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Sustainable urban transportation performance in Ankara: A comparative study

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Abstract

Although sustainable transportation is generally referred to with air pollution, global warming and climate change; it refers to a wide transportation structure that is sustainable in terms of economic, social and environmental effects. In this study, Ankara's sustainable urban transportation performance was compared with İstanbul, İzmir, Konya and Antalya, using the Sustainable Urban Transportation Index (SURKENT), which was previously developed by the author. In SURKENT, 15 sub-indicators are defined under 4 main indicators. The main indicators are Environmental Performance (EP), Transportation Performance (TP), Energy Performance (EnP) and Municipality Governance Performance (MGP). 4 sub-indicators were used under Environmental Performance, 7 under Transportation Performance, 2 under Energy Performance and 2 sub-indicators under Municipality Governance Performance. Minimum-maximum normalization was used for sub-indicators containing quantitative data, and 0-100 scoring was used for qualitative data. The ranking of cities with the highest sustainable urban transportation performance was found as follows: İstanbul, İzmir, Konya, Ankara, Antalya. Ankara; it is 3rd in EP, 3rd in TP, 5th in EnP and 2nd in MGP.

Keywords: Urban transport; Performance index; Sustainable transport; Ankara.

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1. Introduction

According to the data of the United Nations Department of Economic and Social Affairs, it is expected that 2.5 billion people will be added to the urban population by 2050 and 68% of the world's population will live in urban areas [1]. According to World Bank data, today more than half of the world's population, 75% of the population in Europe and 76% of the population in Türkiye live in urban areas [2]. In parallel with this population density living in urban areas, the number of motor vehicles and the use of motor vehicles has increased day by day, and with the expansion of urban areas, the mobility demands of urban residents have increased. As a result of these increases, many cities have faced problems such as traffic delays, traffic accidents, negative environmental impacts and a decrease in the quality of life.

According to the Brundtland Commission Report (1987), sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [3]. Sustainable transportation is meeting the transportation needs of people and goods in a healthy environment, fairly, with affordable costs, and using resources efficiently [4].

Over the past decade, European Union cities have begun to adopt a sustainable planning approach to improve the quality of life. In this approach, the development of public transportation, pedestrian and bicycle transportation, which is more economically and environmentally efficient than the use of private car, is at the forefront.

Indexing studies; it allows countries, cities, institutions and organizations to see their rankings in various subjects and fields. Although there are many indexing studies in various fields, sustainable transportation indexing studies are limited.

In 2009, the European Green City Index was designed in a research project carried out by the Economist Intelligence Unit under the sponsorship of Siemens. With this index, the environmental performance of 30 European cities was measured and ranked, taking into account 30 individual indicators per city [5].

Litman (2011), in his study titled "Sustainability and Livability", defined 40 performance indicators in 4 main categories (Economic, Social, Environmental, Good Governance and Planning) for sustainable transportation. According to Litman, indicators should be selected carefully. Inappropriate or incomplete indicators can

misdiagnose problems and misdirect decision makers [6].

Sustainable Urban Transport Evaluation (SUTE) was developed by the Korea Transport institute in 2014. SUTE consists of two components: Status Evaluation and Policy Evaluation. There are 12 indicators in both components. The weight of the Status Evaluation is 60%, while the weight of the Policy Evaluation is 40% [7].

The Sustainable Urban Transport Index (SUTI) is an excel-based index developed in 2017 by the Economic and Social Commission for Asia and the Pacific (ESCAP) to help summarize, track and compare the performance of Asian cities with regard to sustainable urban transport. SUTI is based on ten indicators that represent the transport system, social, economic and environmental dimensions of sustainable urban transport [8].

SUMI (Sustainable Urban Mobility Indicators) is a tool, coordinated by Rupprecht Consult-Forschung & Beratung GmbH, that assists cities with performing a standardized evaluation of the sustainability of their transport system, identify the strengths and weaknesses of their mobility system and to focus on areas for improvement. The starting point of the SUMI project (2017-2019) is the "SMP2.0 Sustainable Mobility Indicators" developed by WBCSD, the World Business Council for Sustainable Development. The tool consists of 20 spreadsheets, each covering one specific urban mobility indicator. In the project, 46 European urban areas were tested with SUMI [9, 10].

Based on these index studies on sustainable transportation, the SURKENT index was developed by the study author in 2017 [11]. In the SURKENT, indicators that directly affect the sustainable transportation approach of cities and are renewable every year were selected. There are four main indicators in SURKENT: Environmental Performance (EP), Transportation Performance (TP), Energy Performance (EnP) and Municipality Governance Performance (MGP). In the first version of SURKENT, there are 14 sub-indicators under these 4 main indicators, some of which are qualitative and some of which are quantitative. While some of the index studies in the literature include many performance indicators under the headings of economic, social and environmental indicators [6, 7], some others include many performance indicators independent of these three headings [8, 9]. Unlike index studies in the literature, the Municipality Governance Performance indicators is included in SURKENT. Sub-indicators in the MGP allow Türkiye-specific conditions to be included in the index.

In this study, Ankara's sustainable urban transportation performance is compared with Istanbul, Izmir, Konya and Antalya using SURKENT.

2. Methodology

In the study, unlike the first version of the SURKENT index, some indicators were removed and new indicators were added and 15 sub-indicators were defined under 4 main categories. These four main indicators, 15 sub-indicators and the weights of these sub-indicators were determined by consulting 5 different expert opinions (2 civil engineers, 2 city and regional planners and 1 industrial engineer). The % weights in Table 1 were determined by averaging expert opinions for each sub-indicator. In addition, experts were asked to indicate the positive or negative effect of the sub-indicator on sustainable urban transportation performance. The four main categories and sub-indicators in SURKENT are:

Environmental Performance Indicators (EPi)
- CO_2 emissions (EPi1)
- Air quality, particulate matter PM_{10} (EPi2)
- Traffic noise (EPi3)
- Green space per capita (EPi4)

Transportation Performance Indicators (TPi)
- Average vehicle trip per person (TPi1)
- Passenger cars per 1 000 people (TPi2)
- Percentage of public transport trips (TPi3)
- Percentage of trips taken by walking (TPi4)
- Percentage of private car trips (TPi5)
- The length of bicycle paths (TPi6)
- Road traffic deaths per 1000 inhabitants (TPi7)

Energy Performance Indicators (EnPi)
- Fuel consumption per capita (EnPi1)
- Renewable energy potential (EnPi2)

Municipality Governance Performance Indicators (MGPi)
- Intelligent transportation systems (ITS) performance (MGPi1)
- Life quality (MGPi2)

The quantitative data in the sub-indicators were indexed between 0 and 100 by the minimum-maximum normalization technique (Equation 1). Scoring of 0-100 was used for qualitative data. After normalization of the data, index values for the four main indicators were calculated using Equation 2. The final index value was calculated by summing the index values of the 4 main indicators (Equation 3).

$$\text{Normalized } Xi = \frac{(Xi - Xmin)}{(Xmax - Xmin)} . 100 \quad (1)$$

$$\text{Main indicator index} = \sum(\%\ \text{Weight} . \text{Normalized } X_i) \quad (2)$$

$$\text{Final index} = EPi + TPi + EnPi + MGPi \quad (3)$$

Table 1 shows the following information about the indicators: indicator type, weight, effect on the index, normalization technique.

2.1. Environmental Performance Indicators (EPi)

CO_2 emissions (EPi1): CO_2 emissions from road transportation are an important pollutant with a high rate among all greenhouse gas emissions. In this sub-indicator; CO_2 emission values in Gg CO_2 equivalent(e.) per person, per vehicle and per km^2 were used. The data in EPi1 was taken from the study titled "Comparative Analysis of the Amount of Greenhouse Gas Emissions from Road Transportation in Metropolitan Cities of Türkiye" prepared by Dündar (2021) [12]. The weight of EPi1 in the main indicator of environmental performance is 30% and its effect on the final index is negative. Each of the Gg CO_2 equivalent (e.) emission values per person, per vehicle and per km^2 has the same weight (%10).

Air quality, particulate matter PM_{10} (EPi2): Air pollution is a problem that has negative effects on human health and whose importance increases day by day. In this sub-indicator, particulate matter (PM_{10}- $\mu g/m^3$) data in the World Health Organization Air Pollution Data Portal was used [13]. Current data for this sub-indicator can be obtained from the Republic of Türkiye Ministry

Table 1. Indicators table summary

Main Indicators	Sub indicators	Ind. type*	Weight %	Effect **	Norm. technique
Environmental Performance (EP)	CO_2 EPi1	1	30	N	Min-Max
	PM_{10} Epi2	1	30	N	Min-Max
	Traffic noise Epi3	1	15	N	Min-Max
	Green space Epi4	1	25	P	Min-Max
Transportation Performance (TP)	Average vehicle trip TPi1	1	10	N	Min-Max
	Passenger cars TPi2	1	10	N	Min-Max
	Public transport TPi3	1	20	P	Min-Max
	Walking TPi4	1	20	P	Min-Max
	Private car TPi5	1	15	N	Min-Max
	Bicycle path length TPi6	1	15	P	Min-Max
	Road traffic deaths TPi7	1	10	N	Min-Max
Energy Performance (EnP)	Fuel consumption EnPi1	1	50	N	Min-Max
	Renewable energy EnPi2	2	50	P	0-100
Municipality Governance Performance (MGP)	ITS performance MGPi1	2	50	P	0-100
	Life quality MGPi2	2	50	P	0-100

* 1: quantitative 2: qualitative
*** N: Negative P: Positive*

of Environment, Urbanization and Climate Change, National Air Quality Monitoring Network website [14]. The weight of EPi2 in the main indicator of environmental performance is 30% and its effect on the final index is negative.

Traffic noise (EPi3): A significant portion of the noise in urban areas is caused by traffic-related noise. In this sub-indicator, the proportion of the population affected by road traffic noise above 60 dB(A) was used. Noise data in EPi3 was taken from noise action plans of cities. The data for Ankara was produced by the author using noise maps of Ankara Metropolitan Municipality [15-19]. The weight of EPi3 in the main indicator of environmental performance is 15% and its effect on the final index is negative.

Green space per capita (EPi4): Green space; in addition to functions such as microclimate, improving air, filtering dust and reducing noise, it also has functions of positively affecting the physical and spiritual structure of humans [20]. In this sub-indicator, active green space per capita (m^2/person) data was used. The data in EPi4 was taken from activity reports prepared by municipalities [21-25]. The weight of EPi4 in the main indicator of environmental performance is 25% and its effect on the final index is positive.

2.2. Transportation Performance Indicators (TPi)

Average vehicle trip per person (TPi1): In transportation planning, it is necessary to know average number of daily trips per person. In this sub-indicator, the average number of daily vehicle trips per person was used. The data in TPi1 was taken from the study titled "The approaches in urban transportation planning studies in Türkiye; problems and solutions" prepared by Özalp (2007) [26]. The weight of TPi1 in the main indicator of transportation performance is 10% and its effect on the final index is negative.

Passenger cars per 1 000 people (TPi2): Due to policies that prioritize private transportation in Türkiye individual vehicles, which are an inefficient mode of transport compared to public transportation, are widely used. Reducing private vehicle trips is an important parameter for the sustainability of urban transportation. In this sub-indicator, passenger cars per 1,000 people was used. The data in TPi2 was taken from Turkish Statistical Institute (TURKSTAT) [27]. The weight of TPi2 in the main indicator of transportation performance is 10% and its effect on the final index is negative.

Percentage of public transport trips (TPi3): The sustainability of transportation is directly related to the share of public transportation trips in all trips. In many cities around the world that adopt sustainable urban transportation approaches, priority is given to public transportation systems and policies that encourage and promote public transportation are implemented. In this sub-indicator, the share of public transport trips in total trips was used. The data in TPi3 was taken from transportation master plans prepared by municipalities [28, 29, 30, 26]. The weight of TPi3 in the main indicator of transportation performance is 20% and its effect on the final index is positive.

Percentage of trips taken by walking (TPi4): The prevalence of walking trips are great importance in improving personal and social health, reducing environmental pollution and creating more livable cities. In this sub-indicator, the share of trips taken by walking in total trips was used. The data in TPi4 was taken from transportation master plans prepared by municipalities [28, 29, 30, 26]. The weight of TPi4 in the main indicator of transportation performance is 20% and its effect on the final index is positive.

Percentage of private car trips (TPi5): Private car is preferred by road users because it provides comfort and freedom and also due to inadequate public transportation services. High rate of private car trips has a very negative impact on the sustainability transportation. Therefore, private vehicles, which are extremely inefficient in terms of energy consumption, environmental pollution, capacity and traffic safety, should not be encouraged. In this sub-indicator, the share of private vehicle trips in total trips was used. The data in TPi5 was taken from transportation master plans prepared by municipalities [28, 29, 30, 26]. The weight of TPi5 in the main indicator of transportation performance is 15% and its effect on the final index is negative.

The length of bicycle paths (TPi6): Cycling is a mode of transportation that does not pollute the environment, reduces fuel consumption and is also very beneficial for human health. In this sub-indicator, the rate of the bicycle path length to the land of the city (km/km^2) was used. The data in TPi6 was taken from the "Roadmap Workshop for the Development of Bicycle Transportation for Municipalities" report prepared by World Resources Institute (WRI) Türkiye [31]. The weight of TPi6 in the main indicator of transportation performance is 15% and its effect on the final index is positive.

Road traffic deaths per 1000 inhabitants (TPi7): Road traffic accidents are an important public health problem for Türkiye as for all countries. Approximately 1.35 million people worldwide die each year due to road traffic injuries [32]. In addition, traffic accidents cause a serious economic losses for individuals, their families, and for nations. In building a sustainable transportation infrastructure, it is very important to provide a safe traffic environment for all road users. In this sub-indicator, road traffic deaths per 1000 person was used. The data in TPi7 was taken from TURKSTAT [33]. The weight of TPi7 in the main indicator of transportation performance is 10% and its effect on the final index is negative.

2.3. Energy Performance Indicators (EnPi)

Fuel consumption per capita (EnPi1): More than 2/3 of the world's energy consumption; It is met from fossil resources such as coal, oil and natural gas. Similarly, almost all of the primary energy consumption is met from fossil resources in Türkiye. This dependence on fossil resources causes external dependence for Türkiye, which does not have sufficient oil and natural gas reserves [34]. In this sub-indicator, the amount of gasoline and diesel consumption per capita were used. The data in EnPi1 was taken from "Türkiye Oil Market 2021 Sector Report" [35]. Fuel consumption per capita was calculated using TURKSTAT population data. The weight of EnPi1 in the main indicator of energy performance is 50% and its effect on the final index is negative.

Renewable energy potential (EnPi2): Renewable energy sources such as solar, wind, wave power, bioenergy and geothermal energy are important energy sources that do not pollute the environment, reduce countries' external dependence and ensure sustainability in energy consumption [36]. In this sub-indicator; data on wind, geothermal and solar energy potentials of cities were used. The data in EnPi2 was created using Türkiye's Wind Power Plants Distribution Atlas [37], Türkiye's Geothermal Resources, Projections, Problems and Recommendations Report [38] and Solar Energy Potential Atlas [39]. For wind energy potential, the number of wind power plants in operation and the power of the plants (MW), for geothermal energy potential, the number of geothermal wells, and for solar energy potential, the annual average total radiation value (KWh/m2) were taken into account. Renewable energy potentials of cities were produced by the author using 0-100 scoring. The weight of EnPi2 in the main indicator of energy performance is 50% and its effect on the final index is positive.

2.4. Municipality Governance Performance Indicators (MGPi)

Intelligent transportation systems (ITS) performance (MGPi1): ITS are information communication-based systems that exchange versatile data between the user, vehicle, infrastructure, center, and include monitoring, measuring, analysis and control mechanisms. Reducing travel times, increasing traffic safety, efficient use of road capacities, increasing mobility, efficient use of energy and reducing damage to the environment are the main objectives of ITS [40]. In the MGPi1 indicator, the number of smart applications such as mobile information systems, electronic map systems, traffic control cameras, traffic monitoring systems, adaptive traffic control, electronic traffic control systems, variable message signs, smart parking management systems, smart road lighting systems, vehicle tracking systems, electronic fee collection, smart bus stop was taken into account. The data in MgPi1 was created by the author using the information on the Republic of Türkiye Ministry of Environment, Urbanization and Climate Change, Smart Cities Department website and the reports prepared by the ministry [41]. Scoring between 0-100 was used for the ITS performances of cities. The weight of MGPi1 in the main indicator of Municipality Governance Performance is 50% and its effect on the final index is positive.

Life quality (MGPi2): WHO defines Quality of Life as an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns [42]. Transportation activities, which take an important place in urban life, and the problems they bring with them, significantly affect the quality of life of urban residents. The data in MGPi2 was taken from the "Türkiye's Cities Sustainability Research" study prepared by Boğaziçi Universty & Mastercard [43]. In this study, climate, gender equality index, natural resources index, environmental quality index, order and security index, economic performance index, culture-arts and physical infrastructure indicators were taken into account for the quality of life. Quality of life scores were used by converting them into a 0-100 scoring. The weight of MGPi2 in the main indicator of Municipality Governance Performance is 50% and its effect on the final index is positive.

3. Research Findings

Table 2 shows the findings of the environmental performance indicator. According to EPi1, İstanbul has the lowest value in CO_2 emissions per capita, while Ankara has the highest. While İstanbul has the lowest value in CO_2 emissions per vehicle, Konya has the highest. Konya has the lowest value in CO_2 emissions per km^2, while İstanbul has the highest. İstanbul's high population density and high number of vehicles are the factors that affect these results. According to particulate matter PM_{10} ($\mu g/m^3$) data, İstanbul has the lowest value and İzmir has the highest. According to noise data, Antalya has the highest population affected by traffic-related noise, while İzmir has the lowest population. The highest value in the green space per capita belongs to Konya, and the lowest value belongs to Antalya.

Table 3 shows the normalized and weighted EPi data. According to total scores in EPi, Konya ranks first, followed by İstanbul, Ankara, Antalya and İzmir. The sub-indicator that affects Konya's success in this main indicator is the amount of green space per capita. The sub-indicator that causes İzmir to rank fifth is air quality. (PM_{10} $\mu g/m^3$).

Table 4 shows the findings of the transportation performance indicator. According to TPi1, İzmir ranks first in average daily vehicle trips per person. It is followed by İstanbul and Ankara.

Table 2. Data of the environmental performance indicators

	EPi1			EPi2	EPi3						EPi4
	Gg CO_2e (Per person $x10^{-4}$)	Gg CO_2e (Per vehicle $x10^{-4}$)	Gg CO_2e (Per km^2 $x10^{-4}$)	PM_{10} ($\mu g/m^3$)	50-54 (dBA)	55-59 (dBA)	60-64 (dBA)	65-69 (dBA)	>70 (dBA)	Population rate above 60 dB(A)	Green space (m^2/per person
Ankara	14.53	41.49	3196	45.68	Produced from Ankara Metropolitan Municipality noise maps.					30	21
Antalya	11.97	37.17	1490	47.49	100400	63500	44100	32300	41000	41.73	3.2
İstanbul	9.17	37.02	26071	39.66	8890600	1746100	1144500	776800	734300	19.98	7.73
İzmir	11.03	41.65	4050	56.2	2416000	236500	155700	104000	50100	10.46	8.31
Konya	13.18	47.72	720	43.01	290400	173700	112400	84400	85300	37.80	48

Table 3. EPi index scores

	EPi1						EPi2		EPi3		EPi4		EPi Total score
	Gg CO_2e Per person $x10^{-4}$		Gg CO_2e Per vehicle $x10^{-4}$		Gg CO_2e Per km^2 $x10^{-4}$		PM_{10} ($\mu g/m^3$)		Population rate above 60 dB(A)		Green space m^2/per person		
	N	W	N	W	N	W	N	W	N	W	N	W	
Ankara	100.00	-10.00	41.78	-4.18	9.77	-0.98	36.40	-10.92	62.48	-9.37	39.73	9.93	-25.51
Antalya	52.24	-5.22	1.40	-0.14	3.04	-0.30	47.34	-14.20	100.00	-15.00	0.00	0.00	-34.87
İstanbul	0.00	0.00	0.00	0.00	100.00	-10.00	0.00	0.00	30.44	-4.57	10.11	2.53	-12.04
İzmir	34.70	-3.47	43.27	-4.33	13.14	-1.31	100.00	-30.00	0.00	0.00	11.41	2.85	-36.26
Konya	74.81	-7.48	100.00	-10.00	0.00	0.00	20.25	-6.08	87.43	-13.12	100.00	25.00	-11.67

N: Normalized W: Weighted

Table 4. Data of the transportation performance indicators

	TPi1	TPi2	TPi3	TPi4	TPi5	TPi6	TPi7
	Average vehicle trip per inhabitant	Passenger cars per 1 000 people	Percentage of public transport trips	Percentage of trips taken by walking	Percentage of private car trips	The length of bicycle paths (km/km^2)	Road traffic deaths per 1000 inhabitants
Ankara	1.33	298	49	28	23	0.08	0.05
Antalya	1.15	231	42	32	26	0.1	0.09
İstanbul	1.54	207	35	45	20	2.93	0.02
İzmir	1.59	199	39	37	24	0.5	0.06
Konya	1.10	169	37	39	24	1.26	0.12

Table 5. TPi index scores

	TPi1		TPi2		TPi3		TPi4		TPi5		TPi6		TPi7		TPi Total score
	Average vehicle trip per inhabitant		Passenger cars per 1 000 people		Percentage of public transport trips		Percentage of trips taken by walking		Percentage of private car trips		The length of bicycle paths (km/km^2)		Road traffic deaths per 1000 inhabitants		
	N	W	N	W	N	W	N	W	N	W	N	W	N	W	
Ankara	46.94	-4.69	100.00	-10.00	100.00	20.00	0.00	0.00	50.00	-7.50	0.00	0.00	25.14	-2.51	-4.71
Antalya	10.20	-1.02	48.06	-4.81	50.00	10.00	23.53	4.71	100.00	-15.00	0.70	0.11	68.38	-6.84	-12.85
İstanbul	89.80	-8.98	29.46	-2.95	0.00	0.00	100.00	20.00	0.00	0.00	100.00	15.00	0.00	0.00	23.07
İzmir	100.00	-10.00	23.26	-2.33	28.57	5.71	52.94	10.59	66.67	-10.00	14.74	2.21	37.42	-3.74	-7.55
Konya	0.00	0.00	0.00	0.00	14.29	2.86	64.71	12.94	66.67	-10.00	41.40	6.21	100.00	-10.00	2.01

N: Normalized W: Weighted

Konya, where bicycles are widely used and car ownership is lowest, has the lowest average daily vehicle trips per person. According to TPi2, Ankara has the highest value of car ownership per 1000 people. Ankara is followed by Antalya and İstanbul. The higher the rate of public transport trips in a city, the higher the sustainability of transportation. Although Ankara has the highest value in car ownership, it is the city with the highest rate of public transportation trips in all trips. This is an important factor for Ankara to have sustainable urban transportation. İstanbul has the highest value for trips taken by walking. Due to heavy traffic congestion in İstanbul, pedestrian trips are preferred. The rate of private car trips are close to each other in the 5 cities. The increase

in bicycle trips, like the increase in public transportation trips, is a factor that affects the sustainability of the city's transportation. However, the importance of providing safe cycling infrastructure accurately and completely should not be forgotten. According to TPi6, İstanbul ranks first and Konya ranks second in the length of bicycle paths. According to TPi7, Konya has the highest value in the death rate due to road traffic accidents, while İstanbul has the lowest value.

Table 5 shows the normalized and weighted TPi data. According to total scores in TPi, İstanbul ranks first, followed by Konya, Ankara, İzmir and Antalya. İstanbul's score in this main indicator is significantly higher than the other 4 cities. Therefore, it is possible to say that İstanbul is the most successful city in terms of transportation performance indicators. Sub-indicators affecting Istanbul's success are the percentage of pedestrian trips and the length of bicycle paths. The sub-indicator that causes Antalya to rank fifth is the percentage of travel by private vehicle.

Table 6 shows the findings of the energy performance indicator. According to EnPi1, Konya has the highest value in fuel consumption per capita and Ankara's value is very close to Konya. According to EnPi2, İzmir has the highest value in renewable energy potential, while Ankara has the lowest.

Table 7 shows the normalized and weighted EnPi data. According to total scores in EnPi, İstanbul ranks first, followed by İzmir, Antalya, Konya and Ankara. The sub-indicator that affects İstanbul's success in this main indicator is that it has the lowest value in fuel consumption per capita. Ankara ranks last in this main indicator due to having the lowest renewable energy potential.

Table 6. Data of the energy performance indicators

	EnPi1 Fuel consumption per capita	EnPi2 Renewable energy potential			
		Wind	Geothermal	Solar	Average
Ankara	0.3903	20	50	50	40
Antalya	0.3424	40	10	100	50
İstanbul	0.2626	90	20	40	50
İzmir	0.3228	100	100	70	90
Konya	0.3996	50	40	80	57

Table 7. EnPi index scores

	EnPi1 Fuel consumption per capita		EnPi2 Renewable energy potential		EnPi Total score
	N	W	Average	W	
Ankara	93.22	-46.61	40	20	-26.61
Antalya	58.24	-29.12	50	25	-4.12
İstanbul	0.00	0.00	50	25	25.00
İzmir	43.96	-21.98	90	45	23.02
Konya	100.00	-50.00	57	28.5	-21.50

N: Normalized W: Weighted

Table 8 shows the findings of the municipality governance performance indicator and the normalized and weighted MGPi data. According to MGPi1, İstanbul has the highest value in ITS performance, while Antalya has the lowest. Although the quality of life values of the 5 cities are close to each other, Antalya has the highest value and İstanbul has the lowest. According to total scores in MGPi, İstanbul ranks first, followed by Ankara, İzmir, Konya and Antalya. "Sustainable Urban Mobility Plans SUMP", which has been developed by European policy makers since 2005, has started to be implemented in many European cities [44]. Many municipalities in Türkiye have adopted the SUMP planning approach and started working. İstanbul is the city that has made the most progress in SUMP studies. İstanbul Sustainable Urban Mobility Plan (SKHP) was published in March 2022 [45].

Table 8. Data of the municipality governance performance indicators and MGPi index scores

	MGPi1 ITS performance		MGPi2 Life quality		MGPi Total score
	0-100 scoring	W	0-100 scoring	W	
Ankara	80	40	65.60	32.80	72.80
Antalya	50	25	68.30	34.15	59.15
İstanbul	90	45	57.00	28.50	73.50
İzmir	70	35	66.30	33.15	68.15
Konya	60	30	63.20	31.60	61.60

W: Weighted

Table 9 shows the final index scores for 5 cities. According to the final index, İstanbul ranks first, followed by İzmir, Konya, Ankara and Antalya.

Table 9. Final index scores

	EPi score	TPi score	EnPi score	MGPi score	Final index score	Rank
Ankara	-25.51	-4.71	-26.61	72.80	15.97	4
Antalya	-34.87	-12.85	-4.12	59.15	7.30	5
İstanbul	-12.04	23.07	25.00	73.50	109.54	1
İzmir	-36.26	-7.55	23.02	68.15	47.36	2
Konya	-11.67	2.01	-21.50	61.60	30.44	3

4. Conclusions

When evaluated in terms of CO_2 emissions, it is possible to say that Ankara has a negative potential. The fact that Ankara ranks second after Konya in the green space per capita is a positive situation in terms of sustainable transportation. Although Ankara's having the highest value in car ownership creates a negative potential in terms of sustainable transportation, having the highest share of public transport trips in total trips provides a positive potential. Infrastructure work to increase the length of bicycle paths in Ankara continues rapidly. With the SMART Ankara project implemented by Ankara Metropolitan Municipality, efforts continue to make urban transportation more sustainable.

Conflict of Interest Statement

The author declare that there is no conflict of interest in the study.

References

[1] Khor N, Arimah B, Otieno R, Oostrum MV, Mutinda M, Martins JO. Envisaging the Future of Cities, World Cities Report 2022. UN-Habitat press; 2022.

[2] Nuray A, Reis Manap G, Sarioğlu K, A. Sanalan T, Aydi S. Environmental Indicators. Ministry of Environment and Urbanization. ISBN: 978-625-7076-19-7, Publication No: 49-2; 2021.
[3] Brundtland Commission. Report of the World Commission on Environment and Development: Our Common Future. Oxford University Press. UK; 1987.
[4] Öncü E, Öncü Yıldız A. Sürdürülebilir Ulaşım: Devlet Bunun Neresinde? IMO 9. Ulaştırma Kongresi. Türkiye/İstanbul, 16-18 May 2011.
[5] Watson J. European Green City Index: Assessing the environmental impact of Europe's major cities. Publisher: Siemens AG; Munich, Germany, 2009
[6] Litman T. Sustainability and Livability. Summary of Definitions, Goals, Objectives and Performance Indicators. Victoria Transport Pplicy Institute. 11 March 2011.
[7] Ahn KY. Sustainable Urban Transport Evaluation (SUTE) and the Way Forward. The Korea Transport Institute Report; 2015.
[8] Regmi MB, Shivanand Swamy HM. Sustainable Urban Transport Index (SUTI) Data Collection Guideline. Economic and Social Commission for Asia and the Pacific (ESCAP) Report; 2019.
[9] Rupprecht Consult-Forschung & Beratung GmbH. Sustainable Urban Mobility Indicators (SUMI): Harmonisation Guideline. World Business Council for Sustainable Development; 2020.
[10] Rupprecht Consult-Forschung & Beratung GmbH. Sustainable Urban Mobility Indicators (SUMI) Project Details; 2020.
[11] Arıkan Öztürk E. Sustainable Urban Transport Index (SURKENT). TRANSIST 2017 International Istanbul Transportation Congress. Türkiye/İstanbul, 02-04 November 2017.
[12] Dündar AO. Comparative Analysis of the Greenhouse Gas Emissions from Road Transport in the Metropolitan Cities of Türkiye. The Journal of Natural Hazards and Environment. 2021;7(2): 318-337.
[13] WHO World Health Organization. Air Quality Database; Excel version of the database - Ambient (outdoor) air quality database, by country and city; 2022.
14] Republic of Türkiye Ministry of Environment, Urbanisation and Climate Change.National Air Quality Monitoring Network; 2022.
[15] Istanbul Metropolitan Municipality. Istanbul Noise Level Reduction Action Plan (İSGEP); 2018.
[16] İzmir Metropolitan Municipality. İzmir Noise Action Plan (İGEP); 2022.
[17] Akbulut Çoban N, Doğan G. Assessment of Environmental Noise Management Policiy in Antalya. The Second National Acoustics Congress And Exhibition, İzmir; 14-15 September 2017.
[18] Konya Metropolitan Municipality. Konya Environmental Noise Action Plan; 2017.
[19] Ankara Metropolitan Municipality. Strategic Noise Maps; 2020.
[20] Aksoy Y, Akpınar A. A Research About Public Green Area Use and Green Area Demand In Istanbul Fatih District. İstanbul Commerce University Journal of Science; 2011;10(20): 81-96.
[21] Istanbul Metropolitan Municipality. 2021 Annual Activity Report; 2021.
[22] İzmir Metropolitan Municipality. 2021 Annual Activity Report; 2021.
[23] Antalya Metropolitan Municipality. 2021 Annual Activity Report; 2021.
[24] Kaya ÜN. Exploring the relationship between accessibility of urban greenspace and user's psychological well-being: A sample from Konya city. Unpublished Master's Thesis, Konya Technical University, Graduate Education Institute; 2022:34.
[25] Ankara Metropolitan Municipality. 2021 Annual Activity Report; 2021.
[26] Özalp M. The approaches in urban transportation planning studies in Türkiye; problems and solutions. Unpublished Master's Thesis, Gazi Üniversity, Graduate School of Natural and Applied Sciences; 2007: .64, 76, 87, 107, 120.
[27] TURKSTAT Turkish Statistical Institute. The number of road motor vehicles by province 2021.
[28] Istanbul Metropolitan Municipality. İstanbul Transport Annual Report; 2017.
[29] Boğaziçi Project. Konya Transportation Master Plan; 2015.
[30] Boğaziçi Project. Antalya Transportation Master Plan; 2017.
[31] Akı, M. Roadmap Workshop for the Development of Bicycle Transportation for Municipalities. WRI Türkiye, Livable Cities Symposium; 25 October 2018
[32] WHO World Health Organization. Global status report on road safety 2018.
[33] TURKSTAT Turkish Statistical Institute. Road Traffic Accident Statistics; 2021.
[34] Republic of Türkiye Eastern Mediterranean Development Agency (DOĞAKA). Energy Sector Report; 2014.
35] Republic of Türkiye Energy Market Regulatory Authority. Türkiye Oil Market Sector Report; 2021.
[36] Karagöl ET, Kavaz İ. Renewable Energy in the World and Türkiye. SETA Foundation for Politics, Economics and Society Research Press; Issue: 197 April 2017.
[37] Türkiye Wind Power Plants Distribution Atlas, Türkiye Wind Energy Potential Map, enerjiatlasi.com; 2022.
[38] Akkuş İ, Alan H. Türkiye's Geothermal Resources, Projections, Problems and Recommendations Report 2016. Chamber of Geological Engineers of Türkiye Press; ISBN: 978-605-01-0852-1; 2016.
[39] Republic of Türkiye Ministry of Energy and Natural Resources. Solar Energy Potential Atlas; 2022.
[40] Talih, Ö, Tektaş, N.. A brief survey on cooperative intelligent transportation systems and applications. International Journal of Automotive Science and Technology.2023:7(3), 259-268.
[41] Republic of Türkiye Ministry of Environment, Urbanization and Climate Change. Smart Cities Successful Examples. İstanbul, İzmir, Antalya, Konya, Ankara; 2023.
[42] WHO World Health Organization. WHOQOL: Measuring Quality of Life; 2012.
[43] Boğaziçi Üniversity & Mastercard. Türkiye's Cities Sustainability Research; 2011.
44] Rupprecht S, Brand L, Böhler-Baedeker S, Brunner LM. Rupprecht Consult (Editor), Guidelines for Developing and Implementing a Sustainable Urban Mobility Plan, Second Edition; 2019.
[45] Gül ES, Bozdeveci S. İstanbul Sustainable Urban Mobility Plan (SUMP). İstanbul Metropolitan Municipality, Ove Arup & Partners International; 2022