Environ Res Tec, Vol. 5, Issue. 3, pp. 241–248, September 2022

Environmental Research and Technology
https://ert.yildiz.edu.tr - https://dergipark.org.tr/tr/pub/ert
DOI: https://doi.org/10.35208/ert.1109868

Environmental Research & Technology

Research Article

Assessment of the highway logistics on carbon footprint

Ülge TAŞ*[1], Hümeyra BOLAKAR TOSUN[2]

[1]*Department of Industrial Engineering, Aksaray University, Faculty of Engineering, Aksaray, Türkiye*
[2]*Department of Civil Engineering, Aksaray University, Engineering Faculty, Aksaray, Türkiye*

ARTICLE INFO

Article history
Received: 27 April 2022
Revised: 18 July 2022
Accepted: 23 July 2022

Key words:
Carbon footprint; Highway logistics; Multiple regression; Logistic; Transportation

ABSTRACT

Developing the quality of the types of greenhouse gasses used within the global environment and reducing carbon emissions are recognized as the main of current logistic changes policies. The paper aims to evaluate the contribution of the impact of highway logistics activity, one of the most important causes of carbon dioxide emissions, on the carbon footprint of the Southern Central Anatolian provinces. In this context, multiple regression analyses were conducted in three locations in the Southern Central Anatolian (Antalya, Kayseri, Konya) involving a total of 12 monthly highway logistics activities and carbon emissions. Before analysis, summarized the status of all logistic activities in the study area and collected data related to carbon emission in these regions. However, the coupling relationship between carbon emissions and logistic conditions in regions was calculated by the regression model. The carbon footprint linked to logistics, for Antalya was 87% (R=0.87), for Kayseri was 94% (R=0.94), and for Konya was 63% (R=0.63). It can be seen that, in the multiple regression analysis, Kayseri has a higher carbon footprint than Antalya and Konya when an estimation of the quantile was carbon footprint. The main academic contribution of this study brings a new perspective to the future assessment of environmental policies and prepares a quantitative principle for the implementation of future carbon footprint policies.

Cite this article as: Taş Ü, Bolakar Tosun H. Assessment of the highway logistics on carbon footprint. Environ Res Tec 2022;5:3:241–248.

INTRODUCTION

With the improvement of global economics, the nugatory environmental conditions by increased industrial activities are accelerating significantly. The logistics industry has also rapidly developed in the last few years with the serial growth of the global economy [1]. As the main activities of the logistics industry, transportation, warehousing, and handling act for the energy consumption cause intense carbon emissions. Highway logistics is not only important to economic growth, but it also causes an increase in carbon emits. Therefore, decreasing greenhouse gas emissions (especially carbon-derived gases) from logistic activities was deliberated to be an impressive approach to reducing the side-effects of carbon footprint [2–4].

A carbon footprint is the greenhouse gas emissions caused which are explained as carbon dioxide or equivalent gases emitted. A carbon footprint resulting from carbon emission consists of gases—primarily carbon dioxide and monox-

***Corresponding author.**
*E-mail address: ulge.tas@aksaray.edu.tr

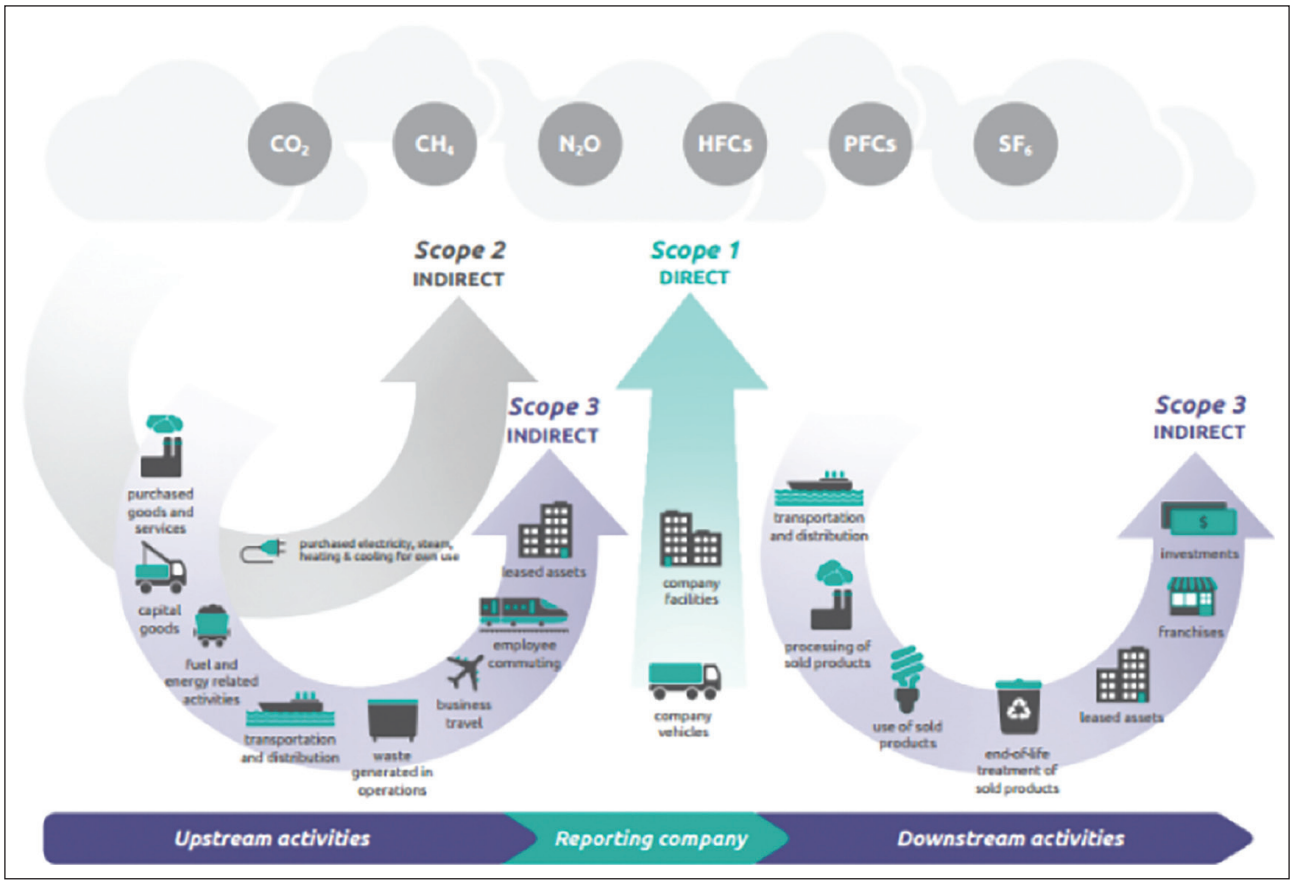

Figure 1. Greenhouse Gas – Protocol Standard [6].

ide—dismissed into the atmosphere by specific humans' actions. Carbon emits are caused by the burning of fossil fuels in the surrounding. Any action to accomplish a human need causes the emissions of carbon. Carbon emissions are recognized as one of the world's largest air-polluting and continue to expand ratio [5]. In order to deal with the negative impacts of carbon footprint, standardization organizations around the world have issued ISO 14064 (standard of greenhouse gas) policies to curb the harm to human health and the destruction of natural resources caused by it. Overview on Scopes according to the Greenhouse Gas-Protocol Standard is given Figure 1.

Figure 1 reporting on scopes 1, 2, and 3 involves collecting data about greenhouse gas output from various sources and compiling it according to the standards of the ISO 14064 equivalent international standard. The ISO 14064 standard provides businesses with data to quantify, report, and verify greenhouse gas emissions. The ISO 14064 standard is included in the ISO 14000 International Standard for environmental management [6].

As an important transport way of the global economy, highway logistics has more and more significance in serving other industries. To evaluate the carbon footprint highway's length is widely used, represented by the carbon emission of highway logistics tools. Thus, the carbon footprint can be regarded as an indicator of highway logistics, and it involves the extent of carbon emission in the air pollution [7].

Environmental and economic impacts of carbon footprint were various and reflected in logistic aspects. In this context, this study attempted to suggest a new framework to evaluate the double-faced efficacy and rate of carbon footprint policies from the perspectives of both environmental and economic. This study aimed to contribution the impact of highway logistics activity, one of the most important causes of carbon dioxide emissions, on the carbon footprint of the Southern Central Anatolian provinces.

After the introduction, chapter 2 first presented the carbon footprint of highway logistics. Nevertheless, after a literature review on this subject, in chapter 3 the method is explained. Chapter 4 presents the study carried out to findings. The impact of the information gathered in the study is discussed, and future studies suggested were discussed in the result chapter.

LITERATURE REVIEW

Carbon footprint is one of the essential standards for all kinds of transport because of its essential role in harming the environment of the companies as well as the preserva-

Table 1. Literature review

Author	Year	Definition
Krstanoski [11]	2006	Estimation of CO_2 emissions from the road transport sector over a 25-year period. He developed a model for the impact of CO_2 gas emissions. As a result of the study, it was estimated that CO_2 emissions will decrease by 32% by 2030 if use implementation of the foreseen measures.
Yang et al. [12]	2009	They investigated how to reduce greenhouse gas emissions from transport by 80% by the 2050 year in California. They focused on three issues based on sub-sectors. It has been stated that there are serious difficulties in practice, those were increasing vehicle efficiency, reducing fuel carbon intensity, and reducing travel demands.
Piecyk and McKinnon [13]	2010	They were investigated the environmental impact. They examined their environmental impacts in the coming years with the help of a questionnaire.
Mondal et al. [10]	2011	They studied carbon emissions from the transportation sector. They found that only highways while CO_2 emissions from transportation were 4.8 in 2007, in 2030 it is predicted that it will increase to 6.9.
Bouchery et al. [14]	2012	They investigated modifying the classical EOQ model as the sustainable order quantity model. The research was for carbon emission regulation. The kinds of literature above developed an inventory model by taking into carbon footprint, environmental or social criteria.
Chavez-Baeza and Sheinbaum-Pardo [15]	2014	They studied greenhouse gases and some pollutants. The estimated future emissions are based on the past situation. The study aimed to detect all kinds of vehicle-related types in the metropolitan areas of the city and reduce emissions.
Quiros et al. [16]	2017	They were investigated, the effects of diesel transport vehicles on the atmosphere. In this study, the weight created by the goods loaded on diesel vehicles and the emission. The relationship between the changes in weight was examined, the direct greenhouse gases of the weight changes were examined.
Gür and Furuncu [17]	2017	In their study they have seen the increase in the regulation's sensitivity to the environment also affecting different countries in the automotive sector. They predicted measures CO_2 gas emission values for the next years.
Argun et al. [18]	2019	They conducted a study to determine the carbon footprint of the district of Konya Province. In the study used the Tier method, the effects of transportation, accommodation, and afforestation were taken into account. As a result of the study emission data were compared with Türkiye and various countries.
Bogacki and Bździuch [19]	2019	They conducted a study in Poland. The effects of buses on emissions were investigated. In the study, only pollutants not only that emissions, direct and indirect greenhouse gases have also increased.
Bilgili et al. [20]	2022	They have been calculated to account for the production processes of the aircraft and passenger trains, the LCA cycle was completed and total emissions were calculated.

tion of environmental values [8]. The trend primarily took off in the 1990s when increased cognize and consciousness about the "carbon footprint" is evidenced. This evidence with The Kyoto Protocol in 1997 asked to decrease greenhouse gases, and 150 countries approved to adopt of the protocol [9]. The number of greenhouse gases emitted to the environment due to direct or indirect acts called the carbon footprint is one of the initial reasons for air pollution and the consumption of natural resources.

With the increase in the level of air pollution caused by greenhouse gases, respiratory diseases can occur in living things. Changes in weather conditions and air pollution impact caused an increase in the nugatory effects on human health.

In addition, globally originating from vehicles created by the logistics industry carbon emissions are known as a

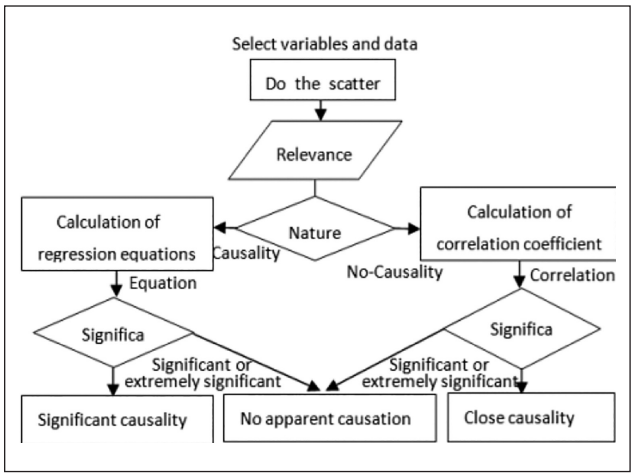

Figure 2. Regression model [21].

Table 2. Number of carbon emission and trucks

	Carbon emission (μg/m³)			Number of truck		
2021	**Antalya**	**Kayseri**	**Konya**	**Antalya**	**Kayseri**	**Konya**
January	22.755	39.907	54.379	24.918	17.193	38.175
February	22.675	39.887	54.499	25.042	17.257	38.252
March	22.694	39.911	54.437	25.165	17.261	38.432
April	22.710	39.927	54.455	25.343	17.288	38.580
May	22.723	39.936	54.463	25.412	17.307	38.606
June	22.741	39.945	54.475	25.519	17.329	38.743
July	22.766	39.955	54.488	25.603	17.381	38.864
August	22.784	39.967	54.494	25.643	17.392	38.951
September	22.801	39.982	54.490	25.727	17.420	39.051
October	22.818	40.009	54.447	25.841	17.461	39.128
November	22.838	40.060	54.493	26.038	17.482	39.206
December	22.859	40.110	54.557	26.139	17.530	39.219

Resource: South Central Anatolia Clean Air Center Directorate and Turkish Statistical Institute - 2021.

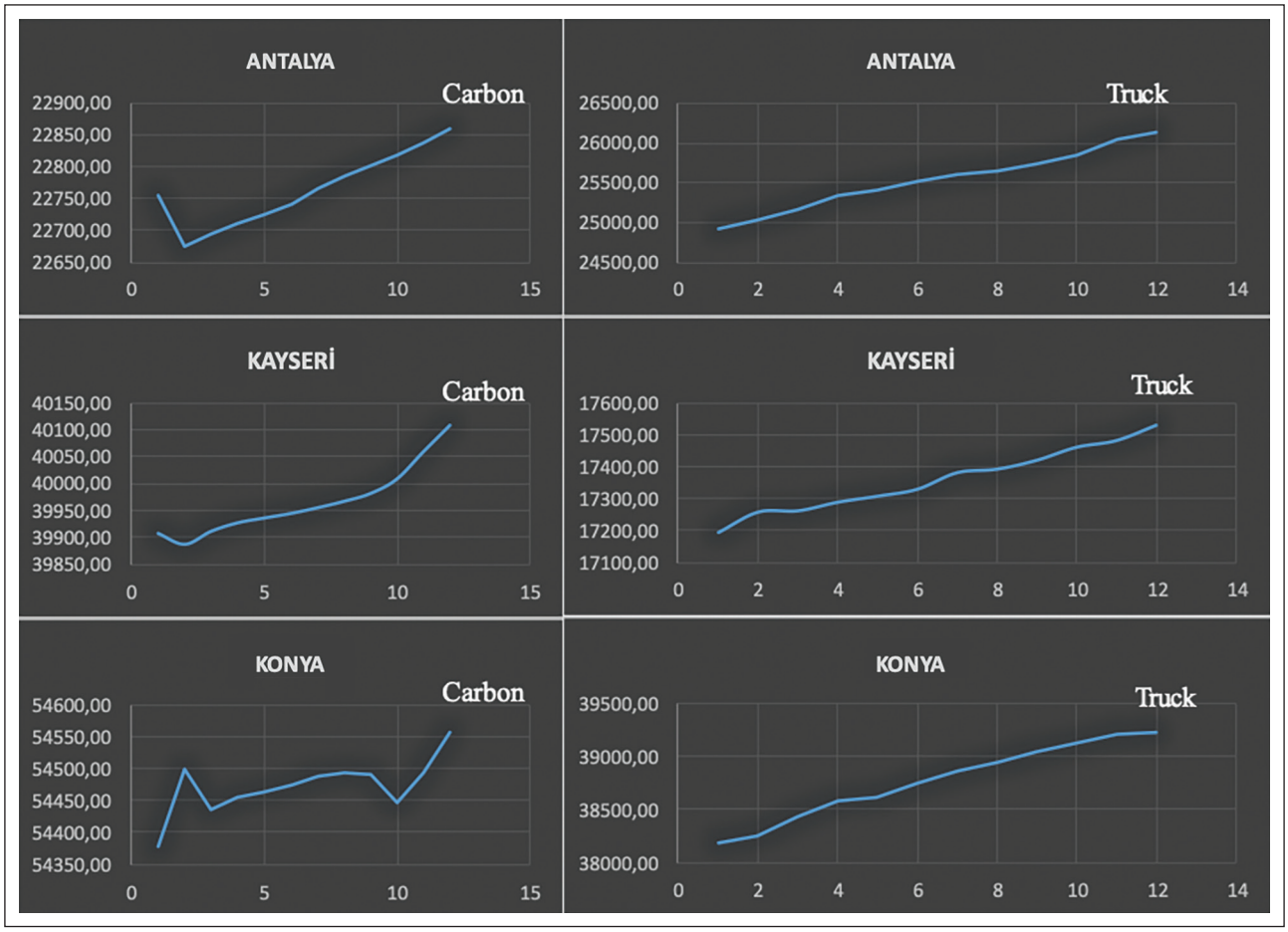

Figure 3. Trends of carbon and trucks.

world problem. Last decades, there has been a continuous increase in the production and logistics of commercial vehicles. The logistic industry is the fastest-growing one of sector in the world. Carbon emissions from fossil fuels are responsible for 22–24% of the greenhouse gas resulting from the highway [10].

Table 3. Multiple regression results

Regression statistics	Antalya	Kayseri	Konya
Multiple R	0.874032182	0.936860144	0.625062621
R square	0.763932255	0.877706929	0.390703281
Adjustable R square	0.740325481	0.865477622	0.329773609
Standard deviation	29.66614999	24.08495931	35.29803351
Observation	12	12	12

Table 4. ANOVA results

	df	Sum of square	Mean square	F	Significance
Antalya					
Regression	1	28480.03857	28480.03857	32.36072156	0.000201428
Difference	10	8800.804555	880.0804555		
Total	11	37280.84312			
Kayseri					
Regression	1	41633.17302	41633.17302	71.77078191	0.000710409
Difference	10	5800.852648	580.0852648		
Total	11	47434.02567			
Konya					
Regression	1	7989.493364	7989.493364	6.412364753	0.029755153
Difference	10	12459.5117	1245.95117		
Total	11	20449.00506			

ANOVA: Analysis of Variance.

In the literature, different researchers define the relationship between carbon footprint and logistics in their ways. The related literature is given in Table 1.

There are many studies in the literature on the carbon footprint for theoretical. In addition, this study is due to a lack of literature includes multiple regression for the local regions. Multiple regression analyses were applied and analyzed to the carbon emission levels where the greenhouse gasses, and the number of trucks. Based on the regression analysis findings, the article presents suggestions for the relationship between carbon footprint and highway logistics. From this viewpoint, of its approach, this research can be an addition to the literature.

MATERIALS AND METHODS

This research aimed to relationship a series of baseline trends in carbon footprint and highway logistics in 2021. In this context, this study to determine the impact of highway logistics activity, one of the most important causes of carbon dioxide emissions, on the carbon footprint of the Southern Central Anatolian provinces. In the first stage of the research, a series of data analyses were held in three locations in the Southern Central Anatolian (Antalya, Kayseri, Konya) involving a total of 12 monthly highway logistics activities and carbon emissions.

The regional logistics were measured in terms of carbon emission, then further multiple regression analyses. In the regression analysis, the multi-correlation coefficient shows the strength between the dependent and independent variables. The predicted value calculated by the regression is a specific coefficient called a point estimate [21]. The regression model is shown in Figure 2.

Based on these two indicators, the relations between carbon emission and highway logistics development were analyzed. Through the evolution trends of these indicators were investigated whether there is that certain convergence exists. Table 2 shows the results of the number of carbon emissions and trucks for the 12 months of 2021 for three provinces.

Specifically, multiple regression was based on variables such as carbon emissions and highway logistic trucks obtained from Table 2 data. In this context, the 95% confidence interval was provided from the multiple prediction values at each of the data points for three regions. According to Table 2, carbon emission and truck graphics in the regions given in Figure 3.

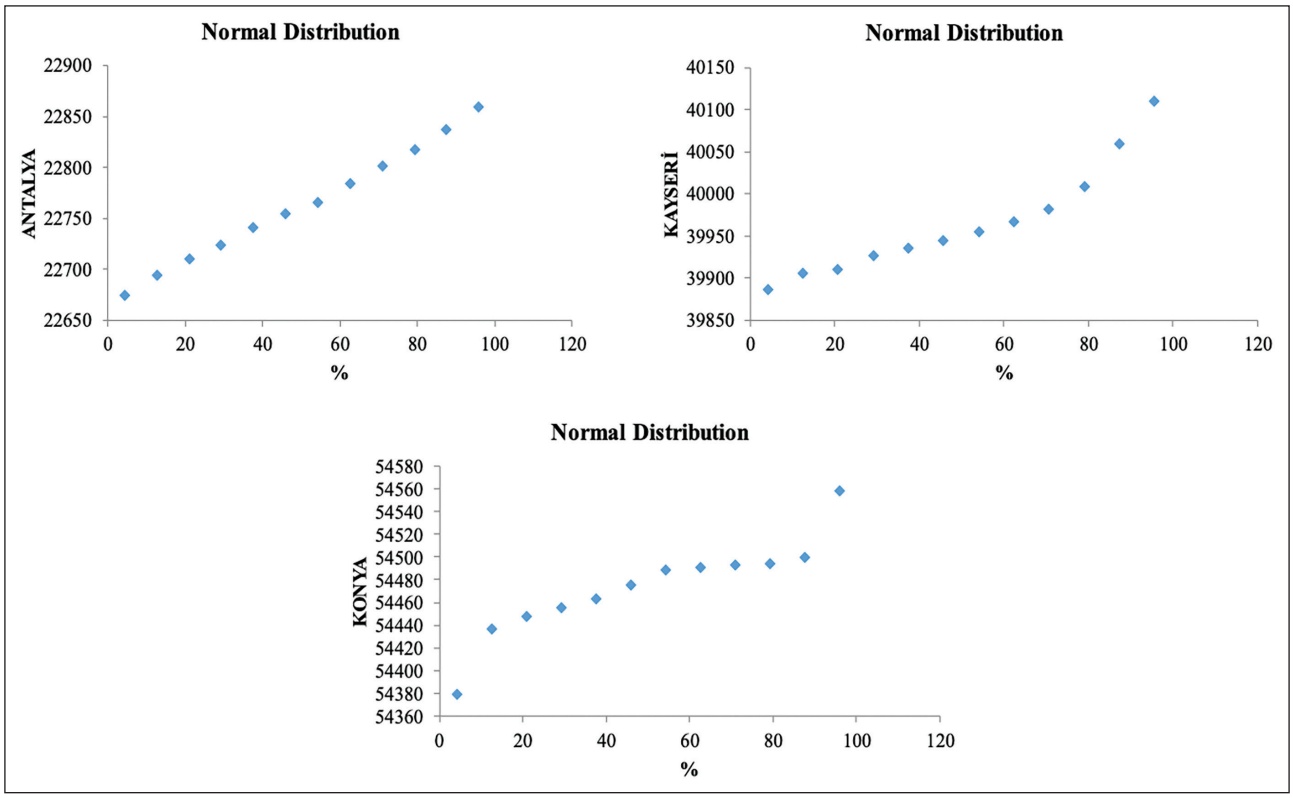

Figure 4. Normal distributions.

The Antalya, Kayseri, and Konya carbon emit and trucks are shown in Figure 3 to compare rates after one year of data is collected. Antalya and Konya's graphs have fluctuated in terms of carbon emissions Kayseri's graph increased at certain rates. However, in logistics, the situation is the same for all three cities.

RESULTS AND DISCUSSION

The regression results helped to identify carbon footprint linkages with carbon emits and highway logistics. The purpose of multiple regression analysis is to explain and predict the effect of change in independent variables on the dependent variable. In the study, the analysis results of the relationship between the number of carbon emissions and highway logistic trucks are expressed with tables and figures. The multiple regression analysis results are given in Table 3.

Multiple regression analysis has been applied with a number of carbon emission variables in order to analyze highway logistics. Furthermore, the significance of the multiple regression models was verified with three samples ($p<0.05$) [22]. As it shows that Table 3 are the adjusted determinations of the multiple regression model per the relationship between carbon emission and highway logistics in Antalya, Kayseri, and Konya. The explanatory ability of the model for Antalya was 87% (R=0.87), Kayseri was 94% (R=0.94), and Konya was 63% (R=0.63). In the multiple regression analysis, Kayseri has a higher determination than Antalya and Konya when an estimation of the quantile was carbon footprint. It was observed that the impact of the carbon footprint was severe on most of the parameters. The multiple R values exceeded the tolerable limits at almost all the stations.

The same data were analyzed according to ANOVA for the 12 monthly periods as Table 4.

This research is a one-way analysis of variance (ANOVA), which is a method of testing differences between three groups and carbon footprint. In a one-way analysis of variance, the same principle is used, with sample homogeneous rather than significant difference being used to measure variability. When the findings were examined, the samples were homogeneous. In all three samples, it was observed that the increase in carbon footprint from the use of carbon emissions and highway logistics significantly. The test statistic F is equal to the "carbon footprint" mean square divided by the error mean square [23]. In this context, the results according to the critical value of F, it was determined that all sample means were comparable at the same time. Moreover, normal distributions in the regions given in Figure 4.

According to the Figure 4, it has been determined that the sample variables are symmetrical and therefore fit the normal distribution. It has been observed that there

is a positive relationship between the variables. In other words, it was stated that as the number of vehicles increased separately within the three provinces, the carbon emission values increased.

In similar studies in the literature, it has been seen that logistic modes are largely dependent on fossil fuels. With high fossil fuel consumption, the logistic sector is responsible for 28% of the total carbon footprint emissions in the USA [24]. In this context, reducing carbon footprint emissions is the most important issue in the modern world and especially, for oil and logistic gas enterprises [25]. From this perspective, this study's findings were appropriate to the related literature, which the carbon footprint with the highway logistics. Due to its original approach, the present research study is a contribution to the industry and literature.

CONCLUSION

Improving the quality of the types of greenhouse gasses used within the global environment and reducing carbon emissions are recognized as the main of current logistic changes policies. Measures to minimize the factors that cause emissions are the priority of all countries. Many national and international studies on the subject have been carried out, while countries determine their social and economic development plans, the environment started to show sensitivity to the issue of sustainability.

In this study, paper aims to evaluate the contribution of the impact of highway logistics activity, one of the most important causes of carbon dioxide emissions, on the carbon footprint of the Southern Central Anatolian provinces. The information about the current situation of changes, especially greenhouse a large amount of carbon, which is the most effective greenhouse gas in the emergence of gas emissions attention to logistic transportation.

In this study multiple regression analysis has been applied with a number of carbon emission variables in order to analyze highway logistics.Also, the significance of the multiple regression models was verified with three samples ($p<0.05$) [22]. As it shows results the adjusted determinations of the multiple regression model per the relationship between carbon emission and highway logistics in Antalya, Kayseri, and Konya. The explanatory ability of the model for Antalya was 87% (R=0.87), Kayseri was 94% (R=0.94), and Konya was 63% (R=0.63).

It can be seen that, in the multiple regression analysis, Kayseri has a higher carbon footprint than Antalya and Konya when an estimation of the quantile was carbon footprint. Considering the density of logistics vehicles passing through the provinces, it has been determined that there is a linear increase in carbon footprint rates. Furthermore, the multiple R values exceeded the tolerable limits at almost all the stations. Fuel consumption depend on the increasing number of vehicles increases and causes a remarkable increase in greenhouse gas emissions. According to the data of the General Directorate of Highways, these provinces are the highest volume provinces of logistic draws attention. The fact that the determined they are so prominent in terms of highway logistics, the trade originating from the provinces own industrial production potentials has been effectiveness. The logistic sector, which is necessary for the continuity of the economic process, due to released emissions, has a structure that threatens environmental sustainability. However, the need for the sector should require development in non-destructive methods is the sector's contribution to the ecosystem.

As a precaution, to reduce the environmental damage scope of highway logistics to spread emission-reducing measures, green logistics practices in activities should be done. In this context, especially environmentally friendly alternative fuels should be developed and used. Based on this study, similar and comparative studies can be carried out in other provinces. The main academic contribution of this study brings a new perspective to the future assessment of environmental policies and prepares a quantitative principle for the implementation of future carbon footprint policies.

Future work can be suggested, for highway logistics cases in which the other provinces measure carbon footprint. As another suggestion, future work can be suggested using methods other than regression analysis. Regarding the limitations of the research concerned, it should be mentioned has been conducted within three locations only and highway logistics.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

REFERENCES

[1] F. Xiao, Z. H. Hu, K. X. Wang, and P. H. Fu, "Spatial distribution of energy consumption and carbon emission of regional logistics," Sustainability, Vol. 7(7), pp. 9140-9159, 2015. [CrossRef]

[2] P. Friedlingstein, R.M. Andrew, J. Rogelj, G.P. Peters, J.G. Canadell, R. Knutti, G. Luderer, M.R. Raupach, M. Schaeffer, and D.P.V. Vuuren, "Persistent growth of CO2 emissions and implications for reaching climate targets," Nature Geoscience, Vol. 7, pp. 709–715, 2014. [CrossRef]

[3] S. Manabe, "Role of greenhouse gas in climate change," Tellus A: Dynamic Meteorology and Oceanography, Vol. 71(1), Article 1620078, 2019. [CrossRef]

[4] Q. Wang, S. Wang, and R. Li, "Determinants of decoupling economic output from carbon emission in the transport sector: A comparison study of four municipalities in China," International Journal of Environmental Research and Public Health, Vol. 16(19), Article 3729, 2019. [CrossRef]

[5] Y. Ren, and T. Fan, "Ecological land protection or carbon emission reduction? comparing the value neutrality of mainstream policy responses to climate change," Forests, Vol. 12(12), Article 1789, 2021. [CrossRef]

[6] Türk Standartları Enstitüsü (TSE). "Kurumsal karbon ayakizi," https://www.iso.org.tr/sanayi-kongresi/doc/Kurumsal_Karbon_Ayakizi_ISO_Kongre_TSE.pdf Accessed on April 24, 2022. [Turkish]

[7] S. Zhang, C. K. M. Lee, H. K. Chan, K. L. Choy, and Z. Wu, "Swarm intelligence applied in green logistics: A literature review," Engineering Applications Artificial Intelligence, Vol. 37, pp. 154–169, 2015. [CrossRef]

[8] C. J. Corbett, and R. D. Klassen, "Extending the horizons: environmental excellence as key to improving operations," Manufacturing and Service Operations Management, Vol. 8(1), pp. 5–22, 2006. [CrossRef]

[9] C. Gonzalez, M. Korchia, L. Menuet, and C. Urbain, "How do socially responsible consumers consider consumption? An approach with the free associations method," Recherche et Applications en Marketing (English Edition), Vol. 24(3), pp. 25–41, 2009. [CrossRef]

[10] P. Mondal, K. Abhishek, A. Varun, S. Nitin, V. Prashant, U.D. Bhangale, and T. Dinesh, "Critical review of trends in GHG emissions from global automotive sector," British Journal of Environment and Climate Change, Vol. 1(1), pp. 1-12, 2011. [CrossRef]

[11] N. Krstanoski, "The problem of speeding in macedonia: Reasons and recommendations," https://scholar.googleusercontent.com/scholar?q=cache:pCupixEUWTkJ:scholar.google.com/+The+Problem+of+Speeding+In+Macedonia:+Reasons+And+Recommendations.%22+&hl=tr&as_sdt=0,5 Accessed on Apr 26, 2022.

[12] C. Yang, D. McCollum, R. McCarthy, and W. Leighty, "Meeting an 80% reduction in greenhouse gas emissions from transportation by 2050: A case study in California," Transportation Research Part D, Vol. 14, pp. 147–156, 2009. [CrossRef]

[13] M. I. Piecyk, and A. C. McKinnon, "Forecasting the carbon footprint of road freight transport in 2020," International Journal of Production Economics, Vol. 128(1), pp. 31–42, 2010. [CrossRef]

[14] Y. Bouchery, A. Ghaffari, Z. Jemai, and Y. Dallery, (2012). "Including sustainability criteria into inventory models," European Journal of Operational Research, Vol. 222(2), pp. 229–240, 2012. [CrossRef]

[15] C. Chavez-Baeza, and C. Sheinbaum-Pardo, "Sustainable passenger road transport scenarios to reduce fuel consumption, air pollutants and GHG (greenhouse gas) emissions in the Mexico City Metropolitan Area," Energy, Vol. 66, pp. 624–634, 2014. [CrossRef]

[16] D. C. Quiros, J. Smith, A. Thiruvengadam, T. Huai, and S. H. Hu, "Greenhouse gas emissions from heavy-duty natural gas, hybrid, and conventional diesel on road trucks during freight transport," Atmospheric Environment, Vol. 168, pp. 36–45, 2017. [CrossRef]

[17] N. Gür, and Y. Furuncu, "Küresel otomotiv sektörünün değişimi ve yerli otomobil projesinin geleceği," Siyaset, Ekonomi ve Toplum Araştırmaları Vakfı Yayınları, Vol. 127(1), pp. 17–59, 2017.

[18] M. E. Argun R. Ergüç and Y. Sarı "Konya/Selçuklu ilçesi karbon ayak izinin belirlenmesi," Selçuk Üniversitesi Mühendislik, Bilim ve Teknoloji Dergisi, Vol. 7(2), pp. 287–297, 2019. [Turkish] [CrossRef]

[19] M. Bogacki, and P. Bździuch, "Predicting the spatial distribution of emissions from urban buses based on previously measured data and scenarios for their modernization in the future. Case study: Krakow, Poland," Atmospheric Environment, Vol. 199, pp. 1-14, 2019. [CrossRef]

[20] L. Bilgili, A. Çetinkaya, and S. L. Kuzu, "Life cycle comparison of passenger air and rail transportation," Environmental Research and Technology, Vol. 5(1), pp. 44–49, 2022. [CrossRef]

[21] L. M. Wang, Regression analysis. Shanghai University of Finance and Economics Press, 2019.

[22] E. J. Pedhazur, "Multiple Regression in Behavioral Research: Explanation and Prediction, 2nd ed., Rinehart and Winston, USA, 1982.

[23] V. Bewick, L. Cheek, and J. Ball, "Statistics review 9: One-way analysis of variance," Critical Care, Vol. 8(2), Article number 130, 2004. [CrossRef]

[24] United States Environmental Protection Agency. Inventory of US greenhouse gas emissions and sinks: 1990-1997. USA: The United States Environmental Protection Agency, 1999.

[25] M.A. Pashkevich, and T.A Petrova, Assessment of widespread air pollution in the megacity using geographic information systems. Journal of Mining Institute, Vol. 228, pp. 738–742, 2017.