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Forecasting of defects causing traffic accidents using time series analysis methods

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Abstract

Traffic accidents can cause millions of people to lose their lives, get injured and lose money every year. Many factors can be mentioned in the occurrence of traffic accidents that have such a big impact. The analysis of these factors and taking steps for the future are great importance in terms of transportation safety. In this study, the defects that cause traffic accidents were examined in five categories. Using time series analysis models, a forecast was made for the values of the defects until 2030. The study concluded that there would be an increase in driver defects which have the highest rate in the occurrence of traffic accidents and in road defect values, while pedestrian and passenger defect values would remain stable, and there would be a decrease in road defect values. Considering the findings obtained, suggestions were presented for all stakeholders creating traffic according to the vision zero understanding.

Keywords: *Traffic accident defects, time series analysis, forecasting, transportation safety.*

Trafik kazalarına sebep olan kusurların zaman serisi analiz yöntemleriyle kestirimi

Öz

Trafik kazaları her yıl milyonlarca insanın hayatını kaybetmesine, yaralanmasına ve maddi kayıplara sebep olabilmektedir. Böylesine büyük etkisi olan trafik kazalarının meydana gelmesinde ise birçok faktörden söz edilebilmektedir. Bu faktörlerin analizi,

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geleceğe yönelik adımlar atılması ise ulaşım güvenliği açısından büyük bir öneme sahiptir. Bu çalışmada trafik kazalarına sebep olan kusurlar beş kategoride incelenmiştir. Zaman serisi analizi modelleri kullanılarak 2030 yılına kadar kusurların değerlerine yönelik tahmin yapılmıştır. Çalışmada trafik kazalarının meydana gelmesinde en yüksek orana sahip olan sürücü ile yol kusur değerlerinde artma meydana geleceği, yaya ve yolcu kusurlarının stabil devam edeceği, yol kusurlarında ise azalma meydana geleceği sonucuna ulaşılmıştır. Elde edilen bulgular dikkate alınarak vizyon sıfır anlayışına göre trafiği oluşturan tüm paydaşlara yönelik öneriler sunulmuştur.

Anahtar kelimeler: *Trafik kaza kusurları, zaman serisi analizi, kestirim, ulaşım güvenliği.*

1. Introduction

Transportation, one of the important functions of life, is essential for mobility. With increasing mobility, the probability of traffic accidents also increases [1, 2]. More than 1.35 million people die and nearly 50 million people are injured in traffic accidents around the world every year [3]. Every year, 10 million children are disabled or injured as a result of traffic accidents. Traffic accidents rank 8th among causes of death and the leading cause of death among children aged 5-14 [4]. A study conducted by the World Health Organization (WHO) states that if no precautions are taken against traffic accidents, the share of traffic accidents in total deaths will increase to 67% [5]. In developing countries, traffic accidents are more remarkable. Although 52% of the world's vehicles are registered in developing countries, 80% of road traffic deaths occur in these countries [6]. When examined in terms of cost, traffic accidents cause economic losses of more than 100 billion dollars every year for developing countries. This cost is almost twice as much as spent on improving traffic safety worldwide [7]. Consequently, the extensive impact of unsafe transportation has made road safety a central focus for transportation engineers, policymakers, and researchers. A wide range of strategies and actions have been taken both locally and globally to ensure road safety and reduce damage and/or loss of life. The World Health Organization has set a target to prevent at least 50% of deaths and injuries in road traffic by 2030 as part of the "Decade of Action for Road Safety 2021-2030" to ensure transport safety [8].

The causes of traffic accidents are complex. Road infrastructure such as road surface conditions, road user behaviors such as driver/pedestrian behaviors, traffic-related factors such as congestion and other environmental problems such as bad weather conditions may be factors in the occurrence of traffic accidents. For this reason, obtaining information about the risk factors contributing to accidents in traffic is vital in formulating the priorities of action plans and interventions to reduce the risks associated with these factors [8]. In this context, a large number of studies have been carried out in order to prevent traffic losses and ensure transportation safety [9]. The aim of this study is to ensure that measures are taken by taking into account the future situation of elements that may endanger traffic safety. In this study prepared in this context, estimates were made for the defects that cause traffic accidents until 2030 using time series analysis methods in the SPSS program. When the studies prepared with this method are examined, it is understood that a large number of studies have been conducted in different countries. In a study conducted in Nigeria, it was aimed to obtain an estimate of the frequency of accidents with a time series. In the study, variables were used as excessive speed, tire

explosion/failure, loss of control, wrong overtaking, brake failure, dangerous overtaking, weather condition, route violation, obstacle, dangerous driving, light violation [10]. In a study conducted in Thailand, time series analysis, regression analysis, curve estimation and road analysis were used with the data of mortality rate per 100,000 people, gross domestic product, number of registered vehicles (motorcycles, trucks and automobiles) and energy consumption of the transportation sector in order to estimate the reduction of the number of accidents [11]. A study conducted in India aimed to predict traffic accidents using time series models. The results of the study show that most fatal accidents are caused by exceeding the legal speed limit, driving under the influence of alcohol and overtaking. According to the time series analysis using SPSS, traffic accidents have been estimated for the year 2025 and it has been obtained that there may be an increase in traffic accidents by 4.5% [12]. In a study conducted in Ghana, time series methods were used to predict traffic accidents that occurred between 1990 and 2019 [13].

2. Materials and methodology

In this study, the future forecasting of defects causing traffic accidents was conducted. The future trends of traffic accident-related defects in Türkiye from 1995 to 2021 were analyzed using time series methods in the SPSS program. The defects causing traffic accidents are classified into five main categories as "Driver", "Pedestrian", "Passenger", "Road" and "Vehicle" defects and this classification was made by TUIK (Turkish Statistical Institute). Below, theoretical information about the rates of investigated defects in Türkiye between 1995 and 2021 and the results of time series models used in the study are given.

2.1. Defects that cause traffic accidents

It is known that there are many defects that cause traffic accidents. In the data obtained from TUIK, the defects that cause traffic accidents are divided into classes as "Driver", "Passenger", "Pedestrian", "Road" and "Vehicle" defects. The percentage distributions of these defects used in the study, covering the years 1995-2021, are shown in Table 1. Graphical representation of the percentage distributions of determined defects are shown in Figure 1 to Figure 5, respectively.

Table 1. Proportional distribution of defects in traffic accidents by years

Year	Driver defects	Passenger defects	Pedestrian defects	Road defects	Vehicle defects
1995	93.26	0.13	4.33	1.51	0.77
1996	94.94	0.54	3.98	0.14	0.40
1997	97.31	0.13	2.14	0.00	0.41
1998	95.96	0.26	2.72	0.45	0.62
1999	95.99	0.23	2.69	0.56	0.53
2000	96.06	0.25	2.40	0.77	0.52
2001	96.56	0.31	2.32	0.43	0.38
2002	96.82	0.23	2.39	0.25	0.31
2003	97.03	0.16	2.32	0.22	0.27
2004	97.3	0.11	2.18	0.19	0.22
2005	97.39	0.11	2.04	0.22	0.25
2006	98.07	0.09	1.62	0.13	0.10
2007	98.03	0.09	1.64	0.11	0.14
2008	90.53	0.43	8.37	0.42	0.26
2009	89.6	0.41	9.09	0.61	0.29

2010	89.72	0.39	9.86	0.69	0.36
2011	90.2	0.39	8.51	0.60	0.30
2012	88.86	0.44	9.75	0.62	0.33
2013	88.69	0.42	8.99	1.05	0.85
2014	88.62	0.47	9.38	0.95	0.58
2015	89.3	0.43	8.80	0.91	0.55
2016	89.59	0.41	8.73	0.81	0.47
2017	89.87	0.37	8.48	0.76	0.52
2018	89.46	0.88	8.44	0.60	0.62
2019	88.02	1.26	8.18	0.51	2.03
2020	88.34	1.45	7.04	0.50	2.67
2021	87.06	1.76	8.20	0.42	2.57

When proportional distribution of defects between 1995 and 2021 in the Table 1 is examined, it is understood that the highest defects rate in all years belongs to drivers. In second place are pedestrian defects. Other types of defects may change over the years.

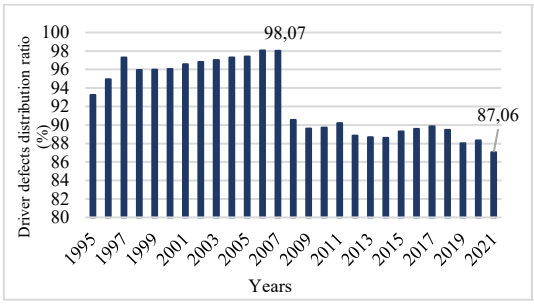

Figure 1. Driver defects (%)

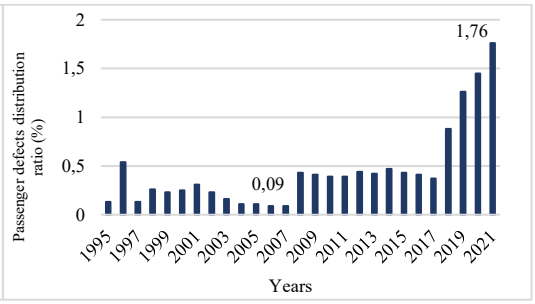

Figure 2. Passenger defects (%)

When Figure 1, which shows the driver defects between 1995 and 2021, was examined, the highest rate was found to be in 2006 with 98.07%, and the lowest rate was found in 2021 with 87.06%. When Figure 2 showing passenger defects is examined, the highest rate was found in 2021 with 1.76%, and the lowest rate was found in 2006 and 2007 with 0.09%.

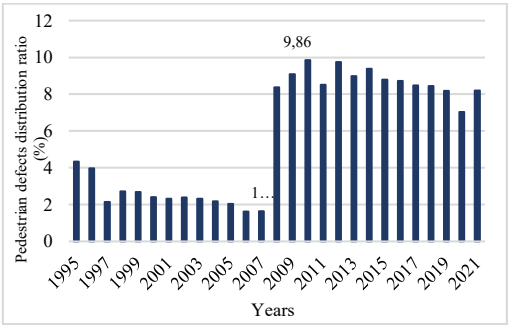

Figure 3. Pedestrian defects (%)

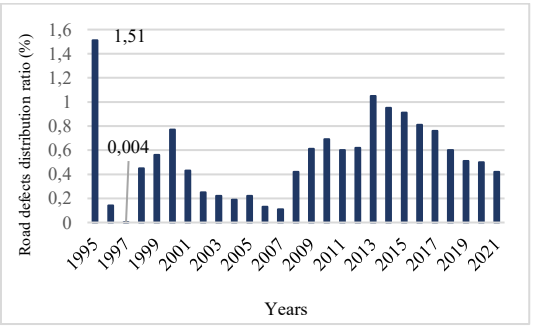

Figure 4. Road defects (%)

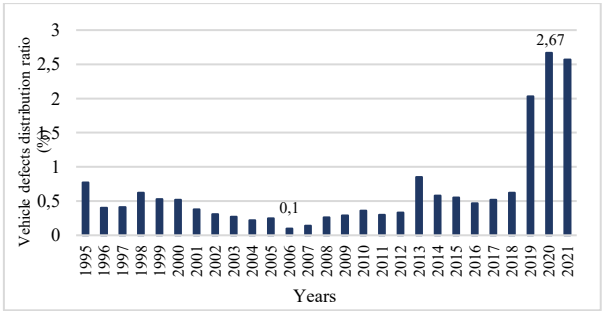

Figure 5. Vehicle defects (%)

When Figure 3 showing pedestrian defects is examined, the highest rate was found in 2010 with 9.86%, and the lowest rate was found in 2006 with 1.62%. When Figure 4 showing road defects is examined, the highest rate was found in 1995 with 1.51%, and the lowest rate was found in 1997 with 0.004%. When Figure 5 showing vehicle defects is examined, the highest rate was found in 2020 with 2.67%, and the lowest rate was found in 2006 with 0.10%.

2.2. Time series method

Time series analysis is one of the important tools of applied statistics used in modeling time series data and forecasting future values. It has been used in studies such as fault detection [14], state economic [15], internet traffic [16], assessment of noise [17]. In this study, it was used to predict the defects that cause traffic accidents in the future. Theoretical information about the models obtained for the data in this study from the existing models in the univariate time series literature is given below.

Holt model:

The time series uses Holt exponential smoothing. The following two coefficients (α and β) are correction coefficients to estimate the bias in the Holt model for forecasting [18]. There is level belong to Holt's exponential smoothing. Also trend parameters are used too. Equations belong to Holt model are shown such as formulations [19]:

$$L(t)=\alpha Y(t)+(1-\alpha)(L(t-1)+T(t-1)) \quad (1)$$
$$T(t)=\gamma(L(t)-L(t-1))+(1-\gamma)T(t-1) \quad (2)$$
$$\hat{Y}(k)=L(t)+kT(t) \quad (3)$$

Brown model:

It is reported that the Brown model is more suitable for increasing or decreasing trends in time series data [18]. Brown's exponential smoothing has level and trend parameters, it can be determined via given formulations [19]:

$$L(t)=\alpha Y(t)+(1-\alpha)L(t-1) \quad (4)$$
$$T(t)=\alpha(L(t)-L(t-1))+(1-\alpha)T(t-1) \quad (5)$$
$$\hat{Y}t(k)=L(t)+(k-1)+\alpha^{-1}T(t) \quad (6)$$

Simple model:

A single level parameter of simple exponential smoothing is given as follows [19]:

$$L(t)=\alpha Y(t)+(1-\alpha)L(t-1) \quad (7)$$
$$\hat{Y}(k)=L(t) \quad (8)$$

Here, L(t) represents an estimate of the level of the series at time t; T(t) represents an estimate of the trend (slope) of the time series at time t; $\hat{Y}(k)$ represents forecast at time t; α is the smoothing parameter for the level, $0\leq\alpha\leq1$; ɣ is the smoothing parameter for the trend, $0\leq \gamma \leq1$; k is the forecasting step

MAPE was used for comparisons in obtaining estimates. Accordingly, MAPE can produce different metrics based on the distance of the estimated values from the real values. Mean absolute percent error (MAPE), one of these metrics, is frequently used to

measure the accuracy of forecasts in time series models. Therefore, in this study, the MAPE metric was used to interpret the success of the model [20]. MAPE is calculated using the formula given below. In formula (9), While "O_i" shows the observed value, "Pt" shows the predicted value [21].

$$\text{MAPE}=\frac{100}{n}\sum_{t=1}^{n}\left|\frac{O_i-P_i}{O_i}\right| \quad (9)$$

3. Findings

In the study, the values of the defects causing traffic accidents that occurred between 1995 and 2021 were taken into account and an estimate was carried out until 2030 for each type of defect using time series with the help of the SPSS program.The models used according to defect types are shown in Table 2. Model statistics of defects are also included in Table 2.

Table 2. Model statistics

Defect Type	Model	R-squared	MAPE	Normalized BIC	Model Statistics (Sig.)
Driver defects	Simple	.547	28.243	24.113	.993
Passenger defects	Holt	.581	32.062	12.797	.997
Pedestrian defects	Simple	.317	7.181	14.908	.867
Road defects	Holt	.138	364.537	14.339	.887
Vehicle defects	Brown	.668	37.111	13.479	.456

R-squared, as shown in Table 2, is a statistical term expressed as the coefficient of determination (R^2). The coefficient of determination is a statistic that reflects the "predictive power" of the regression equation [21]**.** The Bayesian information criterion is a criterion for selecting a model from a finite number of models [22]. The smaller the Normalized Bayesian information criterion (Normalized BIC), the better the model's performance Model statistics (Sig.) expresses the statistical significance of the model [23].

Below is a graphic representation of the forecasting results obtained by the time series analysis. The graphs of the values estimated for driver, passenger, pedestrian, road and vehicle defects until 2030 are shown in Figure 6 to 10. The black y-axis in the graphs shows the beginning of the estimated defect values until 2030. Fit; re-evaluation of observed values with the model used. Additionally, the UCL and LCL values in the graphs represent the upper limit and lower limit values, respectively.

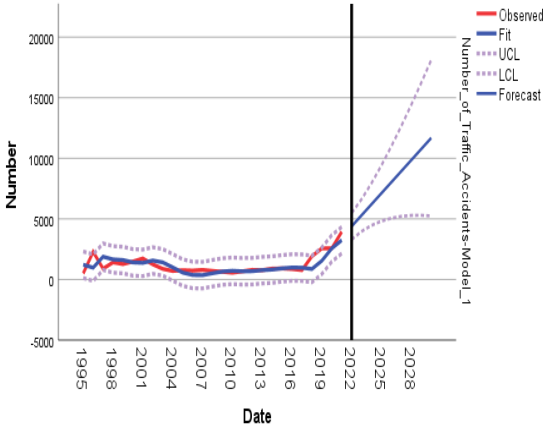

Figure 6. Driver defects by 2030

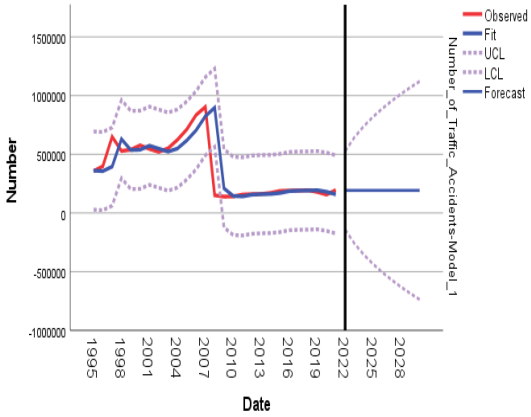

Figure 7. Passenger defects by 2030

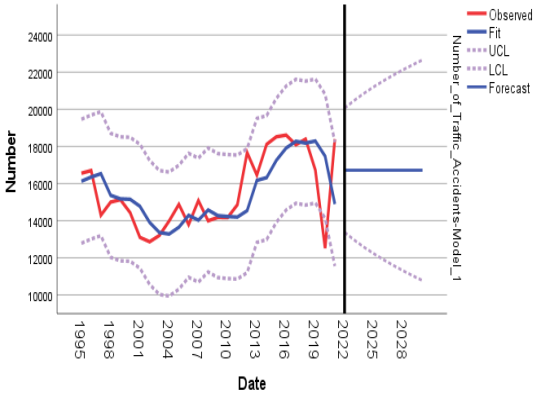

Figure 8. Pedestrian defects by 2030

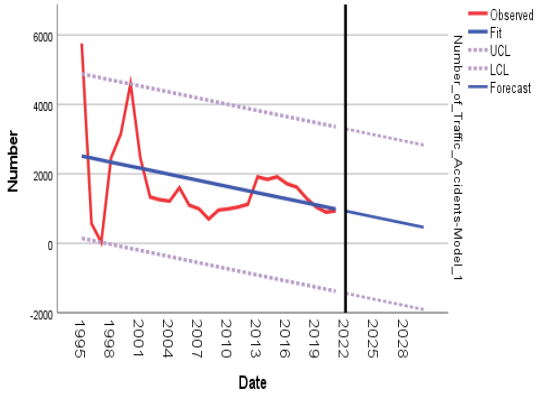

Figure 9. Road defects by 2030

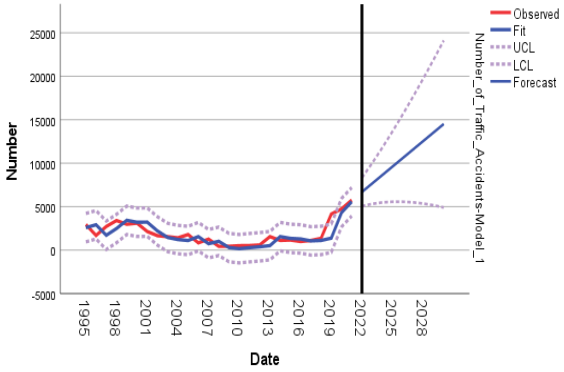

Figure 10. Vehicle defects by 2030

When the graphs showing the estimated values of defects that cause traffic accidents are examined, it is understood that there will be changes in the number of defects until 2030. According to Figure 6, driver defects that cause traffic accidents will be the same as in 2021 until 2030 and will remain stable. In Figure 7, which shows passenger defects, there will be an increase until 2030. Pedestrian defects shown in Figure 8 will be lower by 2030 than in 2021, but will be higher than the lowest values in 2006-2007. When the estimated values of road defects until 2030 are examined in Figure 9, it is understood that there will be a decrease. In Figure 10, the estimated values of vehicle defects that cause traffic accidents are increasing until 2030.

4. Conclusion and recommendations

Within the scope of transportation safety, projects called “vision zero” to reduce fatal accidents are becoming widespread. Vision Zero studies, which started in Sweden in 1997 [24], are today one of the most important initiatives in the field of traffic safety all over the world [25]. It is not possible to accept the loss of human lives due to road traffic as a normal situation. The aim of the decade goal of the traffic safety vision in Türkiye is to reduce the number of deaths resulting from traffic accidents 50% by 2030. The ultimate goal is to provide a traffic system without loss of life by 2050. According to the results obtained from some scientific studies in order to provide safer transportation in traffic [26];

*Infrastructure improvements (such as center divider barriers and intersection improvements), lowering speed limits in risky areas of the road network and increasing traffic police inspections with a combination of both conventional and electronic inspection methods, it is considered possible to reduce traffic accident fatalities by around 50%.

*According to the same studies, improving the safety levels of motor vehicles can also contribute to a 25% reduction in traffic fatalities.

*Reducing the remaining 25% depends on the implementation of interventions such as radical changes in driver training and increased sanctions for violations.

Projects are developed and funds are provided to ensure road safety. Measures such as technical support, mapping and evaluation report on recommendations, establishing an interactive web platform for the latest design standards, training to improve the safety awareness and knowledge of driving instructors and test officers, developing curricula and training materials for driving schools, as well as preparing testing requirements and processes for officials, development of online application and testing system, development of national road design standards, establishing a network with local and international universities, municipal councils and foundations on best practices in the field of sustainable and safe mobility, mapping the most critical corridors and projecting the investments required for safe and smooth sidewalks, bicycle paths, pedestrian crossings and organized public transportation stops along these corridors, conducting a cost-effectiveness analysis of user safety interventions, implementing education and information campaigns about the importance of reducing deaths and injuries in road traffic, collection of crash data, analysis of existing seat belt and other restraint legislation and identification of gaps/deficiencies, encouraging speed control projects in passenger and cargo fleets, and educating and raising awareness of motorcycle users about the relevant regulations based on studies are a few of the activities determined by the United Nations Economic Commission for Europe (UNECE) [27].

In the results of this study, differences were obtained in the forecasting of the defect classes of the main defects that cause traffic accidents until 2030. The forecasts show that driver defects will remain stable, passenger defects will increase, pedestrian defects will be incerase according to 2021 until 2030, road defects will decrease and vehicle defects will increase. According to the vision zero policy adopted, an increase in the defects causing traffic accidents is definitely not a desirable outcome. Therefore, measures need to be taken especially for the driver defects that remain stable and the passenger and

vehicle defects that increase. Accordingly, these findings are important for policy makers and transportation engineers to take steps to ensure transportation safety. In this context, this study has an important place in transportation safety.

References

[1] Oktopianto, Y., R. Rukman, and R.P. Marwanto, Improving traffic safety through a community participation approach, **Jurnal Pengabdian Kepada Masyarakat Semangat Nyata Untuk Mengabdi (JKPM Senyum),** 3(2), 125-130, (2023).

[2] Deretić, N., et al., SARIMA modelling approach for forecasting of traffic accidents, **Sustainability,** 14(8), 4403, (2022).

[3] Cai, B. and Q. Di, Different forecasting model comparison for near future crash prediction, **Applied Sciences**, 13(2), 759, (2023).

[4] https://unece.org/sites/default/files/2021-01/UNRSF_who_we_are_Jan21%20%28002%29.pdf

[5] Hokmabadi, R., et al., The role of high-risk behaviors, fatigue, and drowsiness in the occurrence of road accidents and near miss accidents among Tehran truck drivers in 2019, **Journal of Occupational Health and Epidemiology,** 10(4), 258-265, (2021).

[6] Toroyan, T., M.M. Peden, and K. Iaych, WHO Launches second global status report on road safety, **BMJ Publishing Group Ltd,** (2013).

[7] Najaf, P., et al., Evaluating traffic safety policies for developing countries based on equity considerations, **Journal of Transportation Safety & Security**, 9(sup1), 178-203, (2017).

[8] Sohail, A., et al., Data-driven approaches for road safety: A comprehensive systematic literature review, **Safety Science**, 158, 105949, (2023).

[9] Kaygisiz, Ö., M. Senbil, and A. Yildiz, Influence of urban built environment on traffic accidents: The case of Eskisehir (Turkey). **Case Studies On Transport Policy**, 5(2), 306-313, (2017).

[10] Ihueze, C.C. and U.O. Onwurah, Road traffic accidents prediction modelling: An analysis of Anambra State, Nigeria, **Accident Analysis & Prevention**, 112, 21-29, (2018).

[11] Jomnonkwao, S., S. Uttra, and V. Ratanavaraha, forecasting road traffic deaths in Thailand: Applications of time-series, curve estimation, multiple linear regression, and path analysis models, **Sustainability,** 12(1), 395, (2020).

[12] Sumit, K., et al., An exploration of characteristics and time series forecast of fatal road crashes in Manipal, India. **Sustainability,** 14(5), 2851, (2022).

[13] Twenefour, F., et al., Time series analysis of road traffic accidents in Ghana, **Asian J Probab Stat,** (2021).

[14] Fassois, S. D., & Sakellariou, J. S. Time-series methods for fault detection and identification in vibrating structures. **Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences**, 365(1851), 411-448, (2007).

[15] Hansen, J. V., & Nelson, R. D. Neural networks and traditional time series methods: a synergistic combination in state economic forecasts. **IEEE transactions on Neural Networks,** 8(4), 863-873, (1997).

[16] Cortez, P., Rio, M., Rocha, M., & Sousa, P. Multi-scale Internet traffic forecasting using neural networks and time series methods. **Expert Systems**, 29(2), 143-155, (2012).

[17] Amiri-Simkooei, A. R., Tiberius, C. C., & Teunissen, P. J. Assessment of noise in GPS coordinate time series: methodology and results. **Journal of Geophysical Research: Solid Earth,** 112(B7), (2007).

[18] Akın, M. and S. Eyduran, Zaman serisi analiz yöntemlerini kullanarak 2016-2025 dönemi Türkiye avokado üretiminin belirlenmesi, **Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi,** 27(2), 252-258, (2017).

[19] Kınacı, H., M.G. Ünsal, and R. Kasap, A close look at 2019 novel coronavirus (COVID 19) infections in Turkey using time series analysis & efficiency analysis, **Chaos, Solitons & Fractals,** 143, 110583, (2021).

[20] Gokkus, U., M. S. Yildirim and M. M. Aydin, Estimation of container traffic at seaports by using several soft computing methods: A case of Turkish Seaports**, Discrete Dynamics in Nature and Society**, 2984853, (2017).

[21] Günel, A. Regresyon denkleminin baarısını ölçmede kullanılan belirleme katsayısı ve kritiği, **Doğuş Üniversitesi Dergisi,** 4(2), 133-140, (2003).

[22] Kirca, M. M. Yapı seramiği endüstrisinde kusurlu üretim, ürün sınıflandırma ve verimlilik sürecinin Bayes ağları ile analizi (Master's thesis, Fen Bilimleri Enstitüsü).

[23] Pektaş, Ali Osman, SPSS ile Veri Madenciliği, Dikeyeksen Yayınları, ISBN:978-605-86660-4-7, İstanbul, (2013).

[24] Kristianssen, A. C., Andersson, R., Belin, M. Å., & Nilsen, P. Swedish Vision Zero policies for safety–A comparative policy content analysis, **Safety science,** 103, 260-269, (2018).

[25] Belin, M. Å., Tillgren, P., & Vedung, E. Vision Zero–a road safety policy innovation, **International journal of injury control and safety promotion,** 19(2), 171-179, (2012).

[26] Trafik Güvenliği Vizyonumuz, https://www.guvenlitrafik.gov.tr/3-trafik-guvenligivizyonumuz#:~:text=Trafik%20g%C3%BCvenli%C4%9Fi%20vizyonumuzun%20on%20y%C4%B1ll%C4%B1k,TRAF%C4%B0K%20S%C4%B0STEM%C4%B0N%C4%B0N%20VATANDA%C5%9ELARIMIZA%20SUNULMASI'd%C4%B1r.

[27] https://unece.org/projects-2#