
1-TOPSIS, 2-PROMETHEE, 3-SAW, 4-GRA						

According to the Spearman's rho, as the other characteristics above, all methods have positive correlations. In fact, the correlation coefficients show that these methods have strong correlations. But, the preference order of methods is TOPSIS, PROMETHEE, SAW, and GRA respectively (see Appendix A).

According to TOPSIS method, Rize, Muğla and Ankara take the 3rd, 4th and 5th order respectively after İstanbul and Antalya. Therefore, it can clearly be understood that these are the cities that give the most priority of smarter economies by investing in innovation, entrepreneurship, airlines, and so on. However, Osmaniye and Ağrı take the least score respectively, after Siirt. These three are the cities that do hardly make an effort for smart economy (see Appendix B).

4.1.9 Smart People

Smart people attribute is one of the most important subjects of smart cities. Actually, discussions and debate are mainly focused on the matter of people. Most of the technology developers, governments, and local managers ignore the human factor of smart cities. Human capital as users and producers of Information and Communication Technology is an integral part of smart cities. Hence, technology itself cannot create smart cities. Thus, it should be the first step of smart cities to implement smart people policies rather than technology alone.

Smart People attribute consists of 2 main factors and 6 indicators. The brain power aim is to evaluate the performance of creativity of people. Also, the purpose of education is to evaluate educational condition of a city. The mix of these 2 factors will create smart people (see table 37).

Table 37 Lists of Smart People Factors and Indicators

PEOPLE	**Brain Power**	**C55**	Number of academic staff per 100.000 people -2016	4.17%
		C56	Working in creative industries	4.17%
	Education	**C57**	Percentage of BSc graduates 2015 (* 1000) (ISO 37120: 6.3)	2.08%
		C58	Percentage of MSc graduates 2015 (* 1000) (ISO 37120: 6.7)	2.08%
		C59	Percentage of PhD graduates 2015 (* 1000)	2.08%
		C60	Percentage of students in university 2015 (* 1000)	2.08%

Brain Power

Brain power is one of the most important factors of smart people. The number of academic staff per 100.000 people (C55), and working in creative industries (C56) are the two main determinants of brain power.

Table 38 Brain Power Data

Optimum Values of Brain Power				
	C55 - (max)	Value (per 100.000 p)	C56 - (max)	Value
1	Kırıkkale	911.9052	Ankara	1.7448
2	Sivas	837.5593	İstanbul	1.6406
3	Isparta	516.0019	Kocaeli	1.1199
4	Tunceli	478.1429	İzmir	1.0495
5	Bolu	424.8139	Kars	0.9529
Worst Values of Brain Power				
	C55	Value (per 100.000 p)	C56	Value
81	Siirt	24.7858	Kilis	0.294
80	Şırnak	39.59924	Bolu	0.3287
79	Mardin	53.12489	Giresun	0.3473
78	Batman	69.85625	Uşak	0.3653
77	Ağrı	70.07773	Osmaniye	0.3807

The number of academic staff is the highest value in Kırıkkale with 911 academicians per 100.000 people, while Siirt has the least value with 24 academicians. It is expected İstanbul and Ankara should have had the highest number, yet the result differ due to population ratio. However, Ankara and İstanbul have the highest number of people who work in creative industries with 1.74 and 1.64 points respectively. The least is Kilis with nearly 0.3 points (see table 38).

Education

Like brain power, Education factor is also a must for smart people. These two factors can mainly represent and determine smart people. The factor consists of 4 main indicators; percentage of BSc graduates (C57), percentage of MSc graduates (C58), percentage of PhD graduates (C59), and percentage of students in university.

Table 39 indicates that Ankara dominates educational indicators, but Sivas also has the highest number of university students. Every 165 people out of 1000 graduated from undergraduate (BSc), and every 19 people out of 1000 is graduated master of science, and about 8 people out of 1000 is graduated from philosophy of doctorate in Ankara as the highest values. The least of the graduate numbers is Şanlıurfa, Ağrı and Hakkari respectively in C57, C58 and C59.

Table 39 Education Data

Optimum Values of Education								
	C57 - (max)	Value (‰)	C58 - (max)	Value (‰)	C59 - (max)	Value(‰)	C60 - (max)	Value (‰)
1	Ankara	165.7047	Ankara	19.43868	Ankara	5.784189	Sivas	249.3016
2	Tunceli	140.7593	İstanbul	14.08589	Eskişehir	4.44409	Kırıkkale	245.2284
3	Eskişehir	138.3051	Eskişehir	11.75131	Isparta	3.468748	Karabük	183.7489
4	İzmir	137.0686	İzmir	10.52079	İzmir	3.081027	Isparta	166.0286
5	İstanbul	131.0865	Yalova	9.132694	İstanbul	3.000662	Edirne	102.6659
Worst Values of Education								
	C57	Value (‰)	C58	Value (‰)	C59	Value(‰)	C60	Value (‰)
81	Şanlıurfa	43.8002	Ağrı	1.747044	Hakkari	0.301318	Siirt	4.749496
80	Ağrı	45.73381	Şırnak	1.856446	Şırnak	0.324368	Şırnak	5.387751
79	Muş	49.18675	Şanlıurfa	2.055149	Mardin	0.35903	Hakkari	8.849458
78	Van	51.7568	Muş	2.084516	Muş	0.472197	Mardin	9.68807
77	Şırnak	51.9968	Hakkari	2.392611	Ağrı	0.500722	Batman	18.38623

4.1.10 Evaluation of Smart People

Table 40 Ranking of Smart People according to GRA, TOPSIS, SAW, and PROMETHEE methods

Cities	GRA	TOPSIS	SAW	PRO.	Cities	GRA	TOPSIS	SAW	PRO.
Adana	45	55	46	55	Kahramanmaraş	71	74	68	68
Adıyaman	68	71	67	63	Karabük	10	8	11	7
Afyonkarahisar	51	46	49	44	Karaman	57	51	55	49
Ağrı	80	80	80	78	Kars	23	15	22	22
Aksaray	65	57	60	46	Kastamonu	53	54	51	45
Amasya	55	66	58	54	Kayseri	30	33	30	32
Ankara	1	3	1	1	Kırıkkale	2	2	2	2
Antalya	17	29	23	50	Kırklareli	26	31	28	31
Ardahan	36	23	35	28	Kırşehir	35	42	37	41
Artvin	29	30	32	33	Kilis	77	75	75	66
Aydın	40	49	43	47	Kocaeli	12	20	15	20
Balıkesir	44	63	48	58	Konya	24	25	21	25
Bartın	46	32	42	34	Kütahya	41	38	40	23
Batman	73	72	74	76	Malatya	21	24	18	26
Bayburt	28	17	26	16	Manisa	62	65	63	62
Bilecik	37	41	41	40	Mardin	79	78	79	79
Bingöl	58	48	54	51	Mersin	49	62	52	69
Bitlis	78	77	77	74	Muğla	19	34	24	39
Bolu	13	12	14	9	Muş	67	56	70	72
Burdur	22	21	19	19	Nevşehir	50	43	45	42
Bursa	43	60	47	65	Niğde	48	36	44	35
Çanakkale	16	16	16	18	Ordu	64	68	65	71
Çankırı	32	22	29	21	Osmaniye	76	79	78	77
Çorum	66	70	66	64	Rize	27	26	27	27
Denizli	31	37	31	36	Sakarya	33	35	33	29
Diyarbakır	54	45	59	67	Samsun	39	44	39	43
Düzce	34	27	34	30	Siirt	74	69	76	80
Edirne	11	9	10	10	Sinop	59	67	61	56
Elazığ	20	18	17	17	Sivas	3	1	3	3
Erzincan	14	14	13	13	Şanlıurfa	75	59	73	61
Erzurum	15	11	12	11	Şırnak	81	81	81	81
Eskişehir	5	5	6	6	Tekirdağ	47	61	50	57
Gaziantep	72	73	71	70	Tokat	42	40	38	38
Giresun	56	58	57	52	Trabzon	9	10	8	14
Gümüşhane	25	19	25	15	Tunceli	8	7	9	8
Hakkari	69	64	72	75	Uşak	52	52	53	48
Hatay	70	76	69	73	Van	63	47	64	59
Iğdır	61	53	62	60	Yalova	18	28	20	24
Isparta	6	4	4	5	Yozgat	60	50	56	53
İstanbul	4	6	5	4	Zonguldak	38	39	36	37
İzmir	7	13	7	12					

Smart people is key to the development of the cities having well-educated citizens. Smart people is calculated according to two main elements and 6 criteria. According to results, Ankara is the city which has the smartest people in Turkey according to all methods. Unfortunately, Şırnak is the last (see table 40).

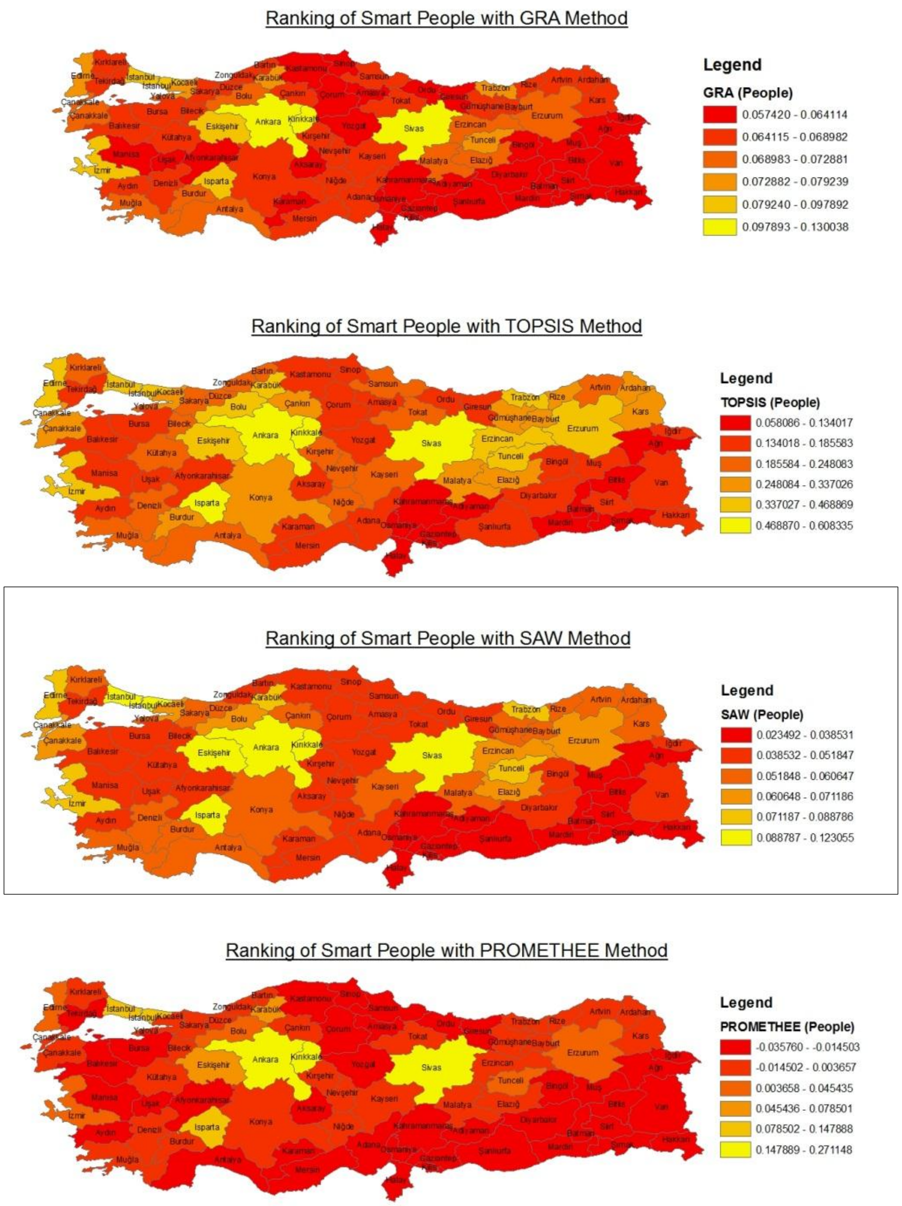


Figure 19 Ranking of Smarter People in Turkish Cities with GRA, TOPSIS, SAW, and PROMETHEE Methods

To the maps, Turkish smart people are accumulated in Ankara, Sivas, and their surroundings except İstanbul and İzmir (see figure 19). It can be said that these cities have the think-tank of Turkey according to their population. Contrarily, southwestern regions of Turkey have unfortunately less proportion of brain power and education.

Table 41 Spearman's Ranking Correlation Coefficient in Smart People

			PEOP_GRA	PEOP_TOPSIS	PEO_SAW	PEOP_PRO.
Spearman's rho	PEOPLE_GRA	Correlation Coefficient	1,000	,950**	,995**	,935**
		Sig. (2-tailed)	.	,000	,000	,000
		N	81	81	81	81
	PEOPLE_TOPSIS	Correlation Coefficient	,950**	1,000	,964**	,965**
		Sig. (2-tailed)	,000	.	,000	,000
		N	81	81	81	81
	PEOPLE_SAW	Correlation Coefficient	**,995****	,964**	1,000	,958**
		Sig. (2-tailed)	,000	,000	.	,000
		N	81	81	81	81
	PEOPLE_PROMETH.	Correlation Coefficient	,935**	,965**	,958**	1,000
		Sig. (2-tailed)	,000	,000	,000	.
		N	81	81	81	81
**. Correlation is significant at the 0.01 level (2-tailed).						
1-SAW, 2-GRA, 3-TOPSIS, 4-PROMETHEE						

In order to prefer the suitable ranking method, it is referred to the Spearman's rho. The coefficients indicate that all methods have a nearly positive perfect relationship. But the most preferable method among them is SAW method, with 0,995 of correlation coefficient. According to the method, cities with the highest scores are Ankara, Kırıkkale, Sivas, Isparta, and İstanbul respectively. However, the cities with lowest scores are Bitlis, Osmaniye, Mardin, Ağrı, and Şırnak respectively (see Appendices A and B).

4.1.11 Smart Living

Smart living represents the qualified living conditions and satisfaction rate of Turkish cities. If only the living condition is better in a city, the city gets closer to become a smart city. Smart living condition will be studied in 5 main factors; culture and well-being, health, housing, safety, and working and income condition. Although most of the indicators of the present characteristic may intersect with the quality of life indices, smarter living indicators are mainly focusing on the combination of quality of life indicators and technology factor. Hence, smart living attribute are composed of 14 main indicators. These are listed below (see table 42);

Table 42 Lists of Smart Living Factors and Indicators

LIVING	**Culture & Well Being**	**C61**	Life satisfaction ratio 2015	1.67%
		C62	Percentage of cinema and theater audience (%) 2015	1.67%
	Health	**C63**	Number of hospital beds per 100 000 people 2012	1.11%
		C64	Number of doctors per 100,000 people	1.11%
		C65	Rate of satisfaction with public health services 2015	1.11%
	Housing	**C66**	Rate of non-kitchen households 2011	0.67%
		C67	Rate of bathroom in households 2011	0.67%
		C68	Number of rooms per person 2015	0.67%
		C69	Rate of availability of toilet in the house 2015	0.67%
		C70	Proportion of people experiencing problems in quality of housing 2015	0.67%
	Safety	**C71**	Violent crime rate (in 1.000.000 people) 2015 (ISO 37120: 14.5)	1.67%
		C72	Safety satisfaction level at night 2015	1.67%
	Working & Income Condition	**C73**	GINI regional coefficient (2014 - 2015)	1.11%
		C74	Average daily earnings (tl) 2015	1.11%
		C75	Satisfaction rate of job 2015	1.11%

Culture & Well Being

Culture and well-being factor are determined by two main indicators; life satisfaction ratio (C61) and percentage of cinema and theater audience (C62).

Table 43 Culture and Well-Being Data

Optimum Values of Culture & Well-Being				
	C61 - (max)	Value (%)	C62 - (max)	Value (%)
1	Sinop	77.66	İstanbul	147.4408
2	Afyonkarahisar	76.43	Eskişehir	144.018
3	Bayburt	75.91	Ankara	125.9072
4	Kırıkkale	75.48	Trabzon	115.5191
5	Kütahya	73.76	Yalova	115.1589
Worst Values of Culture & Well-Being				
	C61	Value (%)	C62	Value (%)
81	Tunceli	41.98	Hakkari	0.286658
80	Osmaniye	45.77	Şırnak	0.439703
79	Diyarbakır	48.67	Iğdır	0.83309
78	Antalya	49.79	Gümüşhane	1.342644
77	Hatay	50.31	Adıyaman	2.903811

Life satisfaction ratio is about 78% in Sinop as the best value, but it is about 42% in Tunceli as worst value. Moreover, Istanbul has the highest rate of cinema and theater audience, whereas Hakkari, Şırnak, and Iğdır have the least (see table 43).

Health

Number of hospital beds per 100 000 people (C63), the number of doctors per 100,000 people (C64) and satisfaction rate of public health services (C65) are the three major criteria of health factor.

Table 44 Health Data

Optimum Values of Health						
	C63 - (max)	Value (per 100.000 p.)	C64 - (max)	Value (per 100.000 p.)	C65 - (max)	Value (%)
1	Elazığ	516	Ankara	302.5124	Isparta	89.13
2	Bolu	503	Edirne	254.6527	Uşak	88.56
3	Isparta	495	Isparta	249.1778	Kırıkkale	88.09
4	Edirne	479	Trabzon	231.1942	Afyonkarahisar	87.33
5	Erzurum	453	İzmir	223.2907	Amasya	86.51
Worst Values of Health						
	C63	Value (per 100.000 p.)	C64	Value (per 100.000 p.)	C65	Value (%)
81	Şırnak	125	Ağrı	85.09063	Hakkari	54.55
80	Mardin	125	Hakkari	86.06766	Şırnak	57.52
79	Kilis	130	Şırnak	86.26948	Muş	61.47
78	Hakkari	137	Mardin	89.389	Ağrı	63.31
77	Şanlıurfa	143	Muş	90.17023	Tunceli	63.56

According to table 44, the highest number of hospital bed is 516 for 100.000 people in Elazığ, but the lowest is only 125 in Şırnak and Mardin. Additionally, the number of doctors shows that the maximum number of doctor is in Ankara with 302 doctors per 100.000 people. However, the minimum number of doctor is in Ağrı, Hakkari, and Şırnak with 85 doctors. Contrary to the number of hospital beds and doctors, the highest satisfaction rate of public health services is in Isparta with 89%, but the least is in Hakkari with nearly 55%.

Housing

Housing factor is investigated with rate of non-kitchen households (C66), rate of bathroom in the house (C67), the number of rooms per person (C68), rate of availability of toilet in the house (C69), and proportion of people experiencing problems in quality of housing (C70). It is anticipated that criteria 66 and 70 must take lower values, whereas criteria 67, 68, 69 should take higher values for the best score.

Table 45 Housing Data

Optimum Values of Housing										
	C66 - (min)	Vl (%)	C67 - (max)	Vl (%)	C68 - (max)	Vl (#)	C69 - (max)	Vl (%)	C70 - (min)	Vl (%)
1	Kocaeli	0.053462	Sakarya	99.89407	Sakarya	1.68	Bolu	99.92	Bolu	9.38
2	Ordu	0.063995	Ordu	99.83262	Artvin	1.62	Karabük	99.85	Isparta	9.5125
3	İstanbul	0.112929	İstanbul	99.79229	Sinop	1.62	Düzce	99.81	Karaman	11.8075
4	Ankara	0.15391	Sinop	99.7897	Çankırı	1.59	Zongulda	99.71	Konya	11.8375
5	Düzce	0.165946	Düzce	99.75048	Giresun	1.57	Kocaeli	99.59	Eskişehir	12.4125
Worst Values of Housing										
	C66	Vl (%)	C67	Vl (%)	C68	Vl (#)	C69	Vl (%)	C70	Vl (%)
81	Kars	13.70917	Iğdır	73.31689	Şırnak	0.75	Ardahan	50.31	Ardahan	44.725
80	Ardahan	12.49717	Kars	75.96695	Mardin	0.77	Kars	56.21	Adıyaman	41.12
79	Ağrı	11.51814	Ardahan	76.68312	Muş	0.82	Mardin	57.96	Bitlis	40.71
78	Bitlis	11.42255	Ağrı	81.1781	Şanlıurfa	0.83	Iğdır	60.71	Ağrı	40.475
77	Iğdır	9.872967	Mardin	81.58904	Hakkari	0.83	Ağrı	64.06	Kars	38.12

The best scores of housing seem to be shared among three cities; Kocaeli, Sakarya, and Bolu. The least proportion of non-kitchen households is in Kocaeli with nearly 5%, while it is Kars that has the highest ratio with about 14%. Although bathroom presence ratio in dwellings is 80% in most of the cities in Turkey, 3 of them is under the 80%, which are Kars, Ardahan, and Ağrı. Additionally, the number of rooms per person is the highest in Sakarya with 1.68 per person, but it is only 0.75 in Şırnak. Also, toilet presence ratio in dwellings is interestingly nearly 50% in Ardahan as the lowest ratio. Yet, the ratio of Bolu is 99.92% as the highest value. Similarly, percentage of households having problems with quality of dwellings is 9.38% in Bolu, whereas Ardahan has the highest ratio with nearly 45% (see table 45).

Safety

Safety factor is evaluated in two main criteria; violent crime rate per 1.000.000 people (C71) and safety satisfaction level at night (C72). According to criteria, it is expected lower values for the criterion 71 and higher values for criterion 72 in order to take best scores. Safety attribute indicates that Tunceli has the highest rate of violent crime with nearly 69%, while Erzincan has the lowest rate with nearly 4%. In addition, the best safety satisfaction level is in Afyonkarahisar with 87%, but it is surprisingly worst in İstanbul with 45% (see table 46).

Table 46 Safety Data

Optimum Values of Safety				
	C71 - (min)	Value (%)	C72 - (max)	Value (%)
1	Erzincan	4.471612	Afyonkarahisar	87.23
2	Gümüşhane	6.832795	Bayburt	85.95
3	Bilecik	9.527212	Rize	85.27
4	Isparta	9.551555	Artvin	81.63
5	Çankırı	10.89621	Kütahya	79.36
Worst Values of Safety				
	C71	Value (%)	C72	Value (%)
81	Tunceli	69.34252	İstanbul	45.1
80	Muğla	52.54279	Batman	48.57
79	Gaziantep	48.69101	Kocaeli	49.02
78	Kars	47.22295	Diyarbakır	51.01
77	Kilis	46.59072	Ankara	51.06

Working & Income Condition

GINI regional coefficient (C73), average daily earnings (C74), and satisfaction rate of job (C75) are three major indicators of working and income condition factor. According to table 47, income equality is the best in Erzurum, Erzincan, and Bayburt with 0.413. However, it is the worst in Zonguldak, Karabük, and Bartın with 0.304. Moreover, average daily earnings are about 85 TL per person/day as the best daily earning, but in Kilis, it is nearly 47 TL per person/day. Additionally, work satisfaction rate is 91.6% in Rize as the highest ratio yet it is only 63.97% in Ağrı as the lowest rate (see table 47).

Table 47 Working and Income Condition Data

Optimum Values of Working and Income Condition						
	C73 - (min)	Value	C74 - (max)	Value (TL)	C75 - (max)	Value (%)
1	Zonguldak	0.304	Zonguldak	85.55262	Rize	91.6
2	Karabük	0.304	Kocaeli	81.99503	Uşak	91.12
3	Bartın	0.304	İstanbul	71.6895	Isparta	90.92
4	Tekirdağ	0.308	Ankara	70.14222	Sinop	89.3
5	Kırklareli	0.308	Kırıkkale	68.41383	Karaman	88.91
Worst Values of Working and Income Condition						
	C73	Value	C74	Value (TL)	C75	Value (%)
81	Erzurum	0.413	Kilis	46.86633	Ağrı	63.97
80	Erzincan	0.413	Mardin	49.04176	Adıyaman	64.26
79	Bayburt	0.413	Giresun	49.11278	Van	64.7
78	Diyarbakır	0.412	Şırnak	49.41608	Batman	64.97
77	Şanlıurfa	0.412	Nevşehir	49.89355	Mardin	67.27

4.1.12 Evaluation of Smart Living

Smart living evaluation process is similar with the other characteristics. However the results of smart living are a bit complex. According to the table 48, each method states different cities as the smartest living. Hence, the results are examined more carefully.

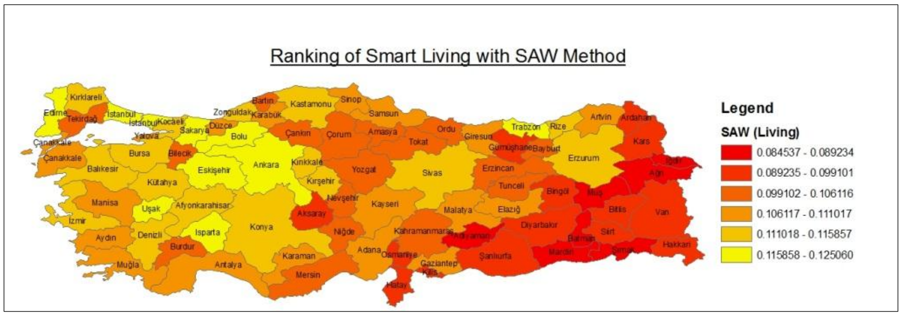
Table 48 Ranking of Smart Living according to GRA, TOPSIS, SAW, and PROMETHEE methods

Cities	GRA	TOPSIS	SAW	PRO.	Cities	GRA	TOPSIS	SAW	PRO.
Adana	55	45	33	17	Kahramanmaraş	37	56	53	50
Adıyaman	71	71	75	77	Karabük	38	20	43	37
Afyonkarahisar	2	32	10	48	Karaman	21	36	35	59
Ağrı	81	81	79	74	Kars	73	79	67	52
Aksaray	62	55	68	66	Kastamonu	17	52	14	27
Amasya	27	58	49	60	Kayseri	46	35	32	30
Ankara	6	6	3	2	Kırıkkale	11	29	15	39
Antalya	50	21	38	14	Kırklareli	41	25	17	35
Ardahan	77	78	73	70	Kırşehir	16	48	13	41
Artvin	35	49	42	53	Kilis	70	77	65	43
Aydın	58	54	36	25	Kocaeli	42	1	19	4
Balıkesir	13	39	18	34	Konya	18	11	16	21
Bartın	29	40	52	51	Kütahya	8	31	20	49
Batman	76	63	76	61	Malatya	53	50	39	29
Bayburt	12	42	54	75	Manisa	40	46	29	40
Bilecik	26	16	56	69	Mardin	80	80	81	72
Bingöl	69	53	71	65	Mersin	61	51	58	31

Table 48 (Continued)

Cities	GRA	TOPSIS	SAW	PRO.	Cities	GRA	TOPSIS	SAW	PRO.
Bitlis	74	73	74	68	Muğla	51	57	31	13
Bolu	4	7	4	18	Muş	78	75	80	73
Burdur	36	44	44	55	Nevşehir	45	38	50	47
Bursa	31	15	25	10	Niğde	49	60	57	62
Çanakkale	30	33	26	33	Ordu	54	9	46	8
Çankırı	28	23	48	58	Osmaniye	65	62	64	42
Çorum	60	61	51	46	Rize	5	41	21	54
Denizli	43	22	22	9	Sakarya	10	13	8	12
Diyarbakır	67	65	63	44	Samsun	32	27	28	32
Düzce	39	26	34	19	Siirt	64	67	62	64
Edirne	22	18	9	20	Sinop	9	37	41	71
Elazığ	44	28	40	22	Sivas	34	30	24	36
Erzincan	33	3	59	76	Şanlıurfa	66	74	69	63
Erzurum	23	34	11	24	Şırnak	75	76	78	79
Eskişehir	7	5	2	3	Tekirdağ	52	24	47	26
Gaziantep	59	59	37	15	Tokat	48	47	55	57
Giresun	19	43	30	38	Trabzon	15	8	5	5
Gümüşhane	56	12	66	81	Tunceli	47	68	45	6
Hakkari	63	69	72	78	Uşak	3	19	7	28
Hatay	68	64	61	45	Van	72	72	70	56
Iğdır	79	70	77	80	Yalova	25	10	27	7
Isparta	1	2	1	16	Yozgat	57	66	60	67
İstanbul	14	4	6	1	Zonguldak	20	17	23	23
İzmir	24	14	12	11					

Figure 20 Ranking of Smarter Living in Turkish Cities with GRA, TOPSIS, SAW, and PROMETHEE Methods



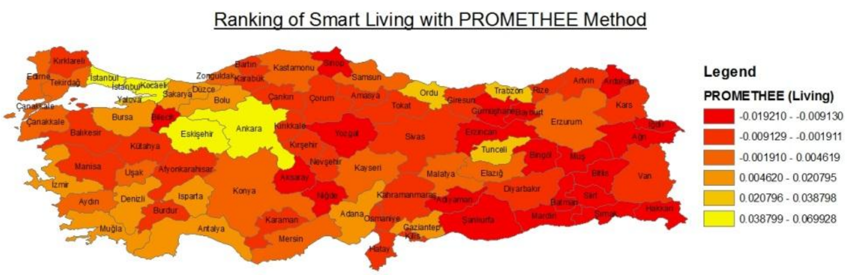


Figure 20 (Continued)

Although not a clear ranking, maps indicate that west part of Turkey has the better condition of smart living. Unfortunately, southeast and east regions of Turkey have the worst living conditions. In order to make the ranking clear, Spearman's rank correlation coefficient test is used (see table 49).

Table 49 Spearman's Ranking Correlation Coefficient in Smart Living

Correlations						
			LIVING_GRA	LIVING_TOPSIS	LIVING_SAW	LIVING_PRO.
Spearman's rho	LIVING_GRA	Correlation Coefficient	1,000	,740**	,856**	,447**
		Sig. (2-tailed)	.	,000	,000	,000
		N	81	81	81	81
	LIVING_TOPSIS	Correlation Coefficient	,740**	1,000	,752**	,604**
		Sig. (2-tailed)	,000	.	,000	,000
		N	81	81	81	81
	LIVING_SAW	Correlation Coefficient	,856**	,752**	1,000	,769**
		Sig. (2-tailed)	,000	,000	.	,000
		N	81	81	81	81
	LIVING_PROMETHE	Correlation Coefficient	,447**	,604**	,769**	1,000
		Sig. (2-tailed)	,000	,000	,000	.
		N	81	81	81	81
**. Correlation is significant at the 0.01 level (2-tailed).						
1-SAW, 2-GRA, 3-TOPSIS, 4-PROMETHEE						

According to Spearman's rho, SAW method takes the highest correlation coefficient, although all methods have positive correlation, which is followed by GRA, TOPSIS, and

PROMETHEE respectively. Hence, the method shows that Isparta, Eskişehir, and Ankara have the highest score of smart living, while Kars, Mardin, and Ağrı have the least scores. This result is consistent with the quality of life index that has been made by TUIK (see Appendices A and B).

4.2 Evaluation of Smart Cities

Smart cities evaluation is made according to 6 main characteristics, 21 factors and 75 criteria. GRA, TOPSIS, SAW, and PROMETHEE methods, as Multi Criteria Decision Analysis (MCDA) methods, are applied for the study because these methods are appropriate for ranking and evaluation of the smartness performance of Turkish cities. After all, Spearman's Rank Correlation is used to relationships of these methods. This gives clues about the preference of ranking methods.

According to table 50, Istanbul is the smartest city in Turkey to all MCDA methods. Also, Ankara is unarguable the second smartest city in Turkey due to all scores of the methods. Yet, the other ranks of the smartness of the cities are a bit complex. For example, Kocaeli is in 8th place in GRA method, but in 3rd in TOPSIS. Hence, to prefer suitable method is a difficult task because these methods do not give totally same results.

Table 50 Total Ranking of Smart Cities according to GRA, TOPSIS, SAW, and PROMETHEE methods

Cities	GRA	TOPSIS	SAW	PRO.	Cities	GRA	TOPSIS	SAW	PRO.
Adana	51	26	28	13	Kahramanmaraş	57	75	68	64
Adıyaman	76	79	77	81	Karabük	22	22	18	24
Afyonkarahisar	14	33	38	41	Karaman	30	59	41	61
Ağrı	81	80	81	80	Kars	70	60	62	67
Aksaray	68	65	67	76	Kastamonu	26	31	29	36
Amasya	50	71	57	73	Kayseri	38	57	33	38
Ankara	2	2	2	2	Kırıkkale	7	15	13	8
Antalya	12	14	10	5	Kırklareli	27	20	17	31
Ardahan	64	46	53	42	Kırşehir	54	63	50	74
Artvin	16	17	20	25	Kilis	66	73	61	39
Aydın	45	48	43	37	Kocaeli	8	3	4	4
Balıkesir	31	43	27	20	Konya	20	24	22	19
Bartın	53	55	55	79	Kütahya	23	50	37	48
Batman	78	64	76	65	Malatya	46	51	42	28
Bayburt	29	29	39	50	Manisa	33	66	58	57
Bilecik	18	27	25	46	Mardin	75	56	75	32
Bingöl	60	39	56	35	Mersin	58	62	59	44
Bitlis	73	69	70	58	Muğla	21	18	14	12

Table 50 (Continued)

Cities	GRA	TOPSIS	SAW	PRO.	Cities	GRA	TOPSIS	SAW	PRO.
Bolu	15	21	21	33	Muş	80	72	80	77
Burdur	41	41	31	59	Nevşehir	43	42	47	53
Bursa	28	23	24	14	Niğde	40	45	51	52
Çanakkale	34	25	23	40	Ordu	63	61	63	70
Çankırı	37	28	32	55	Osmaniye	77	81	78	62
Çorum	59	74	60	56	Rize	4	10	12	23
Denizli	35	49	30	27	Sakarya	5	13	9	11
Diyarbakır	48	30	54	16	Samsun	55	58	46	34
Düzce	52	54	49	66	Siirt	71	70	71	75
Edirne	24	12	15	18	Sinop	36	36	34	60
Elazığ	49	32	35	22	Sivas	6	5	6	3
Erzincan	11	6	19	17	Şanlıurfa	69	76	79	72
Erzurum	32	34	26	49	Şırnak	72	37	73	29
Eskişehir	3	8	3	9	Tekirdağ	56	44	52	69
Gaziantep	67	77	66	30	Tokat	44	53	44	54
Giresun	47	40	45	47	Trabzon	17	9	8	10
Gümüşhane	39	19	48	45	Tunceli	10	7	7	7
Hakkari	62	35	65	26	Uşak	25	47	40	51
Hatay	74	78	72	71	Van	65	52	69	43
Iğdır	79	67	74	68	Yalova	19	16	16	15
Isparta	9	11	11	21	Yozgat	61	68	64	78
İstanbul	1	1	1	1	Zonguldak	42	38	36	63
İzmir	13	4	5	6					

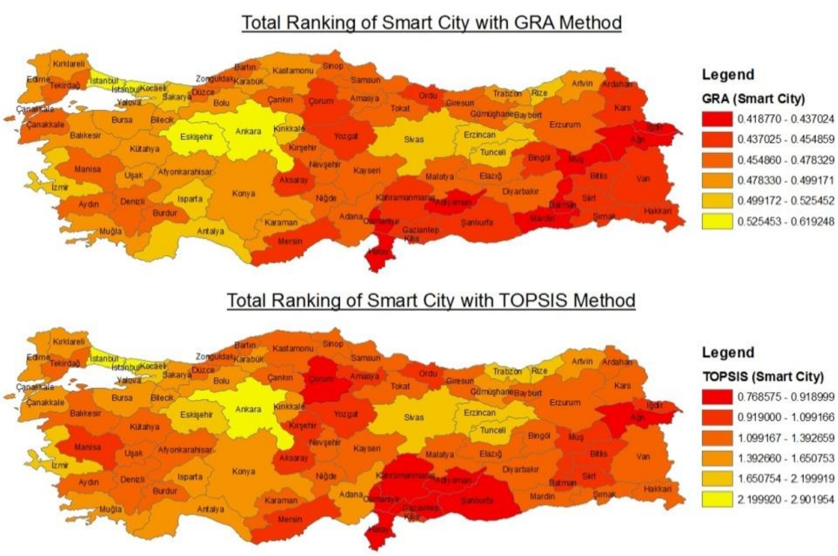


Figure 21 Total Ranking of Smart Turkish Cities with GRA, TOPSIS, SAW, and PROMETHEE Methods

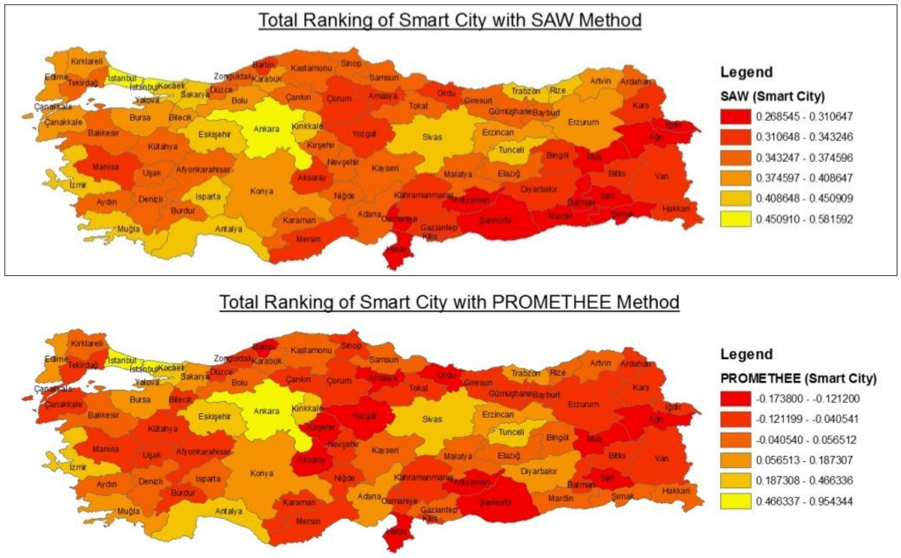


Figure 21 (Continued)

The maps, which are created in ArcGIS 10.2, are indicated that smart cities of Turkey are unsurprisingly aggregated to the west regions of the country. Especially, İstanbul, Ankara, and İzmir are the cities with yellow concentrations, which mean that these cities come into prominence. However, the axe starting from middle of the country to the northeast part also attracts the attention. This linear direction includes the cities of Sivas, Erzincan, Tunceli, Erzurum, Rize, and Trabzon (see figure 21).

Table 51 Spearman's Ranking Correlation Coefficient in Smart Cities (Total Ranking)

			TOTAL_GRA	TOTAL_TOPSIS	TOTAL_SAW	TOTAL_PRO.
Spearman's rho	TOTAL_GRA	Correlation Coefficient	1,000	,861**	,947**	,716**
		Sig. (2-tailed)	.	,000	,000	,000
		N	81	81	81	81
	TOTAL_TOPSIS	Correlation Coefficient	,861**	1,000	,901**	,818**
		Sig. (2-tailed)	,000	.	,000	,000
		N	81	81	81	81
	TOTAL_SAW	Correlation Coefficient	,947**	,901**	1,000	,778**
		Sig. (2-tailed)	,000	,000	.	,000
		N	81	81	81	81
	TOTAL_PROMETHEE	Correlation Coefficient	,716**	,818**	,778**	1,000
		Sig. (2-tailed)	,000	,000	,000	.
		N	81	81	81	81
**. Correlation is significant at the 0.01 level (2-tailed).						
1-SAW, 2-GRA, 3-TOPSIS, 4-PROMETHEE						

To make a clear choice of smartness of the cities, Spearman's rank correlation coefficient is used and observed the relationship between methods. To do this, firstly, ranking of six characters correlation coefficients are individually calculated (see table

51). Then, the Spearman's rank correlation coefficient test is applied for total scores. Spearman's rho shows that the method which has the highest correlation coefficient between the other is SAW method. SAW method has the highest correlation coefficient with GRA and TOPSIS but the second maximum correlation with PROMETHEE. Hence, according to SAW method, İstanbul, Ankara, Eskişehir, Kocaeli, and İzmir can be accepted as the first 5 smartest cities of Turkey; however, Ağrı, Muş, Şanlıurfa, Osmaniye, and Adıyaman are the least 5 smart cities in Turkey (see Appendices A and B).

4.3 Evaluation of Ranking Methods

In the present thesis, different evaluation methods of smart cities are assessed. The evaluation methods, used for ranking and observing smartness of the cities, differ from one another. As mentioned before, GRA, TOPSIS, SAW and PROMETHEE methods, as Multi Criteria Decision Analysis Methods are used to rank and evaluate smartness performance of Turkish cities. GRA analysis measures the closeness of the reference series of the indicators, whereas TOPSIS method measures not only the closeness of ideal solution but also distance from negative ideal solution. Also, SAW method uses average series, while PROMETHEE method uses pair-wise comparison.

According to the scores of smart environment, western and southern parts of Turkey are considered to have smart environment in GRA. Yet, according to TOPSIS method, 4 main focuses attract the attention; İstanbul, Adana, Artvin and Afyonkarahisar. SAW method's scores indicated that western regions of the Turkey have smart environment. In addition to this, PROMETHEE scores show that western parts of Turkey come into prominence with 3 focal points, İstanbul, Ankara and Balıkesir. According to Spearman Correlation Coefficient, PROMETHEE has the highest correlation coefficient. In this part, PROMETHEE's pair-wise comparison can shed light on the study. According to PROMETHEE method, İstanbul, Balıkesir, Ankara and their surroundings have the smarter environment of Turkey (see figure 15) .

Smart transportation and infrastructure scores are generally focused of the central parts of Turkey. According to all methods, İstanbul, Ankara, Sivas and their surroundings have the smarter transportation and infrastructure of Turkey. Spearman's rank correlation coefficient indicates that TOPSIS method has the highest correlation coefficient. Therefore, the method similarly shows 3 main focuses in Turkey. In this characteristic of the smart cities, closeness of the ideal solution and the difference negative ideal solution, namely TOPSIS method, determines the final score (see figure 16).

According to GRA, smarter governance of Turkey concentrated on eastern and southwestern regions of the country. However, other methods indicate that smarter governance of Turkey is focused on the southeastern parts of the country. According to correlation coefficient results, TOPSIS method again takes the highest score. Thus, 3 focal points come into prominence for smarter governance; southeastern region, northwestern region and some eastern cities such as Tunceli and Erzincan (see figure 17).

Smart economy results, in GRA, show that Turkey smarter economies are focused in three cities; İstanbul, Antalya and Ankara. According to TOPSIS and SAW methods, smarter economies of Turkey aggregated on the 3 axes. The first is starting from Antalya to İzmir; the second is beginning from Konya to İstanbul; finally, the third is starting from Rize to Adana. However, according to PROMETHEE method's results, 4 different points attract the attention; İstanbul, Antalya, Ankara and İzmir. Correlation results show that TOPSIS method has the highest correlation coefficient. Thus, the method is the preferable for the last three characteristics (see figure 18).

Smart people result, in GRA, indicates 2 main central parts of Turkey; Ankara, Sivas and its surroundings. PROMETHEE method's result is similar to GRA results. However, TOPSIS and SAW methods show that, although their results have similarities with the other two, the circle of smarter people is slightly larger. Among 4 methods, SAW method has the highest score of correlation coefficient for smarter people of Turkey. Therefore, smarter people of Turkey is determined according to SAW method (see figure 19).

Three methods except PROMETHEE indicate that 2 out of 3 Turkish cities have smart living conditions. Yet, according to PROMETHEE, some of Turkish cities have smarter living condition such as Ankara, İstanbul and their surroundings. Final scores show that SAW method again has the highest correlation coefficient. Therefore, most of the Turkish cities except southeastern regions' cities has smarter living condition in Turkey (see figure 20).

Finally, results of the characteristics show that four different methods have different scores for ranking. According to Spearman rank correlation coefficient, TOPSIS and SAW methods have 3 highest correlation coefficients including total scores; PROMETHEE method has highest correlation coefficient in one analysis; GRA do not have highest score in any characteristics.

The analyses answer the question of the smartness level of the cities because it calculates the closeness of the reference values of the cities. Because there is not a consistent reference values regarding smart cities, the author used the highest score as the best value and the lowest value as the worst value. That means, if there is a reference value of smart cities, any city's condition regarding smartness can be determined. Accordingly, the main idea of reference values is to get closer to the best value and to get further away from the worst. Hence, the inclusion of any city in the calculation process will not disturb the evaluation process. However, the results of the study may change according to used method. Also, the number of criteria used in the study affects the final scores. Due to these reasons, the research is limited to be overlapped with previous ones such as Giffinger's and Cohen's ranking studies.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

Due to rapid urbanization, which will be reaching nearly 70% in 2050, cities will be faced with formidable problems in the near future. Under favor of technological era, smart cities can be a solution for these problems. Starting from this point of view, the thesis intends to highlight the significance of smart cities in this era. Accordingly, the thesis will discuss the different conceptualizations of smart cities, which are inconsistent even today, with reference to their characters and indicator as well as evaluation process. Due to the fact that most city managers recently use the brand of "smart cities" for their cities with the support of technology firms, some scientists concentrated on the evaluation and ranking process of cities. This has been rarely the case for Turkish cities. The major question of the thesis relates to smartness performance of Turkish cities within the international context. Correspondingly, main purpose of the study is to evaluate and rank Turkish cities regarding smartness with inspiration from previous studies, and to develop stepping stones concerning required policies in order to navigate the smartness process.

To begin with, the author has deeply investigated in the concept of smart cities so that the concept can be made clear. The concept of smart city is a term that has been misrepresented since it was introduced. Most of the researchers and technology firms have used the concept of smart cities by bringing technology into the forefront. Therefore, a large number of terms like intelligent city, digital city, knowledge city, creative city, ubiquitous city, and so on has emerged. Surprisingly, these substitute terms have generally focused on the technological aspect of smart cities rather than social aspect. However, studies has shown that people factor of smart cities is one of the most non-negligible factors of smart cities. In addition to this, literature has generally focused on the six axes of smart cities; environment, transport and infrastructure, government, economic, people and living axes of smart cities. These six axes along with technology can only define smart cities in a holistic approach.

In addition to definition of smart cities, evaluation and ranking process of smart cities also important in order to observe improvements of cities regarding smartness performance. Evaluate and ranking smartness performances of cities provide to attract public attention, to open discussion board for smartness of cities, to force actors to take transparent and comprehensible decision for cities and so on. Similarly, the present thesis attempted to evaluate smartness performance of Turkish cities in order to observe and start debate concerning Turkish smart cities on political board.

In the present thesis, an indicator-based approach is used in order to evaluate smartness performance of Turkish cities. In accordance with approach, 6 characteristics, 21 factors and 75 criteria are defined by adapting Turkish case. These indicators are applied 81 Turkish provinces individually. Multi Criteria Decision Analysis (MCDA) methods are chosen in order to rank cities. Although there are a number of MCDA methods, which can be used for selection, ranking and sorting, only four suitable ranking methods have been chosen. Smart cities' thematic maps in Turkey were created using ArcGIS 10.2 software separately according to the scores. The maps give the author clues about the aggregations, concentrations, directions, and locations of smarter and less smart cities of Turkey. These maps have also been created for each characteristic of smart cities, in order to observe changes in terms of smartness among cities. However, after these two major analyses, the obvious ranks of the cities have not been determined due to the fact that all methods have different calculation functions, which do not allow taking an average of the scores. Hence, in order to observe the relationships of methods and make an obvious choice, Spearman's ranks correlation coefficient test has been used for each of the categories and the total score separately.

First of all, according to the results of environmental smartness, those cities that perform as smart environment are concentrated on the west regions of Turkey. It can be inferred from smart environment maps, the west part of Turkey has more environment-sensitive policies than the east part.

Secondly, smart transportation and infrastructure focus on the central regions of Turkey. Two axes of smart transportation and infrastructure attract the attentions except from İstanbul and İzmir. These are the vertical axe starting from Kastamonu to Konya and the horizontal axe starting from Sivas to Bingöl. These have probably resulted due to the accessibility and infrastructure investment of these cities.

Thirdly, smart governance policies are surprisingly focused on the southeast of the Turkey, although the region has many complications. Despite the fact that Turkish cities do not give particular importance of the governance policies, the southeast region's success concerning smart governance issues cannot be ignored. The results indicates that southeast part of Turkey give due importance of not only public engagement, but also political participation and gender equality.

Fourthly, the cities that have smart economy are mainly focused on the southwest region of Turkey. The three axes come into prominence regarding smart economy. The first axe beginning from Antalya to İzmir has the smartest economy, whereas the second axe from Konya to İstanbul has the second smartest economies among Turkish cities. The third axe is starting from Adana to Rize as third smartest economies. These results indicate that smartest investment of Turkish economies have concentrated on three basic axes.

Fifthly, smart people, the most debated issue of the smart cities, are concentrated on the central parts of Turkey by surrounding Ankara and Sivas. Surprisingly, although southeast region of Turkey smarter concerning smart governance, the least smart people are also in that region. This is probably resulted from investments in education and creative industries in the central regions of Turkey.

Sixthly, nearly 2 out of 3 Turkish cities have smart living conditions except by southeast regions. This implies that the southeastern parts of Turkey have a great deal of work to do about smart living policies. Hard living conditions, low level income, internal conflict in the region may probably have brought about less smarter living conditions in the region.

Finally, general scores of the smart cities of Turkey indicate that smart cities of Turkey have mainly located in the western parts of the country. Even though the scores for each character differ from one another, in terms of total scores, while the southeastern regions contain relatively less smart cities, İstanbul and Ankara proves to be by far the smartest cities in Turkey.

Recommendation of Evaluation of Turkish Smart Cities and Policies;

Although the concept of "smart city" is an inconsistent and fuzzy concept, there is still a great deal of work to do on clarifying the contents of this particular concept. The concept of smart cities has been discussed for nearly 30 years now, yet there are hardly ever action regarding the issue in Turkey. In fact, Turk Telekom, nowadays, attempts "Şehirler Akıllanıyor" projects in Kars and Karaman as pilot projects. However, these projects intend to inject ICT into these cities intensely as other technology firms' projects do. Likewise, Vodafone attempts to set a course for smart cities. Vodafone and Deloitte Turkey led by BTK also attempts to measure smartness performance of 30 metropolitan cities of Turkey. Information about the project is not available yet.

Moreover, although smartness performances of Turkish cities are mapped in this research, smartness of Turkish cities is a matter for concern in a holistic perspective. In other words, many cities all over the world make great efforts to become a smart city, yet Turkish cities are at the starting point. Hence, in order to reach the level of smart cities, Turkish cities need some actions and suggestions. According to author, most of the institutions in Turkey have to work synchronously at the first step. Some general suggestions in the light of characteristics of smart cities have been given in the following text:

1. To make cities environmentally smart:
   - ✓ Central government should develop environmental policies in order to encourage, enforce and support local governments regarding smart and sustainable actions

- ✓ Environment related institutions, NGOs and voluntary organizations such as, Ministry of Environment and Urbanization, Greenpeace and TEMA should work together with local and central government in order to guide to create smarter environments.
- ✓ Sources of funds of local governments should be increased to make them invest in smart environment. This may be difficult in the short term, but this will pay off easily and save lives and the world in the long term.

2. To create smarter transportation and infrastructure;
   - ✓ Although this topic is the most interested characteristic of the smart cities concept, and without doubt the most succeeded term of smartness in Turkish cities, city managers should make more integrated, attractive and intelligent transportation decisions with integration of technology.
   - ✓ With the cooperation of the central institutions, Ministry of Science, Industry and Technology, Ministry of Transport, Maritime Affairs and Communication should lead the smart transportation and infrastructure by encouraging and guiding local governments in Turkey.
   - ✓ In order to increase internet usage as one of the determinants of the concept, people should be encouraged with investments on internet infrastructure and cheap or affordable prices. Also, it should be increased free Wi-Fi spaces in order to increase accessibility of the internet especially in public spaces.
   - ✓ Integrated and Intelligent Public Transport Systems are sine qua non of the smart cities. Therefore, it is mandatory for Turkish cities to use these two systems in order to make their transportation systems smarter.
3. To create smarter governance policies;
   - ✓ Community engagement is the key factor of smart governance. Smart cities should be inclusive, participatory, and social.
   - ✓ Policies should be improved to increase the number of women in active politics, education, and work fields in order to remove gender inequality.
   - ✓ Local governments and NGOs together with the Ministry of Development should work on increasing public participation. Also, public participation should be

integrated with online services and social media in order to allow more people to participate.

4. To make local economies smarter;
   - ✓ Setting up a business should be made easy in order to increase the number of entrepreneurs in technological areas with the support of grants.
   - ✓ It is mandatory for firms to employ more qualified employees like engineers, and governmental subsidies should encourage firms to develop technology and produce high value products.
5. To make people smarter;
   - ✓ The major issue of smart people is obviously education. Only increasing the number of universities to ensure smarter people is inadequate. The educational system of Turkey should deeply be considered and a well-established educational system should be built on strong foundations.
   - ✓ People should be encouraged to work in creative industries. This not only makes economies smarter, but also makes people in the cities smarter.
6. To offer a smarter living;
   - ✓ It would not be wrong to say that smarter living can only be achieved by offering smart and qualified living conditions which make people happy. In fact, smarter living is one of the parallel issues of Quality of Life. Making living smarter or more qualified is not only accomplished by increasing environmental quality, but also by increasing the quality of housing, earnings, safety and health insurance, and so on. Central and Local governments should develop policies to make people happy, therefore, their life smarter.
   - ✓ Planning is also important factor for smart living. This can solely be achieved by comprehensive planning; not only planning for physical environment, but also planning for public services like transportation, health care, energy services, and so on.
7. General suggestions to make Turkish cities smarter:
   - ✓ Government should develop policies about smart cities for implementing cities in Turkey and should enact a smart cities law for Turkish cities.

- ✓ Especially, the Ministry of Environment and Urbanization, which is the cornerstone for smart cities in Turkey, should determine a scale or characteristics for smart cities suitable not only for metropolises but also for small-scale cities. Moreover, ideal parameters should be developed for smart cities in Turkey due to the fact that the parameters used in the thesis are unique for this study and the number indicators can affect the final scores. The determined scale and parameters shall provide an opportunity to observe how smart Turkish cities are. In addition, dataset and parameters should be arranged according to European measurement methods in order to compare Turkish cities with European cities.
- ✓ According to the determined scale, deficiencies and shortages of smart cities will be found out and the Ministry will provide actions and develop policies in order to overcome deficiencies. For example, according to this study, the west region of Turkey should give importance to governance issues, whereas the southeast region of the country should work on improving environmental policies.
- ✓ Moreover, although there are some studies, including this thesis, in the world concerning the evaluation of smart cities, the government should develop an evaluation method with a high consistency index.
- ✓ Institutions such as, the Ministry of Environment and Urbanization, and the Ministry of Science, Industry, and Technology have to cooperate in order to achieve the smart city goal of Turkey. Additionally, institutions like TUBITAK and BTK should cooperate with the ministries and local governments.
- ✓ Of course, in order to take action concerning smart cities, a commission including planners, mayors, traffic experts, architects, and engineers should be set up; and the commission should guide the smart cities of Turkey.

REFERENCES

Abid, M. T. (2014). Assessment of Smart City Approach: Its Tools and Components (Unpublished Master's Thesis). Gazimağusa: Institute of Graduate Studies and Research.

Albino, V., Berardi, U., & Dangelico, M. (2015). Smart Cities: Definitions, Dimensions, Performance, and Initiatives. *Journal of Urban Technologies*, *22*(1), 3-21.

Batty, M., Axhausen, K. W., Giannotti, F., Pozdnoukhov, A., Bazzani, A., Wachowicz, M., et al. (2012). Smart cities of the future. *The European Physical Journal Special Topics*, *214*(1), 481-518.

Berry, C. R., & Glaeser, E. L. (2005). *The Divergence of Human Capital Levels Across Cities.* Cambridge: National Bureau of Economic Research.

Caragliu, A., & Del Bo, C. F. (2012). Smartness and European urban performance: assessing the local impacts of smart urban attributes. *Innovation: The European Journal of Social Science Research*, *25*(2), 97-113.

Caragliu, A., & Del Bo, C. F. (2015). Do Smart Cities Invest in Smarter Policies? Learning From the Past, Planning for the Future. *Social Science Computer Review*, *34*(6), 657-672.

Caragliu, A., Del Bo, C., & Nijcamp, P. (2011). Smart Cities in Europe. *Journal of Urban Technology*, *18*(2), 65-82.

Cocchia, A. (2014). Smart and Digital City: A Systematic Literature Review. In R. Dameri, & C. Rosenthal-Sabroux, *Smart City : How to Create Public and Economic Value with High Technology in Urban Space* (pp. 13-43). Switzerland: Springer International Publishing.

Cohen, B. (2014,). *Methodology for 2014 Smart Cities Benchmarking*. Retrieved May 20, 2017, from Fast Company: https://www.fastcompany.com/3038818/the-smartest-cities-in-the-world-2015-methodology

Edvinsson, L. (2006). Aspects on the city as a knowledge tool. *Journal of Knowledge Management, 10*(5), 6-13.

Ercoşkun, Ö. Y. (2016). Ultimate ICT Network in Turkey For Smart Cities. *Planlama, 26*(2), 130-146.

EU. (2014). *Mapping Smart Cities in the EU.* Directorate General for Internal Policies Policy Department A: Economic and Scientific Policy. European Union.

Fertner, C., Giffinger, R., Kramar, H., & Meijers, E. (2007). City ranking of European medium-sized cities. *Future of the Cities.* Copenhagen.

Florida, R. L. (2002). *The Rise of the Creative Class and How It's Transforming Work, Leisure, Community and Everyday Life.* New York: Basic Books.

Giffinger, R. (2007). *Smart Cities Ranking of European medium-sized cities.* Vienna: Centre of Regional Science, Vienna UT.

Giffinger, R., Fertner, C., Kalasek, H., Kalasek, R., Pichler-Milanovic, N., & Meijers, E. (2007). *Smart Cities: Ranking of European Medium-Sized Cities.* Vienna: Centre of Regional Science.

Giffinger, R., Kramar, H., & Haindl, G. (2010). The Role of Rankings in Growing City Competition. *Urban Research & Practice, 3*(3), 299-312.

Glaeser, E. L., & Berry, C. R. (2006). Why Are Smart Places Getting Smarter? *Taubman Centre Policy Brief*(2).

Hollands, R. G. (2008). Will the real smart city please stand up? Intelligent, progressive or entrepreneurial? *City: Analysis of Urban Trends, Culture, Theory, Policy, Action, 12*(3), 303-320.

Hwang, C. L., & Yoon, K. (1981). *Multiple Attribute Decision Making: Methods and Application.* New York: Springer.

IBM. (nd). *Smarter Cities*. Retrieved April 20, 2017, from IBM Website: https://www.ibm.com/smarterplanet/us/en/smarter_cities/overview/

Ishida, T. (2002). Digital City Kyoto. *Communications of the ACM, 45*(7), 78-81.

Julong, D. (1989). Introduction to Grey System Theory. *Journal of Grey System 1*(1), 1-24.

Karaatlı, M., Ömürbek, N., Budak, İ., & Dağ, O. (2015). Çok Kriterli Karar Verme Yöntemleri İle Yaşanabilir İllerin Sıralanması. *Selçuk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*(33), 215-228.

Komninos, N., Pallot, M., & Schaffers, H. (2013). Smart Cities and the Future Internet in Europe. *Journal of the Knowledge Economy, 4*(2), 119-134.

Landry, C. (2013). *Lineages of the Creative City.* Retrieved April 15, 2017, from Charles Landry WebSites: http://charleslandry.com/panel/wp-content/uploads/downloads/2013/03/Lineages-of-the-Creative-City.pdf

Lazaroiu, G. C., & Roscia, M. (2012). Definition methodology for the smart cities model. *Energy, 47*, 326-332.

Lehman, A., O'Rourke, N., Hatcher, L., & Stephanski, L. J. (2005). *JMP for Basic Univariate and Multivariate Statistics: A Step-by-Step Guide.* New York: SAS Press.

Liu, S., & Lin, Y. (2011). *Grey Systems Theory and Applications.* Berlin: Springer.

Lombardi, P., Giordano, S., Farouh, H., & Yousef, W. (2012). Modelling the smart city performance. *Innovation - The European Journal of Social Science Research, 25*(2), 137-149.

MCDM Society. (nd). *Short MCDM History*. Retrieved April 17, 2017, from MCDM Society: http://www.mcdmsociety.org/content/short-mcdm-history-0

Mohanty, S. P., Choppali, U., & Kougianos, E. (2016). Everything You wanted to Know about Smart Cities. *IEEE Consumer Electronics Magazine, 5*(3), 60-70.

Nam, T., & Pardo, T. A. (2011). Conceptualizing Smart City with Dimensions of Technology, People, and Institutions. *The Proceedings of the 12th Annual International Conference on Digital Government Research*, (pp. 282-291). New York.

Paquet, G. (2001). Smart Communities. *LAC Carling Government's Review, 3*(5), 28-30.

PCAST. (2016). *President Council of Advisory on Science and Technology*. Washington.

Röller, L.-H., & Waverman, L. (2001). Telecommunications Infrastructure and Economic Development: A Simultaneous Approach. *American Economic Review, 91*(4), 909-923.

Sağ, N. S. (2011). Dönüşüme Bağlı Kentsel Gelişmenin Yönetilmesinde Bir Araç Olarak Akıllı Büyüme; Konya Kenti Örneği (Unpublished Doctoral Thesis). 63-102. Konya: Selçuk Üniversitesi Fen Bilimleri Enstitüsü.

Smart City Council. (n.d). *Smart City Index Master Indicators Survey*. Retrieved April 15, 2017, from http://smartcitiescouncil.com/resources/smart-city-index-master-indicators-survey

Spearman, C. (1904). The proof and measurement of association between two things. *American Journal of Psychology, 15*(1), 72-101.

Steward, D. (2005). Smart growth in Ireland: From rhetoric to reality. *Progress in Irish Urban Studies, 1*(2), 21-30.

Turan, G. (2015). Çok Kriterli Karar Verme. In B. F. Yıldırım, & E. Önder, *Çok Kriterli Karar Verme Yöntemleri* (pp. 15-20). Bursa: Dora.

Tzeng, G. H., & Huang, J. J. (2011). *Multiple Attribute Decision Making Methods and Applications.* New York: CRC Press.

UN. (2014). *World Urbanization Prospects: The 2014 Revision.* New York: United Nations.

Vassilev, V., Genova, K., & Vassileva, M. (2005). A Brief Survey of Multicriteria Decision Making Methods. *Bulgarian Academy of Sciences Cybernetics and Information Technologies, 5*(1), 3-13.

WHO. (n.d.). *Global Health Observatory (GHO) data*. Retrieved December 24, 2016, from World Health Organisation: http://www.who.int/gho/urban_health/situation_trends/urban_population_growth_text/en/

Wiig, A. (2015). IBM's smart city as techno-utopian policy mobility. *City*, *19*(2), 258-273.

World Bank. (n.d.). *United Nations, World Urbanization Prospects*. Retrieved December 24, 2016, from World Helath Organissation Official Web Site: http://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?locations=TR

Yencken, D. (1988). The Creative City. *Meanjin, 47*(4), 597-608.

Yiğitcanlar, T. (2015). Smart Cities: an affective urban development and management model? *Australian Planner, 52*(1), 27-34.

Yıldırım, B. F. (2015). Gri İlişkisel Analiz. In B. F. Yıldırım, & E. Önder, *Çok Kriterli Karar Verme Yöntemleri* (pp. 229-244). Bursa: Dora.

APPENDICES

APPENDIX A: CALCULATIONS OF THE METHODS

Calculation Process of Grey Rational Analysis (GRA)

Firstly, (raw) data matrix is determined by using equation 3 (see table 52). The rows represent the alternatives (provinces) of the methods and the columns represent the criteria / indicators.

Table 52 Data matrix of the methods

Indicators / Turkish Provinces	Percentage of renewable energy	Energy generation / Energy consumption	Total residential energy use per capita	Total collected municipal solid waste per capita	Amount of PM10 concentration
Indicators (Criteria)	**C1**	**C2**	**C3**	**C4**	**C5**
MAX / MIN	**MAX**	**MAX**	**MIN**	**MIN**	**MIN**
Adana	0.8	214	2424	0.86	25.75
Adıyaman	14.4	47	1615	1.05	51
Afyonkarahisar	94.2	24	1824	1.26	82
Ağrı	0	0	532	1.22	0
Aksaray	52.8	9	1689	1.01	60
Amasya	32.2	122	1613	1	54.25
Ankara	5	64	2140	1.1	56.63
Antalya	1.8	88	2978	1.27	53
Ardahan	0	323	920	1.68	23
Artvin	0	939	1942	1	19
Aydın	79.9	152	2020	1.16	63

After determination of data sets, reference series according to maximum and minimum situations are calculated. That is, if the highest value of any criteria is expected as optimum value, maximum value of the criteria among alternatives is selected. Likewise, if the lowest value of the criteria is expected to be optimum value, the minimum value of the criteria is selected as a reference values (see table 53).

Table 53 Referential series

Indicators	C1	C2	C3	C4	C5
MAX / MIN	**MAX**	**MAX**	**MIN**	**MIN**	**MIN**
Reference Values	100	939	532	0.67	0

The values of table 52 are normalized according to referential series (see table 53) by using equation 3, 4 and 5. In the table 52, dataset can include ratio data, interval data and binary data because all dataset is normalized and take values between 0 and 1(see table 54).

Table 54 Normalization matrix of GRA

Normalization	C1	C2	C3	C4	C5
Norm. References	**1**	**1**	**1**	**1**	**1**
Adana	0.008	0.227902	0.764472	0.833333	0.757075
Adıyaman	0.144	0.050053	0.865181	0.666667	0.518868
Afyonkarahisar	0.942	0.025559	0.839163	0.482456	0.226415
Ağrı	0	0	1	0.517544	1
Aksaray	0.528	0.009585	0.855969	0.701754	0.433962
Amasya	0.322	0.129925	0.86543	0.710526	0.488208
Ankara	0.05	0.068158	0.799826	0.622807	0.465802
Antalya	0.018	0.093717	0.695506	0.473684	0.5
Ardahan	0	0.343983	0.951699	0.114035	0.783019
Artvin	0	1	0.824474	0.710526	0.820755
Aydın	0.799	0.161874	0.814764	0.570175	0.40566

After normalization process, it is calculated absolute value of x_i at the j^{th} point, which means that it is determined absolute difference of any data from reference value.

Table 55 Absolute value of differences of data

Absolute Values	C1	C2	C3	C4	C5
Weights	**1.39%**	**1.39%**	**1.39%**	**0.69%**	**0.69%**
Adana	0.992	0.772098	0.235528	0.166667	0.242925
Adıyaman	0.856	0.949947	0.134819	0.333333	0.481132
Afyonkarahisar	0.058	0.974441	0.160837	0.517544	0.773585
Ağrı	1	1	0	0.482456	0
Aksaray	0.472	0.990415	0.144031	0.298246	0.566038
Amasya	0.678	0.870075	0.13457	0.289474	0.511792
Ankara	0.95	0.931842	0.200174	0.377193	0.534198
Antalya	0.982	0.906283	0.304494	0.526316	0.5
Ardahan	1	0.656017	0.048301	0.885965	0.216981
Artvin	1	0	0.175526	0.289474	0.179245
Aydın	0.201	0.838126	0.185236	0.429825	0.59434

Finally, according to absolute values, the degree of grey coefficient is calculated by using equation 10 and 11. Therefore, sum of the criteria shows the total scores of alternatives. These final scores are ranked, and it is obtained the smartness performance of the cities according to GRA method.

Table 56 Final scores of GRA (Grey Coefficient)

GREY Relation Coefficient	C1	C2	C3	C4	C5	…	Total Score Γ
Adana	0.004654	0.005459	0.009441	0.005208	0.004674	...	0.09685583
Adıyaman	0.005121	0.004789	0.010939	0.004167	0.003539	...	0.08747809
Afyonkarahisar	0.012445	0.00471	0.010509	0.003412	0.002726	...	0.09430841
Ağrı	0.00463	0.00463	0.013889	0.003534	0.006944	...	0.08827845
Aksaray	0.007144	0.004659	0.010783	0.00435	0.003257	...	0.08579113
Amasya	0.005895	0.005069	0.010944	0.004398	0.003432	...	0.08223663
Ankara	0.004789	0.00485	0.009918	0.003958	0.003357	...	0.09581753
Antalya	0.004686	0.004938	0.008632	0.003383	0.003472	...	0.09665434
Ardahan	0.00463	0.006007	0.012665	0.002505	0.004843	...	0.08190308
Artvin	0.00463	0.013889	0.01028	0.004398	0.005112	...	0.0987581
Aydın	0.009906	0.00519	0.010134	0.003734	0.003173	...	0.09815641

Calculation Process of Technique of Order Preference by Similarity to Ideal Solution (TOPSIS)

Data matrix is decided as shown in the table 52. Also, reference series is determined as similar with table 53. The data of table 52 is normalized according to equation 12. These series range from 0-1. Normalization matrix of TOPSIS is shown in table 57;

Table 57 Normalization matrix of TOPSIS dataset

Normalization	C1	C2	C3	C4	C5
Norm. References	**1**	**1**	**1**	**1**	**1**
Adana	0.003025	0.11189	0.064846	0.136942	0.160684
Adıyaman	0.054459	0.024574	0.09733	0.112162	0.08113
Afyonkarahisar	0.356252	0.012548	0.086178	0.093469	0.050459
Ağrı	0	0	0.295466	0.096533	0
Aksaray	0.199682	0.004706	0.093066	0.116604	0.06896
Amasya	0.121776	0.063788	0.097451	0.11777	0.07627
Ankara	0.018909	0.033462	0.073452	0.107064	0.073071
Antalya	0.006807	0.046011	0.052783	0.092733	0.078068
Ardahan	0	0.16888	0.170856	0.070101	0.179897
Artvin	0	0.490955	0.080941	0.11777	0.21777
Aydın	0.302171	0.079473	0.077816	0.101526	0.065677

Normalization matrix of TOPSIS is weighted with decided weights of each criterion (see table 58). Unlike GRA, weighting process of TOPSIS is in 2nd step.

Table 58 Weighted normalization matrix of TOPSIS

	C1	C2	C3	C4	C5
Weights	**1.39%**	**1.39%**	**1.39%**	**0.69%**	**0.69%**
Adana	0.000042	0.001554	0.000901	0.000951	0.001116
Adıyaman	0.000756	0.000341	0.001352	0.000779	0.000563
Afyonkarahisar	0.004948	0.000174	0.001197	0.000649	0.00035
Ağrı	0	0	0.004104	0.00067	0
Aksaray	0.002773	0.000065	0.001293	0.00081	0.000479
Amasya	0.001691	0.000886	0.001353	0.000818	0.00053
Ankara	0.000263	0.000465	0.00102	0.000744	0.000507
Antalya	0.000094	0.000639	0.000733	0.000644	0.000542
Ardahan	0	0.002346	0.002373	0.000487	0.001249
Artvin	0	0.006819	0.001124	0.000818	0.001512
Aydın	0.004197	0.001104	0.001081	0.000705	0.000456

After weighting process, it is determined the ideal solutions (A^{*}) and negative ideal solution (A^{-}) for each alternative by using equation 14 and 15.

Table 59 Determination of ideal solution (A^{*}) and negative ideal solution (A^{-})

	C1	C2	C3	C4	C5
MIN A^{*}	0	0	0.018352	0.065067	0
MAX A^{-}	0.378186	0.490955	0.295466	0.175777	0.459736

After that, separate closeness measures of S_i^{*} and S_i^{-} is calculated by using equation 16 and 17. Finally, C_i^{*} is calculated by using equation 18 in order to measure relative closeness of ideal solutions (see in table 60).

Table 60 Separate measures of S_i^{*} and S_i^{-}, and relative closeness to ideal solution C_i^{*}

	S_i^{*}	S_i^{-}	C_i^{*}
Adana	0.012466	0.006086	0.328058
Adıyaman	0.01431	0.002199	0.133198
Afyonkarahisar	0.013617	0.005399	0.283941
Ağrı	0.014636	0.004052	0.216817
Aksaray	0.013907	0.003311	0.192283
Amasya	0.01369	0.002606	0.159907
Ankara	0.012896	0.00394	0.234047
Antalya	0.013958	0.002965	0.175194
Ardahan	0.01349	0.003706	0.215525
Artvin	0.012467	0.007608	0.378975
Aydın	0.013276	0.004901	0.269648

Calculation Process of Simple Additive Weighting (SAW)

Similar with the other methods, dataset is determined as shown in table 52. The data in table 52 is normalized by using the equations 20, 21 and 22 (see table 61). These normalization series range from 0 to 1. Simple Additive Method do not need to reference series, but need to range.

Table 61 Normalization matrix of SAW

Normalization	C1	C2	C3	C4	C5
Norm. References	1	1	1	1	1
Adana	0.008	0.227902	0.219472	0.77907	0.349515
Adıyaman	0.144	0.050053	0.329412	0.638095	0.176471
Afyonkarahisar	0.942	0.025559	0.291667	0.531746	0.109756
Ağrı	0	0	1	0.54918	0
Aksaray	0.528	0.009585	0.314979	0.663366	0.15
Amasya	0.322	0.129925	0.32982	0.67	0.165899
Ankara	0.05	0.068158	0.248598	0.609091	0.15894
Antalya	0.018	0.093717	0.178643	0.527559	0.169811
Ardahan	0	0.343983	0.578261	0.39881	0.391304
Artvin	0	1	0.273944	0.67	0.473684
Aydın	0.799	0.161874	0.263366	0.577586	0.142857

After normalization process, it is calculated performance value of alternatives P_i by using equation 23 in the light of weights (see table 62).

Table 62 Performance matrix of alternatives in SAW method

	C1	C2	C3	C4	C5	…	Total Score P_i
Weights	1.39%	1.39%	1.39%	0.69%	0.69%		
Adana	0.00011	0.00316	0.00304	0.00541	0.00242	…	0.06907701
Adıyaman	0.002	0.00069	0.00457	0.00443	0.00122	…	0.04694416
Afyonkarahisar	0.01308	0.00035	0.00405	0.00369	0.00076	…	0.06333427
Ağrı	0	0	0.01388	0.00381	0	…	0.04348302
Aksaray	0.00733	0.00013	0.00437	0.00460	0.00104	…	0.04687283
Amasya	0.00447	0.00180	0.00458	0.00465	0.00115	…	0.05115482
Ankara	0.00069	0.00094	0.00345	0.00423	0.00110	…	0.06594523
Antalya	0.00025	0.00130	0.00248	0.00366	0.00117	…	0.06292732
Ardahan	0	0.00477	0.00803	0.00277	0.00271	…	0.04412355
Artvin	0	0.01388	0.00380	0.00465	0.00328	…	0.06427028
Aydın	0.01109	0.00224	0.00365	0.00401	0.00099	…	0.06643001

Calculation Process of Preference ranking Organization Method for Enrichment Evaluation (PROMETHEE)

Like other three methods, dataset is created as shown in table 52. Reference series are also determined as indicated in table 53. After these processes, unlike other methods, preference function of each criterion is selected according to type of data (see in table 63). Each function need to different input. For example, while type 3 preference function just need to indifference threshold (q), type 5 preference function need both indifference threshold (q) and (preference threshold (p). If the range of the criteria needs to type 6 Guassian function, it solely needs to sigma (σ) value.

Table 63 Determination of preference matrix of each indicator, q values, p values and sigma

Indicators	C1	C2	C3	C4	C5
MAX / MIN	**MAX**	**MAX**	**MIN**	**MIN**	**MIN**
Preference Function	**3-Linear Preference**	**3-Linear Preference**	**5-Linear and Indifference Preference**	**5-Linear and Indifference Preference**	**3-Linear Preference**
q-values	-	-	0.000603	0.92206	-
p-values	100	939	532	0.67	0
Sigma (σ)	-	-	-	-	-

After selection of preference function process, data is normalized by using equation 24 and the final score is computed by differentiating positive and negative values. Unlike other methods, PROMETHEE compares each alternative separately and determine scores according to superiority of the alternatives.

Table 64 Determination of final scores according to PROMETHEE method

	Adana	Adıyaman	Afyon.	Ağrı	Aksaray		Positive Values	Final Scores
Adana	0.00000	0.10823	0.09259	0.12219	0.12705	⋯	**0.09190**	**0.05935**
Adıyaman	0.01133	0.00000	0.00853	0.02386	0.01284	⋯	**0.01104**	**-0.04555**
Afyon.	0.09862	0.10159	0.00000	0.10753	0.08425	⋯	**0.09056**	**0.05037**
Ağrı	0.05641	0.04320	0.04755	0.00000	0.04469	⋯	**0.04686**	**-0.02343**
Aksaray	0.04333	0.03881	0.00458	0.05759	0.00000	⋯	**0.03713**	**-0.01876**
⋮	⋮	⋮	⋮	⋮	⋮	⋯	⋮	⋮
Negative Values	**0.03256**	**0.05660**	**0.04019**	**0.07029**	**0.05588**		-	-

Spearman's rank correlation coefficient calculation and determination of rank methods order

Spearman rank correlation is a non-parametric test that is used to measure the degree of association between two variables. In the study, Spearman's rank correlation test is used in order to measure relationship between 4 methods results. According to table 65, TOPSIS and PROMETHEE methods have the highest correlation coefficient **(0,839)**. Due to the fact that TOPSIS method has the highest level correlation with the other 2 methods, preference of TOPSIS method is higher than the other methods. Hence, PROMETHEE method has the second top spearman rank's correlation coefficient. In order to decide 3rd and 4th preference methods, correlation coefficients of TOPSIS and PROMETHEE are analyzed separately. Each of the method, SAW method has higher score than GRA method. Therefore, the preference of the methods, although all methods have positive correlation coefficient, is TOPSIS, PROMETHEE, SAW and GRA respectively.

Table 65 Spearman's rank correlation coefficient

Correlations						
			TRAN_GRA	TRA_TOPSIS	TRA_SAW	TRA_PRO.
Spearman's rho	TRANS_INF_GRA	Correlation Coefficient	1,000	,654**	,800**	,494**
		Sig. (2-tailed)	.	,000	,000	,000
		N	81	81	81	81
	TRANS_INF_TOPSIS	Correlation Coefficient	,654**	1,000	,794**	,839**
		Sig. (2-tailed)	,000	.	,000	,000
		N	81	81	81	81
	TRANS_INF_SAW	Correlation Coefficient	,800**	,794**	1,000	,601**
		Sig. (2-tailed)	,000	,000	.	,000
		N	81	81	81	81
	TRANS_INF_PROMETHEE	Correlation Coefficient	,494**	,839**	,601**	1,000
		Sig. (2-tailed)	,000	,000	,000	.
		N	81	81	81	81
**. Correlation is significant at the 0.01 level (2-tailed).						
1-TOPSIS, 2-PROMETHEE, 3-SAW, 4-GRA						

APPENDIX B: RESULTS OF MULTI CRITERIA DECISION ANALYSES

According to the gathered information of cities, the results are given in the tables below. In order to help calculation, in all methods the top values are used as positive reference values and the least values are used as negative reference values.

The Results of Grey Rational Analysis (GRA)

Table 66 The Results of Grey Rational Analysis (GRA)

	ENV.	TR. & INF.	GOV.	ECON.	PEOPLE	LIV.	Γ_{avr}
Adana	0.09686	0.07857	0.07242	0.06439	0.06510	0.08695	0.46428
Adıyaman	0.08748	0.07395	0.07205	0.06131	0.06174	0.07643	0.43295
Afyonkarahisar	0.09431	0.08008	0.08740	0.06546	0.06385	0.10808	0.49917
Ağrı	0.08828	0.07833	0.06354	0.06326	0.05801	0.06735	0.41877
Aksaray	0.08579	0.07540	0.07228	0.06512	0.06259	0.08381	0.44499
Amasya	0.08224	0.08321	0.07765	0.06465	0.06364	0.09391	0.46530
Ankara	0.09582	0.08987	0.07949	0.09055	0.13004	0.10499	0.59076
Antalya	0.09665	0.07724	0.07301	0.09697	0.07073	0.08864	0.50324
Ardahan	0.08190	0.08524	0.07287	0.07269	0.06616	0.07176	0.45061
Artvin	0.09876	0.08705	0.08468	0.06515	0.06736	0.09221	0.49521
Aydın	0.09816	0.07650	0.07681	0.06535	0.06566	0.08592	0.46839
Balıkesir	0.09301	0.08117	0.07810	0.06601	0.06533	0.09901	0.48263
Bartın	0.08400	0.08027	0.07544	0.06541	0.06507	0.09312	0.46331
Batman	0.08839	0.07594	0.07557	0.05763	0.06094	0.07257	0.43104
Bayburt	0.08923	0.08606	0.07481	0.06360	0.06767	0.10240	0.48377
Bilecik	0.08235	0.09421	0.08553	0.06912	0.06591	0.09435	0.49147
Bingöl	0.08932	0.08145	0.07437	0.06366	0.06352	0.07922	0.45154
Bitlis	0.09206	0.07763	0.07608	0.06073	0.05997	0.07351	0.43999
Bolu	0.09437	0.07866	0.07722	0.06719	0.07258	0.10698	0.49700
Burdur	0.08547	0.07504	0.08255	0.06693	0.06907	0.09204	0.47110
Bursa	0.09366	0.07986	0.08053	0.07207	0.06535	0.09280	0.48428
Çanakkale	0.07982	0.08476	0.08119	0.06617	0.07178	0.09310	0.47683
Çankırı	0.08241	0.08185	0.08722	0.06336	0.06691	0.09376	0.47550
Çorum	0.08256	0.07480	0.08262	0.06460	0.06232	0.08550	0.45239
Denizli	0.09373	0.07659	0.08027	0.06790	0.06721	0.09065	0.47635
Diyarbakır	0.09715	0.07631	0.08898	0.05968	0.06375	0.08093	0.46680
Düzce	0.08607	0.07532	0.07877	0.06561	0.06627	0.09157	0.46361
Edirne	0.08529	0.08526	0.07808	0.06545	0.07514	0.09565	0.48486
Elazığ	0.09144	0.07820	0.07043	0.06606	0.06994	0.09005	0.46611
Erzincan	0.08434	0.09123	0.09908	0.06649	0.07233	0.09259	0.50606
Erzurum	0.09382	0.07931	0.07327	0.06455	0.07231	0.09507	0.47833
Eskişehir	0.10044	0.09459	0.07530	0.06749	0.08580	0.10450	0.52812

Table 66 (Continued)

	ENV.	TR. & INF.	GOV.	ECON.	PEOPLE	LIV.	Γ_{avr}
Gaziantep	0.09258	0.07740	0.06536	0.06538	0.06108	0.08588	0.44768
Giresun	0.08635	0.08018	0.07555	0.06519	0.06360	0.09602	0.46688
Gümüşhane	0.09130	0.08034	0.08229	0.06289	0.06819	0.08670	0.47172
Hakkari	0.09583	0.07641	0.07450	0.06000	0.06149	0.08303	0.45127
Hatay	0.08770	0.07287	0.07233	0.06207	0.06148	0.08056	0.43702
Iğdır	0.08565	0.07588	0.07113	0.06511	0.06314	0.07000	0.43090
Isparta	0.08937	0.08038	0.07770	0.06527	0.08430	0.11664	0.51365
İstanbul	0.10634	0.11775	0.08094	0.11965	0.09608	0.09849	0.61925
İzmir	0.09372	0.08138	0.08067	0.07180	0.08006	0.09476	0.50238
Kahramanmaraş	0.08955	0.07356	0.07791	0.06094	0.06120	0.09170	0.45486
Karabük	0.08965	0.08337	0.08218	0.06504	0.07670	0.09167	0.48861
Karaman	0.09111	0.08408	0.08120	0.06727	0.06357	0.09570	0.48294
Kars	0.08390	0.07867	0.07055	0.06548	0.06887	0.07450	0.44198
Kastamonu	0.09551	0.08657	0.07848	0.06377	0.06376	0.09622	0.48431
Kayseri	0.09295	0.07813	0.07959	0.06514	0.06735	0.08963	0.47278
Kırıkkale	0.09137	0.07813	0.07713	0.06433	0.10385	0.10247	0.51728
Kırklareli	0.08486	0.08576	0.08783	0.06682	0.06812	0.09090	0.48430
Kırşehir	0.08399	0.07616	0.07651	0.06296	0.06624	0.09706	0.46292
Kilis	0.09196	0.07677	0.07846	0.06246	0.06016	0.07809	0.44791
Kocaeli	0.10042	0.07906	0.08700	0.08462	0.07384	0.09082	0.51577
Konya	0.09150	0.08857	0.07769	0.06723	0.06853	0.09605	0.48957
Kütahya	0.09449	0.07606	0.07877	0.06670	0.06552	0.10416	0.48570
Malatya	0.09679	0.07809	0.07054	0.06460	0.06977	0.08709	0.46689
Manisa	0.09478	0.07932	0.08073	0.06798	0.06303	0.09146	0.47731
Mardin	0.09087	0.07631	0.07856	0.05984	0.05944	0.06942	0.43444
Mersin	0.09253	0.07641	0.07266	0.06280	0.06463	0.08395	0.45299
Muğla	0.09145	0.07982	0.08017	0.07976	0.07008	0.08790	0.48917
Muş	0.08778	0.07435	0.06813	0.06103	0.06174	0.07094	0.42398
Nevşehir	0.08290	0.07941	0.08667	0.06537	0.06448	0.08980	0.46862
Niğde	0.08696	0.07776	0.08860	0.06442	0.06471	0.08876	0.47121
Ordu	0.09046	0.07528	0.07156	0.06422	0.06263	0.08708	0.45123
Osmaniye	0.08372	0.07448	0.07318	0.05934	0.06027	0.08148	0.43246
Rize	0.09502	0.08205	0.09257	0.07884	0.06779	0.10580	0.52208
Sakarya	0.09218	0.09039	0.10215	0.06626	0.06641	0.10289	0.52029
Samsun	0.08575	0.07713	0.07466	0.06612	0.06579	0.09274	0.46218
Siirt	0.08799	0.07622	0.07627	0.05681	0.06092	0.08287	0.44108
Sinop	0.08730	0.07647	0.08119	0.06306	0.06337	0.10415	0.47553
Sivas	0.08726	0.08993	0.08498	0.06462	0.09928	0.09233	0.51841
Şanlıurfa	0.09235	0.08158	0.06922	0.05948	0.06045	0.08118	0.44427
Şırnak	0.09416	0.07747	0.07898	0.05950	0.05742	0.07343	0.44097
Tekirdağ	0.08025	0.07887	0.07962	0.06977	0.06471	0.08734	0.46056
Tokat	0.08868	0.07649	0.08536	0.06358	0.06542	0.08909	0.46861
Trabzon	0.09430	0.08149	0.07248	0.07184	0.07677	0.09792	0.49481
Tunceli	0.08980	0.08810	0.10122	0.06547	0.07822	0.08911	0.51193
Uşak	0.09217	0.07732	0.07836	0.06585	0.06382	0.10719	0.48472
Van	0.09321	0.07668	0.07916	0.06122	0.06276	0.07491	0.44794
Yalova	0.09313	0.08625	0.07892	0.06708	0.07008	0.09438	0.48983
Yozgat	0.08142	0.07566	0.08240	0.06241	0.06330	0.08617	0.45135
Zonguldak	0.08685	0.07685	0.07955	0.06435	0.06587	0.09572	0.46918

The Results of Technique of Order Preference by Similarity to Ideal Solution (TOPSIS)

Table 67 The Results of Technique of Order Preference by Similarity to Ideal Solution (TOPSIS)

	ENV.	TR. & INF.	GOV.	ECON.	PEOPLE	LIV.	C_i^*
Adana	0.3292	0.2764	0.2565	0.1289	0.1704	0.2627	1.4240
Adıyaman	0.1290	0.0963	0.2315	0.0586	0.1340	0.1547	0.8040
Afyonkarahisar	0.2836	0.1034	0.3706	0.0860	0.1842	0.2843	1.3121
Ağrı	0.2125	0.1406	0.2259	0.0432	0.0742	0.0999	0.7963
Aksaray	0.1894	0.0965	0.2800	0.0715	0.1677	0.2415	1.0465
Amasya	0.1647	0.1163	0.2425	0.0705	0.1460	0.2393	0.9793
Ankara	0.2337	0.3479	0.3533	0.3237	0.5582	0.4503	2.2670
Antalya	0.1825	0.1572	0.2471	0.4627	0.2389	0.3180	1.6064
Ardahan	0.2122	0.1896	0.3049	0.1048	0.2612	0.1204	1.1929
Artvin	0.3813	0.1770	0.4266	0.0744	0.2387	0.2572	1.5553
Aydın	0.2715	0.0926	0.3163	0.0783	0.1791	0.2476	1.1855
Balıkesir	0.2747	0.1345	0.2975	0.0815	0.1557	0.2710	1.2150
Bartın	0.1231	0.1490	0.3228	0.0544	0.2277	0.2697	1.1467
Batman	0.1671	0.1023	0.4153	0.0438	0.1270	0.1934	1.0490
Bayburt	0.1727	0.2247	0.3218	0.0510	0.2939	0.2677	1.3318
Bilecik	0.1813	0.2522	0.3413	0.0948	0.2040	0.3473	1.4208
Bingöl	0.2310	0.2310	0.3006	0.0511	0.1812	0.2523	1.2471
Bitlis	0.2391	0.1522	0.3139	0.0447	0.1087	0.1484	1.0070
Bolu	0.1906	0.1253	0.3072	0.0905	0.3616	0.4134	1.4886
Burdur	0.1499	0.1098	0.3448	0.0749	0.2792	0.2645	1.2232
Bursa	0.1737	0.2098	0.3967	0.1743	0.1609	0.3531	1.4686
Çanakkale	0.2234	0.1526	0.3926	0.0812	0.2961	0.2827	1.4285
Çankırı	0.1107	0.2042	0.4150	0.0581	0.2743	0.3153	1.3778
Çorum	0.1352	0.1188	0.2558	0.0651	0.1364	0.2076	0.9190
Denizli	0.1633	0.1271	0.2712	0.0903	0.2161	0.3166	1.1845
Diyarbakır	0.1992	0.1583	0.5157	0.0829	0.1844	0.1879	1.3286
Düzce	0.1372	0.0891	0.3114	0.0780	0.2417	0.2949	1.1523
Edirne	0.3012	0.2151	0.3384	0.0739	0.3806	0.3222	1.6315
Elazığ	0.2211	0.1719	0.2240	0.1149	0.2924	0.2921	1.3164
Erzincan	0.1630	0.2099	0.4766	0.0931	0.3404	0.4682	1.7512
Erzurum	0.1492	0.1558	0.2772	0.0827	0.3623	0.2781	1.3055
Eskişehir	0.1704	0.2690	0.2708	0.1041	0.4551	0.4542	1.7236
Gaziantep	0.1529	0.1176	0.1334	0.1034	0.1237	0.2391	0.8702
Giresun	0.2040	0.1130	0.3163	0.1682	0.1673	0.2673	1.2362
Gümüşhane	0.2621	0.1623	0.4227	0.0468	0.2919	0.3588	1.5447
Hakkari	0.2092	0.2766	0.4621	0.0497	0.1478	0.1576	1.3029
Hatay	0.1399	0.0731	0.2443	0.0726	0.1179	0.1896	0.8374
Iğdır	0.1921	0.1473	0.2865	0.0732	0.1738	0.1569	1.0297
Isparta	0.1561	0.1149	0.2970	0.0875	0.5089	0.4708	1.6351
İstanbul	0.4715	0.6048	0.3768	0.5560	0.4286	0.4643	2.9020
İzmir	0.1744	0.2790	0.3929	0.2145	0.3453	0.3549	1.7609
Kahramanmaraş	0.1453	0.0929	0.2516	0.0528	0.1204	0.2401	0.9032
Karabük	0.1751	0.1862	0.3326	0.0660	0.3971	0.3194	1.4764
Karaman	0.1421	0.1381	0.3011	0.0893	0.1764	0.2731	1.1200
Kars	0.1832	0.1267	0.3143	0.0772	0.2985	0.1158	1.1157

Table 67 (Continued)

	ENV.	TR. & INF.	GOV.	ECON.	PEOPLE	LIV.	C_i^*
Kastamonu	0.2211	0.2842	0.3341	0.0588	0.1733	0.2526	1.3242
Kayseri	0.1332	0.1413	0.2556	0.1082	0.2256	0.2749	1.1388
Kırıkkale	0.2079	0.1421	0.2610	0.0775	0.6079	0.2904	1.5867
Kırklareli	0.2879	0.1495	0.4745	0.0835	0.2334	0.2973	1.5262
Kırşehir	0.1285	0.1281	0.2857	0.0591	0.1991	0.2584	1.0590
Kilis	0.2235	0.1469	0.2815	0.0652	0.1182	0.1245	0.9598
Kocaeli	0.3193	0.1611	0.3687	0.1991	0.2882	0.5140	1.8504
Konya	0.1786	0.3045	0.2324	0.0974	0.2553	0.3643	1.4324
Kütahya	0.1954	0.1065	0.2768	0.0915	0.2159	0.2858	1.1719
Malatya	0.2173	0.1425	0.2098	0.0803	0.2563	0.2566	1.1629
Manisa	0.1499	0.1111	0.2886	0.0820	0.1460	0.2599	1.0376
Mardin	0.1890	0.1200	0.4645	0.1532	0.1075	0.1116	1.1457
Mersin	0.1539	0.1628	0.2670	0.0751	0.1573	0.2528	1.0689
Muğla	0.2184	0.1303	0.3733	0.3683	0.2242	0.2397	1.5542
Muş	0.1541	0.1486	0.2953	0.0645	0.1681	0.1308	0.9613
Nevşehir	0.1193	0.1270	0.4167	0.0906	0.1967	0.2717	1.2220
Niğde	0.2110	0.1062	0.3789	0.0659	0.2179	0.2158	1.1958
Ordu	0.1505	0.0801	0.2439	0.0769	0.1392	0.4085	1.0992
Osmaniye	0.1396	0.1139	0.1884	0.0396	0.0811	0.2059	0.7686
Rize	0.2030	0.1168	0.4508	0.3752	0.2539	0.2696	1.6693
Sakarya	0.2799	0.2348	0.4229	0.0959	0.2216	0.3554	1.6104
Samsun	0.2011	0.1068	0.2357	0.0923	0.1946	0.2928	1.1234
Siirt	0.1624	0.1684	0.3215	0.0241	0.1386	0.1666	0.9817
Sinop	0.2281	0.1252	0.4654	0.0579	0.1455	0.2727	1.2948
Sivas	0.1886	0.2645	0.2736	0.1275	0.6083	0.2891	1.7517
Şanlıurfa	0.1328	0.1397	0.2372	0.0743	0.1618	0.1335	0.8793
Şırnak	0.2098	0.2729	0.4745	0.1245	0.0581	0.1286	1.2683
Tekirdağ	0.1415	0.1073	0.3711	0.1013	0.1603	0.3152	1.1966
Tokat	0.1833	0.0957	0.3518	0.0589	0.2060	0.2592	1.1549
Trabzon	0.1782	0.1768	0.2463	0.3025	0.3781	0.4130	1.6949
Tunceli	0.1985	0.2455	0.6733	0.0690	0.4030	0.1588	1.7482
Uşak	0.2363	0.1024	0.2835	0.0692	0.1754	0.3210	1.1878
Van	0.1510	0.1224	0.4818	0.0693	0.1840	0.1507	1.1593
Yalova	0.2603	0.1528	0.4348	0.1000	0.2417	0.3739	1.5636
Yozgat	0.1150	0.0906	0.3928	0.0505	0.1789	0.1797	1.0074
Zonguldak	0.2086	0.0948	0.3570	0.0581	0.2106	0.3223	1.2513

The Results of Simple Additive Weighting (SAW)

Table 68 Results of Simple Additive Weighting (SAW)

	ENV.	TR. & INF.	GOV.	ECON.	PEOPLE	LIV.	P_{avr}
Adana	0.0691	0.0433	0.0721	0.0332	0.0467	0.1093	0.3738
Adıyaman	0.0469	0.0290	0.0717	0.0208	0.0384	0.0892	0.2961
Afyonkarahisar	0.0633	0.0319	0.0860	0.0191	0.0458	0.1159	0.3621
Ağrı	0.0435	0.0311	0.0636	0.0190	0.0261	0.0853	0.2685
Aksaray	0.0469	0.0342	0.0720	0.0266	0.0423	0.0970	0.3189
Amasya	0.0512	0.0379	0.0756	0.0265	0.0428	0.1049	0.3388
Ankara	0.0659	0.0650	0.0797	0.0736	0.1231	0.1232	0.5305
Antalya	0.0629	0.0412	0.0705	0.0767	0.0582	0.1083	0.4178
Ardahan	0.0441	0.0471	0.0792	0.0314	0.0522	0.0924	0.3465
Artvin	0.0643	0.0488	0.0991	0.0271	0.0531	0.1068	0.3993
Aydın	0.0664	0.0314	0.0775	0.0269	0.0485	0.1084	0.3592
Balıkesir	0.0695	0.0369	0.0782	0.0305	0.0460	0.1135	0.3746
Bartın	0.0438	0.0410	0.0808	0.0235	0.0494	0.1041	0.3427
Batman	0.0515	0.0260	0.0816	0.0161	0.0348	0.0875	0.2975
Bayburt	0.0490	0.0524	0.0790	0.0220	0.0560	0.1032	0.3616
Bilecik	0.0537	0.0601	0.0862	0.0326	0.0497	0.1027	0.3851
Bingöl	0.0564	0.0430	0.0822	0.0222	0.0442	0.0935	0.3415
Bitlis	0.0550	0.0321	0.0849	0.0185	0.0327	0.0919	0.3149
Bolu	0.0568	0.0394	0.0783	0.0308	0.0665	0.1198	0.3916
Burdur	0.0520	0.0357	0.0840	0.0282	0.0596	0.1061	0.3655
Bursa	0.0628	0.0398	0.0820	0.0450	0.0462	0.1115	0.3874
Çanakkale	0.0571	0.0465	0.0882	0.0229	0.0640	0.1110	0.3898
Çankırı	0.0406	0.0467	0.0946	0.0234	0.0543	0.1052	0.3649
Çorum	0.0513	0.0325	0.0811	0.0252	0.0399	0.1044	0.3345
Denizli	0.0606	0.0362	0.0771	0.0320	0.0537	0.1126	0.3722
Diyarbakır	0.0619	0.0279	0.0900	0.0223	0.0426	0.0984	0.3432
Düzce	0.0513	0.0328	0.0803	0.0282	0.0525	0.1088	0.3537
Edirne	0.0574	0.0494	0.0826	0.0275	0.0743	0.1174	0.4086
Elazığ	0.0513	0.0392	0.0707	0.0328	0.0618	0.1076	0.3634
Erzincan	0.0481	0.0497	0.1030	0.0314	0.0666	0.1008	0.3996
Erzurum	0.0524	0.0393	0.0787	0.0274	0.0689	0.1157	0.3824
Eskişehir	0.0622	0.0612	0.0733	0.0345	0.0903	0.1245	0.4460
Gaziantep	0.0564	0.0285	0.0573	0.0320	0.0366	0.1084	0.3192
Giresun	0.0589	0.0355	0.0810	0.0283	0.0433	0.1095	0.3565
Gümüşhane	0.0577	0.0394	0.0883	0.0156	0.0571	0.0973	0.3554
Hakkari	0.0523	0.0439	0.0801	0.0180	0.0360	0.0934	0.3237
Hatay	0.0510	0.0260	0.0707	0.0251	0.0368	0.0991	0.3088
Iğdır	0.0451	0.0337	0.0768	0.0189	0.0420	0.0859	0.3024
Isparta	0.0558	0.0363	0.0788	0.0297	0.0920	0.1251	0.4176
İstanbul	0.0827	0.0901	0.0845	0.1147	0.0917	0.1179	0.5816
İzmir	0.0594	0.0502	0.0840	0.0521	0.0773	0.1154	0.4385
Kahramanmaraş	0.0527	0.0264	0.0770	0.0211	0.0370	0.1035	0.3177
Karabük	0.0578	0.0467	0.0889	0.0260	0.0743	0.1066	0.4002
Karaman	0.0544	0.0389	0.0837	0.0307	0.0441	0.1085	0.3603
Kars	0.0385	0.0343	0.0775	0.0248	0.0582	0.0973	0.3305
Kastamonu	0.0573	0.0493	0.0842	0.0238	0.0450	0.1140	0.3736
Kayseri	0.0530	0.0370	0.0787	0.0320	0.0543	0.1094	0.3645

Table 68 (Continued)

	ENV.	TR. & INF.	GOV.	ECON.	PEOPLE	LIV.	P_{avr}
Kırıkkale	0.0546	0.0417	0.0780	0.0272	0.0991	0.1139	0.4145
Kırklareli	0.0614	0.0450	0.0994	0.0298	0.0554	0.1137	0.4047
Kırşehir	0.0449	0.0381	0.0783	0.0230	0.0507	0.1142	0.3492
Kilis	0.0593	0.0373	0.0819	0.0224	0.0337	0.0978	0.3324
Kocaeli	0.0755	0.0392	0.0914	0.0560	0.0652	0.1133	0.4406
Konya	0.0594	0.0495	0.0753	0.0340	0.0583	0.1139	0.3905
Kütahya	0.0567	0.0350	0.0766	0.0316	0.0497	0.1133	0.3629
Malatya	0.0595	0.0351	0.0702	0.0275	0.0596	0.1077	0.3598
Manisa	0.0566	0.0309	0.0748	0.0238	0.0417	0.1098	0.3376
Mardin	0.0510	0.0280	0.0844	0.0225	0.0298	0.0845	0.3002
Mersin	0.0557	0.0360	0.0707	0.0259	0.0446	0.1020	0.3350
Muğla	0.0599	0.0421	0.0847	0.0607	0.0576	0.1095	0.4144
Muş	0.0404	0.0275	0.0700	0.0206	0.0368	0.0849	0.2802
Nevşehir	0.0439	0.0389	0.0918	0.0289	0.0473	0.1047	0.3555
Niğde	0.0519	0.0329	0.0872	0.0258	0.0485	0.1022	0.3486
Ordu	0.0555	0.0284	0.0736	0.0246	0.0400	0.1054	0.3276
Osmaniye	0.0514	0.0284	0.0680	0.0173	0.0320	0.0982	0.2954
Rize	0.0590	0.0377	0.1045	0.0467	0.0557	0.1128	0.4164
Sakarya	0.0662	0.0483	0.1015	0.0318	0.0527	0.1175	0.4179
Samsun	0.0568	0.0327	0.0746	0.0317	0.0497	0.1099	0.3555
Siirt	0.0535	0.0334	0.0820	0.0100	0.0333	0.0985	0.3106
Sinop	0.0579	0.0378	0.0962	0.0224	0.0422	0.1069	0.3635
Sivas	0.0570	0.0554	0.0835	0.0318	0.0987	0.1115	0.4379
Şanlıurfa	0.0466	0.0276	0.0672	0.0202	0.0351	0.0961	0.2928
Şırnak	0.0526	0.0365	0.0875	0.0218	0.0235	0.0854	0.3073
Tekirdağ	0.0491	0.0359	0.0833	0.0284	0.0457	0.1054	0.3477
Tokat	0.0608	0.0298	0.0902	0.0237	0.0498	0.1029	0.3573
Trabzon	0.0591	0.0403	0.0756	0.0504	0.0767	0.1190	0.4211
Tunceli	0.0551	0.0573	0.1169	0.0266	0.0752	0.1058	0.4368
Uşak	0.0620	0.0331	0.0778	0.0260	0.0446	0.1177	0.3612
Van	0.0505	0.0259	0.0850	0.0215	0.0407	0.0939	0.3175
Yalova	0.0699	0.0440	0.0924	0.0317	0.0589	0.1103	0.4073
Yozgat	0.0426	0.0302	0.0881	0.0213	0.0434	0.1005	0.3262
Zonguldak	0.0544	0.0334	0.0887	0.0241	0.0509	0.1118	0.3632

The Results of Preference ranking Organization Method for Enrichment Evaluation (PROMETHEE)

Table 69 The Results of Preference ranking Organization Method for Enrichment Evaluation (PROMETHEE)

	ENV.	TR. & INF.	GOV.	ECON.	PEOPLE	LIV.	*T*
Adana	0.0593	0.0716	-0.0183	0.0327	-0.0194	0.0061	0.1319
Adıyaman	-0.0456	-0.0396	-0.0201	-0.0306	-0.0204	-0.0175	-0.1738
Afyonkarahisar	0.0504	-0.0352	0.0029	-0.0405	-0.0149	-0.0061	-0.0433
Ağrı	-0.0234	-0.0352	-0.0135	-0.0486	-0.0296	-0.0160	-0.1664
Aksaray	-0.0188	-0.0405	-0.0162	-0.0279	-0.0159	-0.0110	-0.1303
Amasya	-0.0190	-0.0403	-0.0129	-0.0265	-0.0187	-0.0090	-0.1265
Ankara	0.0463	0.1163	-0.0129	0.2287	0.2711	0.0558	0.7054
Antalya	0.0203	-0.0128	-0.0157	0.2497	-0.0164	0.0086	0.2337
Ardahan	-0.0084	-0.0022	-0.0117	0.0026	-0.0124	-0.0140	-0.0461
Artvin	0.0643	-0.0172	-0.0003	-0.0285	-0.0133	-0.0075	-0.0025
Aydın	0.0548	-0.0433	-0.0081	-0.0259	-0.0159	0.0005	-0.0379
Balıkesir	0.0735	0.0124	-0.0089	-0.0111	-0.0198	-0.0024	0.0436
Bartın	-0.0511	-0.0241	-0.0066	-0.0486	-0.0133	-0.0070	-0.1507
Batman	-0.0225	-0.0385	0.0189	-0.0308	-0.0268	-0.0091	-0.1089
Bayburt	-0.0297	0.0389	-0.0128	-0.0465	-0.0059	-0.0164	-0.0723
Bilecik	-0.0091	0.0220	-0.0111	-0.0286	-0.0142	-0.0132	-0.0543
Bingöl	0.0143	0.0260	-0.0090	-0.0369	-0.0169	-0.0106	-0.0331
Bitlis	0.0009	-0.0125	-0.0086	-0.0390	-0.0250	-0.0132	-0.0974
Bolu	-0.0097	-0.0073	-0.0068	-0.0260	0.0127	0.0057	-0.0314
Burdur	-0.0018	-0.0428	-0.0057	-0.0336	-0.0072	-0.0084	-0.0994
Bursa	0.0076	0.0288	0.0054	0.0546	-0.0207	0.0169	0.0926
Çanakkale	0.0280	-0.0252	-0.0022	-0.0353	-0.0068	-0.0016	-0.0431
Çankırı	-0.0519	0.0087	0.0135	-0.0412	-0.0100	-0.0088	-0.0897
Çorum	-0.0246	0.0095	-0.0159	-0.0344	-0.0205	-0.0061	-0.0919
Denizli	-0.0038	0.0117	-0.0108	-0.0149	-0.0136	0.0177	-0.0137
Diyarbakır	-0.0029	-0.0106	0.1100	0.0001	-0.0212	-0.0054	0.0701
Düzce	-0.0219	-0.0480	-0.0080	-0.0263	-0.0125	0.0052	-0.1115
Edirne	0.0479	0.0371	-0.0048	-0.0301	0.0125	0.0033	0.0659
Elazığ	-0.0052	0.0459	-0.0154	0.0208	-0.0067	0.0018	0.0413
Erzincan	-0.0157	0.0337	0.0750	-0.0070	0.0013	-0.0173	0.0699
Erzurum	-0.0423	-0.0096	-0.0096	-0.0106	0.0058	0.0007	-0.0656
Eskişehir	0.0141	0.0792	-0.0124	0.0054	0.0631	0.0541	0.2033
Gaziantep	-0.0073	0.0142	-0.0294	0.0123	-0.0220	0.0079	-0.0244
Giresun	0.0134	-0.0379	-0.0099	-0.0051	-0.0169	-0.0043	-0.0606
Gümüşhane	0.0087	-0.0150	0.0332	-0.0572	-0.0048	-0.0192	-0.0543
Hakkari	-0.0257	0.0622	0.0375	-0.0375	-0.0268	-0.0181	-0.0084
Hatay	-0.0253	-0.0452	-0.0137	-0.0077	-0.0242	-0.0055	-0.1217
Iğdır	-0.0181	-0.0182	-0.0080	-0.0322	-0.0199	-0.0190	-0.1154
Isparta	-0.0058	-0.0340	-0.0107	-0.0065	0.0914	0.0070	0.0413
İstanbul	0.1231	0.1782	-0.0098	0.4765	0.1163	0.0699	0.9543
İzmir	0.0029	0.0759	0.0021	0.1129	0.0053	0.0161	0.2151
Kahramanmaraş	-0.0303	-0.0022	-0.0152	-0.0317	-0.0212	-0.0067	-0.1073
Karabük	-0.0015	0.0065	-0.0069	-0.0327	0.0526	-0.0038	0.0141

Table 69 (Continued)

	ENV.	TR. & INF.	GOV.	ECON.	PEOPLE	LIV.	*T*
Karaman	-0.0099	-0.0248	-0.0117	-0.0312	-0.0160	-0.0090	-0.1026
Kars	-0.0355	-0.0257	-0.0080	-0.0264	-0.0109	-0.0074	-0.1139
Kastamonu	-0.0125	0.0458	-0.0073	-0.0449	-0.0159	0.0000	-0.0347
Kayseri	-0.0242	0.0065	-0.0165	0.0078	-0.0131	-0.0010	-0.0405
Kırıkkale	-0.0023	-0.0166	-0.0147	-0.0134	0.2572	-0.0043	0.2060
Kırklareli	0.0492	-0.0361	0.0048	-0.0279	-0.0127	-0.0032	-0.0259
Kırşehir	-0.0244	-0.0311	-0.0150	-0.0377	-0.0144	-0.0049	-0.1276
Kilis	0.0282	-0.0071	-0.0101	-0.0270	-0.0209	-0.0053	-0.0423
Kocaeli	0.0984	0.0302	-0.0053	0.1170	-0.0098	0.0467	0.2773
Konya	0.0134	0.0733	-0.0160	0.0033	-0.0112	0.0023	0.0651
Kütahya	0.0022	-0.0350	-0.0128	-0.0028	-0.0109	-0.0062	-0.0656
Malatya	0.0005	0.0182	-0.0165	-0.0069	-0.0120	-0.0010	-0.0176
Manisa	-0.0271	-0.0009	-0.0112	-0.0294	-0.0202	-0.0048	-0.0936
Mardin	-0.0097	-0.0261	0.0509	0.0015	-0.0317	-0.0146	-0.0297
Mersin	-0.0233	0.0271	-0.0148	-0.0185	-0.0212	-0.0010	-0.0518
Muğla	0.0172	-0.0331	-0.0034	0.1589	-0.0141	0.0094	0.1348
Muş	-0.0463	-0.0199	-0.0103	-0.0256	-0.0238	-0.0148	-0.1409
Nevşehir	-0.0250	-0.0363	0.0170	-0.0153	-0.0145	-0.0061	-0.0801
Niğde	0.0025	-0.0392	0.0082	-0.0285	-0.0134	-0.0094	-0.0798
Ordu	-0.0355	-0.0425	-0.0131	-0.0303	-0.0228	0.0230	-0.1212
Osmaniye	-0.0150	0.0132	-0.0217	-0.0485	-0.0273	-0.0053	-0.1046
Rize	0.0091	-0.0361	-0.0006	0.0866	-0.0120	-0.0078	0.0391
Sakarya	0.0319	0.0352	0.0686	-0.0017	-0.0124	0.0160	0.1377
Samsun	-0.0027	-0.0044	-0.0144	0.0049	-0.0148	-0.0012	-0.0328
Siirt	-0.0155	-0.0015	-0.0061	-0.0617	-0.0331	-0.0104	-0.1284
Sinop	0.0103	-0.0381	0.0062	-0.0454	-0.0196	-0.0144	-0.1010
Sivas	0.0272	0.1014	-0.0196	0.0199	0.2343	-0.0036	0.3595
Şanlıurfa	-0.0546	-0.0162	-0.0165	-0.0082	-0.0201	-0.0094	-0.1250
Şırnak	-0.0271	0.0307	0.0327	-0.0003	-0.0358	-0.0187	-0.0183
Tekirdağ	-0.0276	-0.0388	-0.0040	-0.0260	-0.0196	0.0005	-0.1155
Tokat	0.0095	-0.0350	-0.0107	-0.0293	-0.0141	-0.0087	-0.0883
Trabzon	-0.0012	0.0210	-0.0132	0.1144	0.0011	0.0335	0.1555
Tunceli	-0.0025	0.0667	0.1198	-0.0312	0.0255	0.0333	0.2117
Uşak	0.0322	-0.0367	-0.0084	-0.0478	-0.0160	-0.0001	-0.0767
Van	-0.0389	-0.0273	0.0635	-0.0155	-0.0198	-0.0086	-0.0466
Yalova	0.0726	-0.0126	0.0028	-0.0081	-0.0111	0.0268	0.0703
Yozgat	-0.0495	-0.0434	0.0166	-0.0417	-0.0172	-0.0121	-0.1474
Zonguldak	-0.0026	-0.0461	-0.0056	-0.0391	-0.0138	0.0017	-0.1056

Total Results of 4 Methods: GRA, TOPSIS, SAW and PROMETHEE

Table 70 Final Scores of 4 Methods

	GRA	TOPSIS	SAW	PROMETHEE
Adana	0.464282311	1.424027757	0.373769376	0.131931508
Adıyaman	0.432948086	0.803980856	0.296056687	-0.173781693
Afyonkarahisar	0.499171289	1.31212361	0.362077792	-0.043326575
Ağrı	0.418769603	0.796273304	0.268544656	-0.166378683
Aksaray	0.444989549	1.046468607	0.318926631	-0.130258572
Amasya	0.46529621	0.979281699	0.338795235	-0.126500146
Ankara	0.590764805	2.266998071	0.530475465	0.705369056
Antalya	0.503243695	1.606434096	0.417804586	0.23372658
Ardahan	0.45060577	1.192872343	0.346518906	-0.046108967
Artvin	0.495208018	1.55531064	0.39929784	-0.002454766
Aydın	0.468391222	1.185487987	0.359150359	-0.037890107
Balıkesir	0.482633655	1.21502967	0.374595575	0.043645342
Bartın	0.463314274	1.146686784	0.342681267	-0.150695257
Batman	0.431039926	1.049005975	0.2975152	-0.108900951
Bayburt	0.48376698	1.331835896	0.361593154	-0.072308382
Bilecik	0.491467122	1.420843843	0.38508416	-0.054284507
Bingöl	0.451543452	1.24711447	0.341512992	-0.03310715
Bitlis	0.439987189	1.006978007	0.314947575	-0.097378092
Bolu	0.497004401	1.488565898	0.391569557	-0.031383343
Burdur	0.471101321	1.223154598	0.365481061	-0.099415093
Bursa	0.484279898	1.468574833	0.387394543	0.092607211
Çanakkale	0.476825981	1.428514109	0.389758913	-0.043122687
Çankırı	0.475503153	1.377757811	0.364892937	-0.089697059
Çorum	0.452392813	0.918999202	0.334450566	-0.091884245
Denizli	0.476347376	1.184545833	0.372222274	-0.013697603
Diyarbakır	0.466796432	1.328571295	0.34324552	0.07007397
Düzce	0.463605872	1.152281203	0.353738921	-0.111540054
Edirne	0.48486467	1.631539772	0.408647009	0.065921521
Elazığ	0.466110694	1.316377946	0.363425156	0.041284725
Erzincan	0.506055696	1.751218412	0.399588226	0.069894835
Erzurum	0.478328739	1.305456155	0.382382863	-0.065621993
Eskişehir	0.528117514	1.723632701	0.446020881	0.203329628
Gaziantep	0.447676269	0.870198505	0.319218413	-0.024361161
Giresun	0.46688212	1.236214564	0.356471084	-0.060636499
Gümüşhane	0.471718997	1.544669474	0.355440045	-0.054255053
Hakkari	0.451270622	1.302922766	0.323657831	-0.008369081
Hatay	0.437024095	0.837379785	0.308756501	-0.121660544
Iğdır	0.430899247	1.029657422	0.302372889	-0.115440213
Isparta	0.51365057	1.635105258	0.417647904	0.041314867
İstanbul	0.619247849	2.901954212	0.581592196	0.954344472
İzmir	0.502384356	1.760936154	0.438462653	0.21514614
Kahramanmaraş	0.454858643	0.903168823	0.317665817	-0.10732577
Karabük	0.488609962	1.476354092	0.400243416	0.014135696

Table 70 (Continued)

	GRA	TOPSIS	SAW	PROMETHEE
Karaman	0.482937767	1.120040277	0.360329509	-0.102571217
Kars	0.441982971	1.11569574	0.330533019	-0.113942727
Kastamonu	0.484308135	1.324229719	0.373643382	-0.034695595
Kayseri	0.472782224	1.138819125	0.364474074	-0.040522757
Kırıkkale	0.517279451	1.586699162	0.414545692	0.205994631
Kırklareli	0.484302833	1.526154047	0.404652371	-0.025859529
Kırşehir	0.462920521	1.058971555	0.349235561	-0.127590817
Kilis	0.447905025	0.959848244	0.332405167	-0.042260754
Kocaeli	0.515770868	1.850361235	0.44060646	0.277315179
Konya	0.489572448	1.432379536	0.390511848	0.065125186
Kütahya	0.485700727	1.171918795	0.362944931	-0.065615888
Malatya	0.466894082	1.162863803	0.359757553	-0.017642479
Manisa	0.477308692	1.037550044	0.337571873	-0.093594473
Mardin	0.434439463	1.145740091	0.300209982	-0.029685692
Mersin	0.452987978	1.068906863	0.334963786	-0.05182434
Muğla	0.489174939	1.554171625	0.414446167	0.134787978
Muş	0.423976381	0.961349901	0.280237343	-0.140850695
Nevşehir	0.468620707	1.222033851	0.355485427	-0.080098113
Niğde	0.471211466	1.195782844	0.348607733	-0.079821548
Ordu	0.451232788	1.099165712	0.327566875	-0.121161199
Osmaniye	0.432463445	0.768575215	0.295361839	-0.104600296
Rize	0.522082393	1.669324535	0.416399938	0.039105744
Sakarya	0.520285333	1.610416404	0.417922335	0.137660803
Samsun	0.462179078	1.123413924	0.355538816	-0.032815224
Siirt	0.441079015	0.981651673	0.310646764	-0.128402716
Sinop	0.47552969	1.294800503	0.363451322	-0.100952329
Sivas	0.5184061	1.751732359	0.437895451	0.359548122
Şanlıurfa	0.444265097	0.879269615	0.29280317	-0.124953406
Şırnak	0.44096623	1.268330652	0.307313513	-0.018329563
Tekirdağ	0.460563375	1.196636782	0.347703433	-0.115534271
Tokat	0.468607323	1.15487372	0.357338129	-0.088288639
Trabzon	0.494809511	1.694917745	0.421091128	0.155514322
Tunceli	0.511928772	1.748202158	0.436798404	0.21168559
Uşak	0.484724927	1.187754512	0.361204334	-0.076712605
Van	0.447941594	1.159263566	0.317535755	-0.046635338
Yalova	0.489833866	1.563552661	0.407282551	0.070264212
Yozgat	0.451348713	1.007422077	0.326162545	-0.147351508
Zonguldak	0.469181065	1.251298394	0.363249601	-0.105629352