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FORECASTING ROAD FREIGHT AND PASSENGER TRANSPORT DEMANDS IN TÜRKİYE USING THE EXPONENTIAL SMOOTHING

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Abstract: Exponential smoothing is a popular technique used to analyze and forecast trends in various industries such as road transportation and passenger transportation. This method is used to calculate weighted averages using historical data and adjust forecasts based on recent trends. In the Turkish context, forecasting transportation demands using exponential smoothing provides valuable information for transportation planning and resource allocation. The increasing number of vehicles has caused many negative environmental consequences. This study analyzed ten years of data on road freight and passenger transportation on a regional scale in order to make future predictions. In the study, solution suggestions are presented based on the findings and the policies that should be implemented to solve the problem are evaluated.

Keywords: Transportation, Transport demands, Exponential smoothing method, Forecasting

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1. Introduction

Transporting goods and people from one place to another via road vehicles is known as road transport. It is an essential component of the global logistics industry, responsible for moving around 70% of all world trade. The road transport process can be divided into four stages: planning, loading, transportation, and delivery. The planning stage involves taking into account factors such as the quantity and nature of the load, the transport distance, and the delivery date. The type of transport vehicle, cargo packaging, and palletizing are also determined during this stage. Loading is the process of securely placing the load onto the transport vehicle, carried out by loading personnel. Transporting the load from one point to another is then done by the driver. Finally, delivery involves handing over the cargo to the buyer, which is done by the loading personnel. The benefits of road transportation include its convenience, safety, speed, punctuality, and affordability. The advantages of road transportation are:

- Flexibility: Road transportation is more flexible than other types of transportation. Different vehicle types can be used depending on the amount and nature of the load.
- Speed: Road transportation is faster than other types of transportation.
- Cost: Road transportation is cheaper than other types of transportation.
- The disadvantages of road transport are:
- Capacity: Road transportation has less capacity than other types of transportation.
- Safety: Road transportation can be more dangerous than other types of transportation.
- Environmental impact: Road transportation may create more environmental impact than other types of transportation.

Road transportation is the most widely used type of transportation today because of those advantages (URL1). The transportation sector is the second largest energy consumer sector worldwide and makes a profound contribution to the economy, more obviously in developing countries (He et al., 2020) and (Sharif et al., 2019). The transportation sector around the world also causes an increase in the release of hazardous gases, such as CO_2 emissions in the air, and manufacturers are working to make the transportation sector more sustainable, which will give an alarming signal to this policy (Amin et.al., 2020). The increase and continuous growth of carbon emissions from the transportation sector attract the attention of politicians for sustainable transportation. A sustainable transport system is a key component of sustainable economic growth, providing its citizens with accessibility and mobility in safe and environmentally friendly transport modes (Alshehrya and Belloumia, 2016) and (Özkan et al., 2019). The energy used in road transportation can provide social and economic development, but it can have a negative impact on the environment and cause climate changes on a global scale (Figueroa and Ribeiro, 2013). Many recent studies emphasize that policies that direct transport towards a low-carbon path should be aligned with sustainable development goals and principles (Amekudzi, 2011). The energy used in road transportation can provide social and economic development, but it is thought to have a negative impact on the environment and cause climate change on a global scale (Edenhofer, 2015). According to the report published by the Organization of Petroleum Exporting Countries, the number of private vehicles used in 2009 is expected to increase from approximately 870 million to 1.76 billion in 2035 (Kahn et al., 2007). According to the same report, this rate in OECD countries will be four times higher than in countries that are still industrializing modeled regional and global car ownership for the year 2100 (Meyer et al., 2012) Global results give a range of 1.4–2.0 billion cars for 2035 and 1.7–2.8 billion cars for 2050.

According to studies, making significant transportation policy changes that reduce passenger travel levels themselves is the most effective way to timely and profoundly reduce transportation emissions in existing economies. This study utilized ten-year regional data on road freight and passenger transportation to make future predictions and discuss the results.

2. Materials and Methods

SPSS 21.0 and Eviews 9 software were used to analyze the data. Exponential correction methods were used in the 2023-2025 estimates of vehicle-km, passenger-km and ton-km data obtained from the General Directorate of Highways (KGM). Exponential correction methods are one of the most widely used methods in science. Series that have components that vary over time and that can be expressed with more than one regression curve since there is no regression curve are called stochastic trend series. The exponential smoothing method is known as a method suitable for all series with stochastic and deterministic trends (Yağımlı and Ergin, 2017). This trend can create future predictions using historical data with error and seasonality components (Bowerman at al., 1979). Exponentially decreasing data, but predominantly moving average data, are used. As a result of these ideas, the exponential smoothing method produces modeling of different components. Among these components, seasonal changes, trends, and overlapping components in the series at specified intervals are included (Yağımlı and Ergin, 2017). Exponential smoothing trend method is known as a minor method of feasible prediction. It is an important way to make predictions when there are only a few observations to base it on. In contrast to constant coefficient regression model predictions, exponential smoothing trend method predictions are adjusted based on past prediction errors (Bowerman at al., 1979). Since annual data between 2013 and 2022 were used in this study, that is, there was no seasonal data, the Holt-Winters exponential smoothing method was used. The method used is suitable for series with no seasonal changes. Additionally, the method used is like the double smoothing method in that it does not include a seasonal component and produces linearly trending forecasts. The method called the double smoothing method is more discriminative because it uses only one parameter, but this method is a two-parameter method. The smoothed $\hat{y}_t$series is expressed by the following formula (equation 1):

$$\hat{y}_{t+k} = \alpha + bk \qquad (1)$$

In this formula, a and b are defined as the permanent component and the trend. These two coefficients are defined as follows (Equation 2-3):

$$a(t) = \alpha y_t + (1-\alpha)\big(a(t-1) + b(t-1)\big) \qquad (2)$$

$$b(t) = \beta\big(a(t) - a(t-1)\big) + 1 - \beta b(t-1) \qquad (3)$$

where $0<\alpha, \beta, \gamma < 1$ are the damping factors. This is a two-parameter exponential smoothing method. Estimates are calculated as given in Equation 4:

$$\hat{y}_{T+k} = a(T) + b(T)k \qquad (4)$$

The predictions expressed here lie in the linear trend intersected by the slope. Holt-Winters exponential smoothing model can be applied when both trend and seasonality are present, with the two components being either additive or multiplicative. Winters additive and multiplicative models was extremely high and both additive and multiplicative models (Djakaria and Saleh, 2021; Konarasinghe, 2021). T Non-Seasonal Two-Parameter Holt-Winters are not by addition with or multiplication by $\gamma = 0$. The condition $\gamma = 0$ only restricts the temporal variation of seasonal factors (Bergmeir et al., 2016).

3. Results and Discussion

3.1. Findings Regarding Vehicle-Km Data

Table 1 includes the vehicle-km data of the highways between 2013 and 2022.

According to analyzing the vehicle-km data from Table 1, it is evident that the vehicle-km values have increased between 2013 and 2022. The 1st Region had the highest vehicle-km values in 2013 and 2022, whereas the 6th Region had the lowest vehicle-km values in 2013 and the 9th Region had the lowest values in 2022. Figure 1 depicts the regional level of vehicle-km values on highways from 2013 to 2022.

The data in Table 2 indicates that the largest proportional increase compared to the previous year happened in 2021 with a 17.4% increase. Based on the data from 2013, the total change in vehicle-km in 2022 is a 60% increase. At a regional level, the 6th Region had the highest proportional increase compared to the previous year with 103% in 2021, while the 14th Region had the highest increase in 2017 with 82.9%. Based on the 2013 data, the 14th Region saw the highest increase in vehicle-km on highways with 497% and the 6th Region with 258% in 2022. Figure 2 displays the regional level of proportional increase in vehicle-km on highways between 2013 and 2022.

Table 1. 2013-2022 vehicle-km values of highways (x1000)

Region	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1	9,373,246	9,615,197	10,048,391	10,057,524	10,754,897	11,016,764	11,567,943	9,472,109	10,871,917	11,620,266
2	1,840,373	2,108,009	2,389,097	2,548,834	2,781,404	2,880,849	3,782,512	3,239,337	3,741,236	4,120,231
4	2,554,100	2,690,956	3,042,077	3,282,559	3,420,856	3,460,344	3,671,414	3,453,687	4,135,131	4,121,714
5	3,211,085	3,313,686	3,891,533	4,124,861	4,365,945	4,202,703	4,579,920	4,346,316	4,987,506	5,041,811
6	239,218	264,644	306,561	326,778	347,780	299,392	370,926	362,289	735,459	855,702
9	320,001	318,510	335,246	331,349	361,571	349,807	379,961	335,151	436,891	429,682
14	426,807	448,667	568,299	671,541	1,227,961	1,405,242	1,953,121	2,089,794	2,439,661	2,549,440
Total	17,964,830	18,759,669	20,581,204	21,343,446	23,260,414	23,615,101	26,305,797	23,298,683	27,347,801	28,738,846

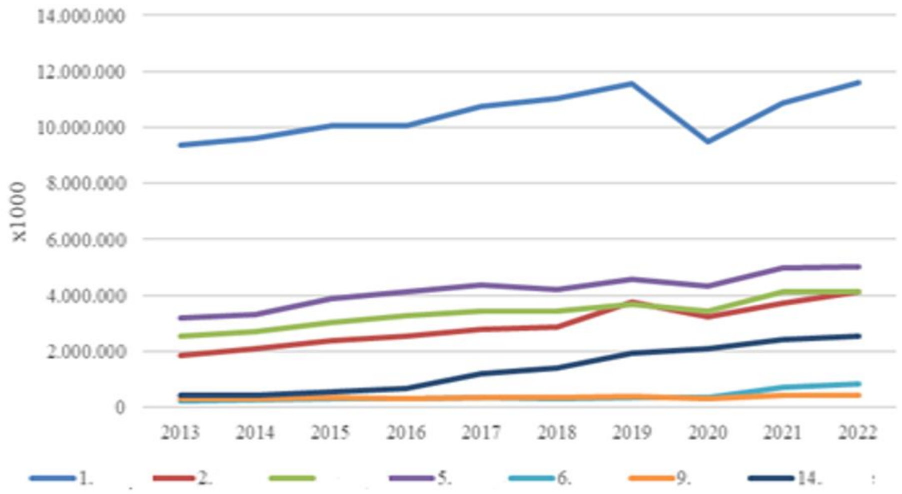

Figure 1. 2013-2022 vehicle-km values of highways (x1000).

Table 2. 2013-2022 vehicle-km change rates of highways (%)

Area	2014	2015	2016	2017	2018	2019	2020	2021	2022	2013-2022
1	2.6	4.5	0.1	6.9	2.4	5.0	-18.1	14.8	6.9	24.0
2	14.5	13.3	6.7	9.1	3.6	31.3	-14.4	15.5	10.1	123.9
4	5.4	13.0	7.9	4.2	1.2	6.1	-5.9	19.7	-0.3	61.4
5	3.2	17.4	6.0	5.8	-3.7	9.0	-5.1	14.8	1.1	57.0
6	10.6	15.8	6.6	6.4	-13.9	23.9	-2.3	103.0	16.3	257.7
9	-0.5	5.3	-1.2	9.1	-3.3	8.6	-11.8	30.4	-1.7	34.3
14	5.1	26.7	18.2	82.9	14.4	39.0	7.0	16.7	4.5	497.3
Total	4.4	9.7	3.7	9.0	1.5	11.4	-11.4	17.4	5.1	60.0

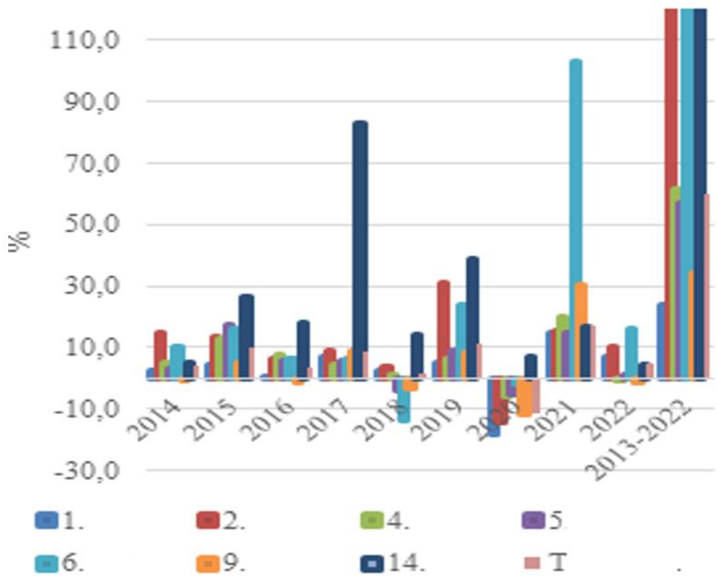

Figure 2. 2013-2022 vehicle-km change rates of highways compared to the previous year (y axis %).

According to Figure 2, it is evident that there was a rapid change in vehicle-km rates, especially in a negative direction, in all regions in 2020 and in a positive direction in all regions in 2021.

Table 3 includes the vehicle-km 2023-2025 forecast results of highways. The non-seasonal Holt-Winters (No Seasonal) method was used as the forecasting method.

Table 3. Vehicle-km 2023-2025 estimation results of highways (x1000)

Area	2023	2024	2025
1	11,530,467	11,593,445	11,656,422
2	4,272,927	4,535,987	4,799,047
4	4,366,588	4,547,836	4,729,085
5	5,256,279	5,454,603	5,652,926
6	1,102,829	1,344,886	1,586,943
9	425,104	445,773	466,442
14	2,752,738	2,948,425	3,144,112
Total	29,265,372	30,395,426	31,525,480

Based on the Holt-Winters non-seasonal double-parameter exponential correction, the prediction results show that the total vehicle kilometers traveled on highways will reach 31,525,480,000 by 2025. Additionally, when examining these results at the regional level, it is observed that the 1st Region will continue to have the highest vehicle-kilometer value in 2025.

3.2. Findings on Passenger-Km Data

Table 4 shows the passenger-km data of the highways between 2013 and 2022.

According to Table 4, it is seen that the passenger-km values increased between 2013 and 2022. In 2013, the highest passenger-km values were in the 1st Region, the lowest passenger-km values were in the 6th Region, in

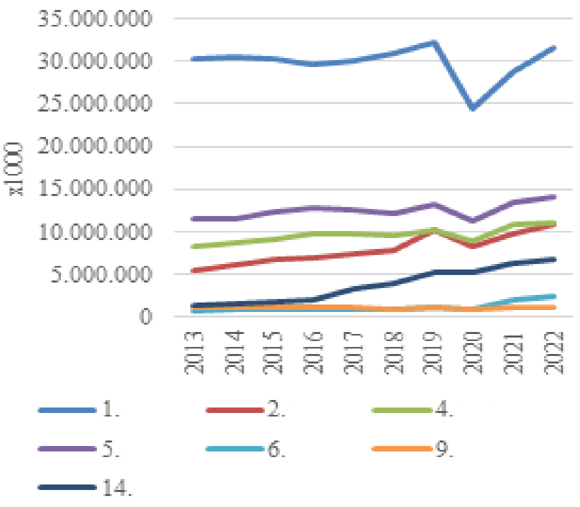

Figure 3. 2013-2022 passenger-km values of highways (x1000).

Based on Table 5, the year with the highest proportional increase, compared to the previous year, was 2020 with a 20.2% rise. In 2022, the total passenger-km change is expected to increase by 32% when compared to the figures from 2013. At a regional level, the greatest proportional increase compared to the previous year occurred in the 6th Region in 2021 (105%), and in the 14th Region in 2017 (71%). Based on 2013 data, it is noteworthy that the highest increase in passenger-km values on highways in 2022 took place in the 14th Region (380%) and in the 6th Region (185%). Figure 4 illustrates the regional level of the proportional increase in passenger-km values on highways between 2013 and 2022. Figure 4 shows that there has been a significant change in passenger-km rates, especially negative in 2020 and positive in 2021, across all regions.

Table 4. 2013-2022 passenger-km values of highways (x1000)

Region	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1	30,281,515	30,468,944	30,311,035	29,670,496	30,079,065	30,955,116	32,274,161	24,492,245	28,817,243	31,494,552
2	5,431,719	6,083,866	6,674,117	7,038,355	7,450,457	7,768,206	10,251,643	8,222,334	9,725,348	10,943,829
4	8,363,070	8,618,078	9,229,735	9,715,846	9,825,595	9,656,624	10,192,313	8,865,138	10,864,595	11,067,571
5	11,431,733	11,484,347	12,447,559	12,759,908	12,578,186	12,189,180	13,240,113	11,382,607	13,375,120	14,061,621
6	828,337	891,645	977,804	1,018,416	999,488	869,660	1,068,726	950,408	1,950,905	2,363,647
9	1,244,230	1,198,777	1,151,487	1,083,682	1,086,683	1,053,790	1,141,543	885,952	1,185,690	1,227,453
14	1,413,706	1,545,180	1,730,390	1,987,997	3,392,382	3,896,897	5,333,551	5,306,587	6,337,051	6,788,729
Total	58,994,310	60,290,837	62,522,127	63,274,700	65,411,856	66,389,473	72,502,050	60,105,271	72,255,952	77,947,402

Table 5. 2013-2022 passenger-km change rates of highways (%)

Area	2014	2015	2016	2017	2018	2019	2020	2021	2022	2013-2022
1	0.6	-0.5	-2.1	1.4	2.9	4.3	-24.1	17.7	9.3	4.0
2	12.0	9.7	5.5	5.9	4.3	32.0	-19.8	18.3	12.5	101.5
4	3.0	7.1	5.3	1.1	-1.7	5.5	-13.0	22.6	1.9	32.3
5	0.5	8.4	2.5	-1.4	-3.1	8.6	-14.0	17.5	5.1	23.0
6	7.6	9.7	4.2	-1.9	-13.0	22.9	-11.1	105.3	21.2	185.3
9	-3.7	-3.9	-5.9	0.3	-3.0	8.3	-22.4	33.8	3.5	-1.3
14	9.3	12.0	14.9	70.6	14.9	36.9	-0.5	19.4	7.1	380.2
Total	2.2	3.7	1.2	3.4	1.5	10.7	-18.2	20.2	7.9	32.1

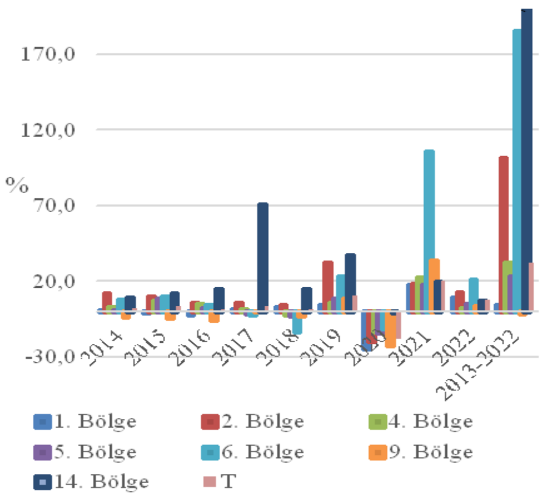

Figure 4. 2013-2022 passenger-km change rates of highways compared to the previous year (%).

Figure 4 illustrates the regional level of the proportional increase in passenger-km values on highways between 2013 and 2022. Figure 4 shows that there has been a significant change in passenger-km rates across all regions, especially negative in 2020 and positive in 2021. Table 6 shows the passenger-km 2023-2025 forecast results of highways. The non-seasonal Holt-Winters (No Seasonal) method was used as the forecasting method.

According to Table 5, the year that had the highest proportional increase in passenger-km compared to the previous year was 2020, with a rise of 20.2%. It is expected that in 2022, the total passenger-km change will increase by 32% compared to the numbers from 2013. At a regional level, the 6th Region had the greatest proportional increase compared to the previous year in 2021 (105%), and the 14th Region had the highest in 2017 (71%). It is worth noting that based on 2013 data, the highest increase in passenger-km values on highways in 2022 took place in the 14th Region (380%) and the 6th Region (185%).

Table 6. Passenger-km 2023-2025 forecast results of highways (x1000)

Area	2023	2024	2025
1	29,743,093	29,499,958	29,256,823
2	10,947,954	11,564,872	12,181,789
4	10,950,178	11,208,889	11,467,600
5	13,483,068	13,712,212	13,941,355
6	3,044,552	3,746,889	4,449,226
9	1,193,327	1,274,302	1,355,277
14	7,276,967	7,773,605	8,270,243
Total	73,784,36	75,263,668	76,742,701

3.3. Findings on Ton-Km Data

Table 7 includes ton-km data of highways between 2013 and 2022.

Table 7 data reveals that the ton-km values on highways have increased between 2013 and 2022. In 2013, the 1st Region had the highest ton-km values, while the 6th Region had the lowest. Similarly, in 2022, the 1st Region had the highest ton-km values, but the lowest were recorded in the 9th Region. Regional level ton-km values on highways between 2013 and 2022 are displayed in Figure 5.

Table 8 shows the change in ton-km data of highways at the regional level.

As Table 8, the highest proportional increase in ton-km values when compared to the previous year was recorded in 2021 at 17.9%. When compared to 2013, the total ton-km change in 2022 recorded an increase of 54.7%. The 6th Region recorded the highest proportional increase compared to the previous year in 2021 at 64.3% and the 14th Region recorded the same in 2017 at 53.9%.

Table 7. 2013-2022 ton-km values of highways (x1000)

Region	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1	24,841,564	25,978,351	26,667,732	26,605,152	27,684,119	28,836,103	28,591,508	27,075,092	31,640,354	31,655,989
2	3,013,552	3,287,588	3,603,833	3,915,975	4,311,525	4,783,947	6,852,455	6,021,556	7,189,090	8,335,133
4	7,171,248	7,637,588	8,347,276	8,870,871	8,472,227	8,499,779	8,729,400	8,506,144	10,188,632	9,881,511
5	12,347,585	12,927,194	13,969,457	14,385,420	14,427,253	14,217,564	15,425,187	15,460,914	17,503,573	18,873,952
6	835,350	929,246	1,086,233	1,185,431	1,128,446	1,024,494	1,216,286	1,320,837	2,169,578	2,908,691
9	1,611,370	1,625,944	1,610,179	1,499,090	1,586,260	1,513,559	1,648,895	1,368,370	1,808,203	1,986,114
14	1,257,564	1,343,215	1,591,018	1,817,677	2,796,703	3,242,044	3,883,990	3,932,667	4,601,682	5,379,799
Total	51,078,233	53,729,126	56,875,728	58,279,616	60,406,533	62,117,490	66,347,721	63,685,580	75,101,112	79,021,189

Table 8. shows the change in ton-km data of highways at the regional level

Area	2014	2015	2016	2017	2018	2019	2020	2021	2022	2013-2022
1	4.6	2.7	-0.2	4.1	4.2	-0.8	-5.3	16.9	0.0	27.4
2	9.1	9.6	8.7	10.1	11.0	43.2	-12.1	19.4	15.9	176.6
4	6.5	9.3	6.3	-4.5	0.3	2.7	-2.6	19.8	-3.0	37.8
5	4.7	8.1	3.0	0.3	-1.5	8.5	0.2	13.2	7.8	52.9
6	11.2	16.9	9.1	-4.8	-9.2	18.7	8.6	64.3	34.1	248.2
9	0.9	-1.0	-6.9	5.8	-4.6	8.9	-17.0	32.1	9.8	23.3
14	6.8	18.4	14.2	53.9	15.9	19.8	1.3	17.0	16.9	327.8
Total	5.2	5.9	2.5	3.6	2.8	6.8	-4.0	17.9	5.2	54.7

Based on 2013, the highest increase in ton-km values on highways in 2022 was recorded in the 14th Region at 327.8%, followed by the 6th Region at 248.2%, and the 2nd Region at 176.6%. Figure 6 shows the regional level of the proportional increase in ton-km values on highways between 2013 and 2022. According to Figure 6, it is evident that there was a rapid change in ton-km rates, especially in a negative direction, in all regions in 2020. However, in 2021, there was a positive change in all regions.

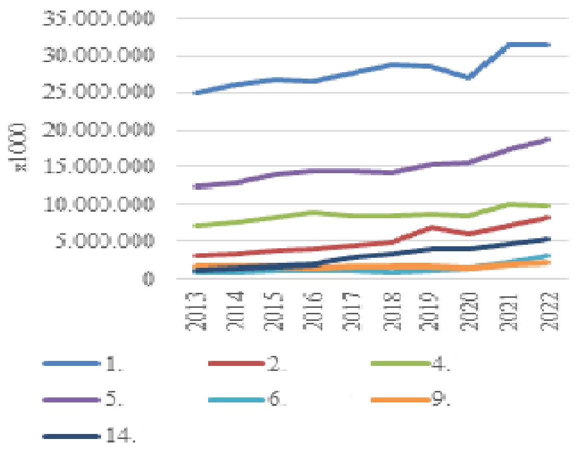

Figure 5. The course of ton-km values of highways in 2013-2022 (x1000).

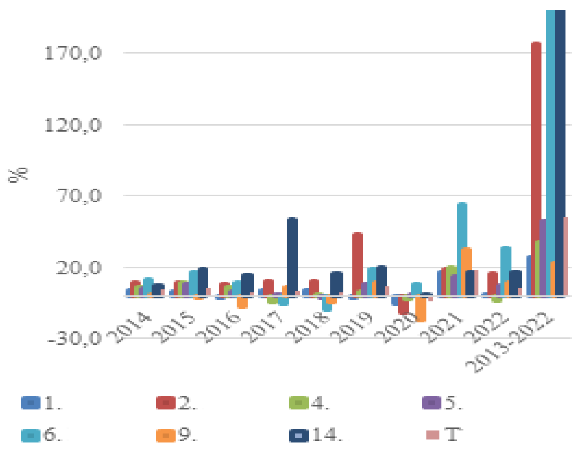

Figure 6. 2013-2022 ton-km change rates of highways compared to the previous year (%).

Table 9 shows the ton-km 2023-2025 forecast results of highways. The non-seasonal Holt-Winters (No Seasonal) method was used as the forecasting method.

Table 9. Ton-km 2023-2025 forecast results of highways (x1000)

Area	2023	2024	2025
1	32,375,088	33,173,996	33,972,904
2	8,973,032	9,892,933	10,812,833
4	10,080,944	10,368,802	10,656,660
5	19,669,503	20,479,463	21,289,423
6	3,715,267	4,527,095	5,338,924
9	1,983,754	2,181,963	2,380,172
14	5,736,174	6,133,070	6,529,966
Total	76,230,983	79,413,384	82,595,784

According to the Holt-Winters non-seasonal double-parameter exponential correction, the prediction results in Table 9 reveal that the total tonne-kilometers (ton-km) on highways will reach 82,595,784,000 by 2025. Additionally, when analyzed at a regional level, it is observed that the 1st Region will continue to have the highest ton-km value in 2025.

4. Conclusion

Upon examining the study results, it has been determined that passenger and cargo carrying capacity has increased in certain regions over the years and is predicted to continue to increase in the future. However, these increases in road transportation have negative impacts such as environmental pollution, climate change, and traffic accidents. Therefore, it is crucial to reduce transportation where possible. To achieve this, the following measures can be taken:

- Encourage the use of public transportation by prioritizing information and awareness-raising campaigns.
- Promote environmentally friendly transportation methods like walking and cycling.
- Implement deterrent measures to encourage people to reduce their daily travel distances.
- Increase public awareness through commercial approaches such as electronic shopping, and reduce people's need for physical shopping.
- Develop smart transportation systems to optimize traffic flow.

Transportation-related greenhouse gas emissions make up a significant portion of Türkiye's total emissions. To reduce these emissions, we can take measures such as changing transportation preferences and improving transportation infrastructure. Additionally, we need to ensure that the transportation system promotes sustainable development by meeting basic accessibility needs that are consistent with human and ecosystem health, producing limited amounts of greenhouse gas emissions, and paying attention to the affordability, equity, and efficiency of the system.

Author Contributions

The percentage of the author(s) contributions is presented below. The author reviewed and approved the final version of the manuscript.

	H.B.T.
C	100
D	100
S	100
DCP	100
DAI	100
L	100
W	100
CR	100
SR	100
PM	100
FA	100

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The author declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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