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Statistical Analysis of Defects Causing Traffic Accidents in Türkiye

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Highlights

- The defects that cause traffic accidents have been examined in five classes.
- The relationship between these defects was analyzed using statistical methods.
- At the end of the study, recommendations for safe transportation were presented.

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Abstract

Road traffic accidents can result in death, injury, financial loss and moral damage and pose a major problem. Traffic accidents, which are recognized as a social problem all over the world and whose causes include many interrelated factors, need to be addressed in a multidisciplinary manner. Safe traffic is a right for everyone. In this direction, many studies in the international literature and traffic accident data in Türkiye were examined in this study, which was prepared to understand the factors that cause traffic accidents, prevent traffic accidents and ensure safe traffic in full. In this study, according to the records of the General Directorate of Security on traffic accidents with fatalities and injuries occurring in Türkiye between 2013 and 2021, five main defects causing traffic accidents, namely “Driver”, “Passenger”, “Pedestrian”, “Road” and “Vehicle”, and a total of 69 sub-defects belonging to these main defects were analyzed. Statistical analysis of the relationship between these defects was performed with One Way Anova and Kruskal Wallis methods. The study also presents recommendations on strategies to improve traffic safety at local and global level for traffic accidents, which is an important health and social policy issue that concerns the whole world today.

1. INTRODUCTION

Every year, traffic accidents cause thousands of people to be injured, lose their lives and cause financial losses to the people involved in the accident [1]. Injuries resulting from road traffic accidents, which directly or indirectly affect millions of people worldwide, are projected to become the fifth leading cause of impact on the global burden of disease by 2030 [2]. The highway traffic system is a complex structure where there is interaction between the road, the road environment, vehicles and road users [3]. The factors that cause traffic accidents include all the components of this complex structure. While the human factor is the largest contributing factor to all vehicle accidents, other factors should not be ignored. Focusing on a single factor and not considering the possible interaction of other contributing factors can lead to possible unintended consequences in traffic safety [4]. For this reason, all the factors that caused the accident should be understood in the best possible way [5]. In this study, all parameters consisting of “Vehicle”, “Driver”, “Pedestrian”, “Road” and “Passenger” main defects and sub-defects belongs to these defects classified by the Turkish Statistical Institute (TUIK), which are effective in the occurrence of traffic accidents, were analyzed [6].

1.1. Driver Defects

Among the defects that cause traffic accidents, the largest proportion belongs to drivers, and approximately 90% of traffic accidents are caused by human factors [7]. There may be cases in which this rate reaches 95% [8]. According to the data of the General Directorate of Security in Türkiye, driver defects that cause

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traffic accidents include “Driving drunk”, “Speeding and not following speed limits”, “Not following the rules of crossing priority”, “Turning or changing lanes without signaling”, “Making deceptive overtaking”, “Not following the vehicle in front close to the tracking distance”, “Using a mobile phone while driving” and “Usurping the right of pedestrians to pass priority at pedestrian crossings” as the most common violations [9].

According to research, the rate of traffic accidents caused by drunk driving is approximately 10% [10], alcohol reduces driving ability [11], and there is also an increase in the rate of fatal accidents due to an increase in the amount of alcohol in the blood [12]. A study in Serbia found a strong correlation between blood alcohol level and injury, according to the results of a study conducted among injured victims of traffic accidents with more than 0.03% alcohol in their blood and those with no alcohol at all. Research has shown that drunk drivers are 3.80 times more likely to be injured in fatal accidents [13]. A study examining the death rate of drivers in fatal alcohol-related accidents in Japan found that the death rate of drivers with an alcohol connection was approximately 67%, while the death rate of drivers without an alcohol connection was approximately 34% [14].

Excessive speed in traffic is considered one of the most important factors in the occurrence of accidents, and driving speed is an important factor in terms of road safety. Speed affects the severity of the accident and is also associated with the risk of being involved in an accident [15]. In a study conducted in the Democratic Republic of Congo, when the factors causing traffic accidents were analyzed, it was found that speeding was the biggest factor with 32% [10]. Approximately 60% of fatal accidents in New Zealand are caused by excessive speed [16]. Among the risk behaviors that cause traffic accidents, “Failure to comply with the rules of transit priority” also has an important share. When the accidents caused by drivers are examined in traffic accidents occurring in Türkiye, it is observed that the rate of traffic accidents caused by failure to comply with the priority of transit is remarkably high compared to other accidents [17]. In a study examining the causes of traffic accidents, it was found that failure to comply with the priority of passing at intersections had a rate of 19% in accidents with material damage and 35.6% in fatal accidents. [18].

In a study examining the effect of changing lanes on traffic accidents, it was found that drivers who change lanes suddenly are 2.53 times more likely to be involved in a traffic accident than others. Drivers who look in the side mirror and out the window before changing lanes are 4.61 and 3.85 times less likely to be involved in an accident, respectively [19]. A study in Jordan found a correlation between aggressive driving in traffic and driver behaviors related to lane violations, zigzag driving and crossing the road that increase the rate of traffic accidents [20]. When the causes of traffic accidents are examined, incorrect overtaking is considered one of the important causes of accidents. Complex maneuvers on a two-lane highway cause accidents [21]. In one study, erroneous overtaking and risky maneuvering behaviors, which are considered driver defects, ranked third and fourth with 16% and 15%, respectively [10]. In US states, the rate of overtaking-related traffic accidents can reach 38% [22].

A safe distance must be maintained to reduce accidents [23]. Keeping vehicles moving at a safe distance in traffic contributes to the harmonious flow of traffic [24]. Among risk behaviors, not adhering to the following distance and following the vehicle in front too closely can cause rear-end crashes, which are the most common in traffic [25]. Failure to maintain the required safe distance from the vehicle in front and improper driving cause approximately 2/3 of simple transportation accidents [26]. Most of the accidents involving pedestrians occur while crossing the street [27]. Pedestrian safety is highly dependent on vehicle speed. A pedestrian hit by a vehicle traveling at 50 km/h has almost eight times the risk of fatal injury compared to a pedestrian hit by a vehicle traveling at 30 km/h [28].

1.2. Passenger Defects

When traffic accidents are analyzed, passengers’ negligent behavior can also be associated with traffic accidents resulting in death and injury. In a study conducted to examine traffic accidents in Thailand, which ranks second in the world in terms of deaths due to traffic accidents, it was reported that being in the cab of a pickup truck and not using seat belts were among the passenger defects [29]. In a study conducted to examine the causes and responsible factors of traffic accidents in India, the defect of passengers in vehicles in traffic accidents was found to be 3%. In the study, none of the drivers and passengers in the vehicle were wearing helmets or seat belts, which was considered alarming [30].

The presence of passengers in the vehicle can also affect the occurrence of traffic accidents [31]. A study in Florida found that drivers generally show safer driving behavior when they are with passengers, and that more passengers reduce the potential for a driver's accident. In addition, the study found that when the driver is younger, the driver's accident potential increases with a younger passenger [32]. In the study investigating the possibility of having an accident according to the driver's gender and passenger type, the female driver's accident risk perception differed according to the passenger in the vehicle. For a female driver, having a son as the passenger created a higher risk perception than having a co-worker as the passenger. The risk perception of male drivers was found to be the same for both passengers [33]. As a result of these studies conducted in connection with the gender and age of the driver, it can be concluded that the number of passengers in the vehicle and the type of passenger can affect the probability of a traffic accident.

1.3. Pedestrian Defects

According to 2013 EU data, pedestrians account for more than 22% of traffic fatalities. 69% of pedestrian fatalities occur in urban areas [34]. Traffic accidents involving pedestrians constitute an important problem in traffic accidents all over the world due to increasing population, urbanization, drivers and pedestrians not obeying traffic rules. Road characteristics (number of lanes, road width), number of people trying to cross the road, road user characteristics (demographic characteristics such as age, gender, education level) may affect pedestrian decision to cross the road [35]. In a study conducted to examine the behavior of pedestrians crossing the road at uncontrolled intersections in Bangladesh, it was found that most of the pedestrians did not apply the traffic rules despite knowing them. The reasons for this were found to be lack of awareness, gender (male pedestrians violated crosswalks more often), age (more misbehavior was found in younger pedestrians), education level (as education level increased, pedestrians obeyed the rules more), pedestrian non-compliance (the majority of pedestrians who did not obey the rules thought that the crosswalk was not in the appropriate place), and income level (pedestrians with higher income obeyed the rules more) [36]. In a study conducted to determine whether pedestrians cross legally or not, it was found that male and child pedestrians were more likely to cross illegally than females [27]. Unsafe behavior of pedestrians in traffic can increase the risk of serious or fatal injury during an accident. For example, the likelihood of a pedestrian suffering a serious injury may increase by 27.86% and 20.73%, respectively, depending on whether they are distracted or not [37].

1.4. Road Defects

One of the factors that causes traffic accidents is road defects. Defects such as insufficient visibility, insufficient shoulder width, inappropriate curve design, and inappropriate lighting are recognized as defects that cause traffic accidents [38]. In a study conducted to examine the causes and responsible factors of traffic accidents in India, road defects in traffic accidents were found to be 4% [30]. There are also studies showing that 29% of traffic accidents are caused by the road [39]. Road elements such as road geometry, road surface conditions, roadside hazards, road complementary buildings, and road equipment can have an impact on the occurrence of traffic accidents [40]. Traffic-related fatalities are 0.74% on straight roads and 3.09% on winding uphill/downhill roads [41]. In a study conducted in the Uşak province of Türkiye, it was found that factors such as side access roads, uncontrolled pedestrian crossings and road geometry were prominent in the occurrence of traffic accidents [42].

1.5. Vehicle Defects

Studies investigating the effects of vehicle defects on traffic accidents show that the share of vehicle defects in the occurrence of traffic accidents can vary between 2.5% and 8%. This rate is more likely to increase in developing countries. In a study investigating common vehicle defects and their impact on traffic accidents in Bangladesh, it was found that defects such as tire explosion, brake failure, and wire breakage were the most common defects causing traffic accidents. Among the defects, the most important vehicle defect was identified as tire explosion with a rate of 45.3% [3]. In a study conducted in Lithuania to investigate the relationship between vehicle defects and traffic accidents, the highest positive correlation was obtained between traffic accidents and deceleration system failure. A similar result was achieved in the technical condition of the tires.

The weakest positive correlation between traffic accidents and vehicle defects was found in the steering system and the lighting system [43]. In a study conducted in South Africa to examine the relationship between mechanical defects and traffic accidents, brake and tire factors were found to be the two dominant factors causing traffic accidents. Overloading was also considered one of the issues to be considered [4]. A study in China examined the effects of large buses and vehicles carrying dangerous goods on traffic accidents by month, time and location factors. The study found that driver fatigue, excessive speed and vehicle malfunction were directly related to accidents. Brake system failure and overload were found to have a significant impact on the accidents investigated in the study [44]. In a study conducted in Malaysia, which examined bus types and vehicle-related defects, it was found that among vehicle defects, the defect caused by deceleration was effective in causing traffic accidents with a rate of 56% [45]. The aim of this study is to analyze the "Vehicle", "Driver", "Pedestrian", "Road" and "Passenger" defects and all the sub-defects related to these defects that cause traffic accidents in Türkiye by statistical methods and to present suggestions for taking appropriate steps to contribute to traffic safety. Accordingly, the data on fatal and injury traffic accidents between 2013-2021 obtained from TUIK were analyzed.

2. MATERIAL METHOD

Within the scope of the study, the defects that cause traffic accidents are first shown. In the second part, statistical analysis of the relationships between these defects was carried out using One Way Anova and Kruskal Wallis methods in the SPSS program.

2.1. Types of Defects that Cause Traffic Accidents

In the study, the data obtained from the Turkish Statistical Institute (TUIK) covers the defects of "Driver", "Passenger", "Pedestrian", "Road" and "Vehicle". These defects and the sub-defects belonging to each of these defects are shown in Table 1.

Table 1. *Defects that cause traffic accidents [6]*

Driver defects			
1	Driving under the influence of alcohol	16	Failure to comply with the priority of passage in places where the coating is narrow
2	Not adjusting the vehicle speed according to the conditions required by the road, weather and traffic	17	Failure to comply with passenger loading and boarding rules
3	Rear-end collision	18	Parking in the wrong or prohibited places
4	Driving excessively fast	19	Driving with missing, damaged or unsuitable vehicle equipment
5	Failure to comply with the rules for changing direction	20	Inappropriate use of light
6	Violating the prohibition on passing	21	Taking passengers over the transportation limit
7	Failure to observe the priority of passage at intersections	22	Dangerous or excessive loading
8	Running a red light	23	Riding bicycles, M.bicycles and motorcycles without following the rules
9	Collision with a parked car	24	Keeping animals on the highway outside the settlement, except in compulsory cases, using passenger animals and hand-driven vehicles against traffic rules
10	Failure to comply with the general conditions governing maneuvers	25	Driving disrespectfully, throwing something out of the vehicle-spilling, using a phone while driving
11	Encroaching into the lane	26	Not to slow down at pedestrian and school crossings, not to give pedestrians the right of way
12	Violating the no vehicle sign	27	In cases where school vehicles flash the "STOP" sign, other vehicles do not stop and are misused
13	Driving under the influence of drugs	28	Not having or using a seat belt,
14	Failure to comply with vehicle driving times	29	Drivers should not have or use protective helmets and glasses on motorcycles.

Table 1. *(Continued) [6]*

15	Driving their vehicles below the speed limit or slowing down unnecessarily abruptly	30	Not stopping at the scene of the accident, not taking the necessary precautions and not reporting it to the authorities
		31	Other defects of the driver
Passenger defects			
1	Not using a helmet	5	Traveling while drunk
2	Not Wearing a Seat Belt	6	Not stopping at the scene of an accident, not taking the necessary precautions
3	Getting on and off vehicles in an uncontrolled manner	7	Other defects of the passenger
4	Throwing or spilling something on the road in a way that obstructs traffic		
Pedestrian defects			
1	Not complying with the rules of passing in places where there are no crossings or intersections	7	Failure to take measures to prevent collisions in low visibility day and night
2	Failure to comply with traffic lights and signs	8	Not stopping at the scene of an accident, not taking the necessary precautions
3	Taking actions that endanger traffic on the vehicle road	9	Throwing or spilling something on the road in a way that makes traffic difficult
4	Failure to obey crossing rules	10	Drunk driving
5	Going to the highway	11	Other pedestrian defects
6	Not to go on the left side of the vehicle road		
Road defects			
1	Sitting on the wheel track	5	Loose material on the road surface
2	Lane Collapse	6	Pothole on the road
3	Collapse	7	Other road defects
4	Low banquet		
Vehicle defects			
1	Defective brake	8	Turn Signal
2	Defective rod	9	Door
3	Sheave, shaft, gearbox, gear failure	10	Tire burst
4	Axle fracture	11	Klaxon
5	Defective steering	12	Windscreen wiper
6	Headlamp	13	Other defects of the vehicle
7	Rear Lights		

In this study, defects are numbered as in Table 1. According to TUIK, vehicle defects consist of thirteen sub-defects, pedestrian defects of eleven, road defects of seven, passenger defects of seven and driver defects of thirty-one.

2.2. Used Methods

One Way Anova and Kruskal Wallis methods are applied in cases where the relationship of more than two factors is examined in the application of statistical analyses. The method to be used is determined according to whether the data is suitable for normal distribution. In determining whether the data is distributed normally, the values of the Skewness coefficient (Skewness) and Kurtosis coefficient (Kurtosis) are taken into account. When these values are between -2.0 and +2.0, it is assumed that the data is normally distributed. Kruskal Wallis, one of the non-parametric methods [46], One Way Anova, one of the parametric methods, were applied in cases with normal distribution [47], and in cases where normal distribution was not provided.

2.3. Analysis Methods Used in the Traffic Accidents

In this study, Kruskal Wallis and One Way Anova tests were applied to determine the relationship between defects causing traffic accidents and the number of these defects. Kruskal Wallis test, one of the non-parametric methods used in cases where normal distribution does not occur, and One Way Anova test, one of the parametric methods, were used in cases where normal distribution occurred. Torsen and Atule [48] used Kruskal Wallis and Friedman tests, which are non-parametric methods, in the study in which they analyzed traffic accidents. In Adamawa State, Nigeria, traffic light violations were found to have the highest rate among the violations causing traffic accidents. In another study conducted to examine traffic accidents in Bangladesh, statistical methods such as Time series, Kruskal Wallis, Mann Whitney U and Univariate Linear Model were used. In the study, it was found that the type of vehicle and the location where the accident occurred were effective in traffic accidents [49]. In the study conducted to examine traffic accidents in Ethiopia, statistical methods such as t-test, Chi-square, One-way/Two-way ANOVA were used. The study found that 80% of traffic accidents were caused by driver error. Other factors contributing to traffic fatalities were identified as bad weather, vehicle conditions, incomplete traffic system information, and inadequate medical and ambulance services [50]. One Way Anova and Correlation Analysis were applied in a study examining traffic accidents in the Philippines. The study found that age and vehicle size have a strong impact on traffic accidents [51]. Anova and Post-Hoc Analysis methods were used in the study conducted by Gulzar et al. in which traffic accidents occurring in Punjab, Sindh, Khyber Phaktoon Khwa and Baluchistan provinces of Pakistan were analyzed [52]. Paçacı, Kasap and Çubuk investigated the effect of education level, gender and location on traffic accidents using Krsukal Wallis and One Way Anova methods in Türkiye [53]. Kruskal Wallis method was used to analyze traffic accidents in Nigeria according to vehicle types [54]. The Kruskal Wallis method was used in the study conducted to analyze traffic accidents in Morocco according to the road design and the surface condition of the road [55]. In a study for improving transportation in Poland, the distribution of the number of accidents by hours was compared using Kruskal Wallis and Kolmogorov-Smirnov tests [56]. In a study conducted in the USA, the relationship between shoulder types and speed limits was examined using the Kruskal Wallis method in order to compare crash rates [57]. In a study conducted in India, the Kruskal Wallis method was used to examine the relationship between traffic accidents and transportation modes [58].

3. VISUAL EXPRESSION OF DEFECTS IN TRAFFIC ACCIDENTS

In the study, the defect rates of total traffic accidents occurring in urban and rural areas between 2013 and 2021, obtained from TUIK, are shown in Figure 1.

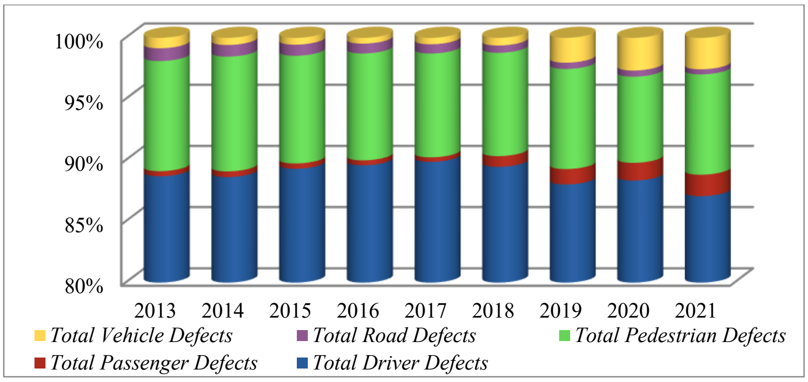

Figure 1. *Rates of defects causing traffic accidents [6]*

Figure 1 shows that between 2013 and 2021, the highest number of defects causing fatal and injury traffic accidents in Türkiye belongs to driver defects. Drivers are followed by pedestrians. The order of the number of sub-defects of each main defect is given below. Driver defects are shown in Figure 2, passenger defects in Figure 3, pedestrian defects in Figure 4, road defects in Figure 5 and vehicle defects in Figure 6.

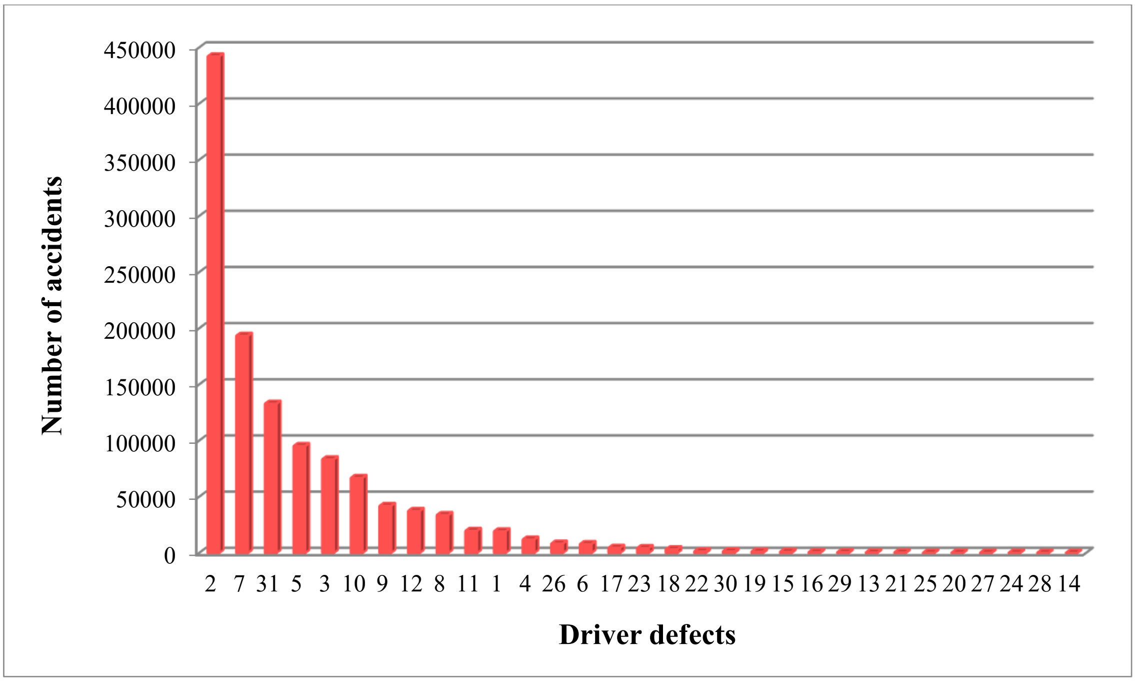

Figure 2. *Number of driver defects [6]*

When the impact of driver defects on traffic accidents is analyzed in Figure 2, the top five driver defects that have the highest impact on the occurrence of traffic accidents are listed as “Not adjusting the vehicle speed according to the conditions required by the road, weather and traffic”, “Failure to observe the priority of passage at intersections”, “Other defects of the driver”, “Failure to comply with the rules for changing direction” and “Rear-end collision”.

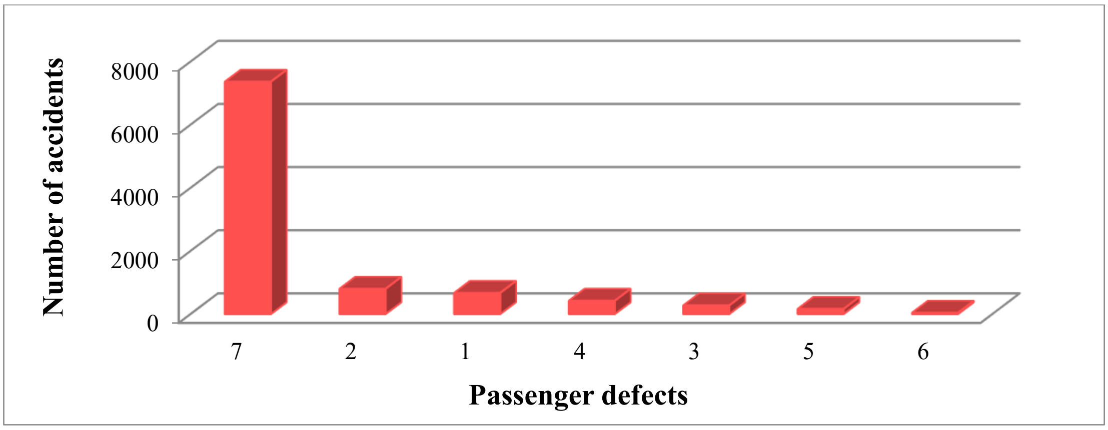

Figure 3. *Number of passenger defects [6]*

When the passenger defects in traffic accidents are analyzed in Figure 3, “Other defects of the passenger”, “Not wearing a seat belt”, “Not using a helmet”, “Throwing or spilling something on the road in a way that obstructs traffic” and “Getting on and off vehicles in an uncontrolled manner” are the passenger defects with the highest number.

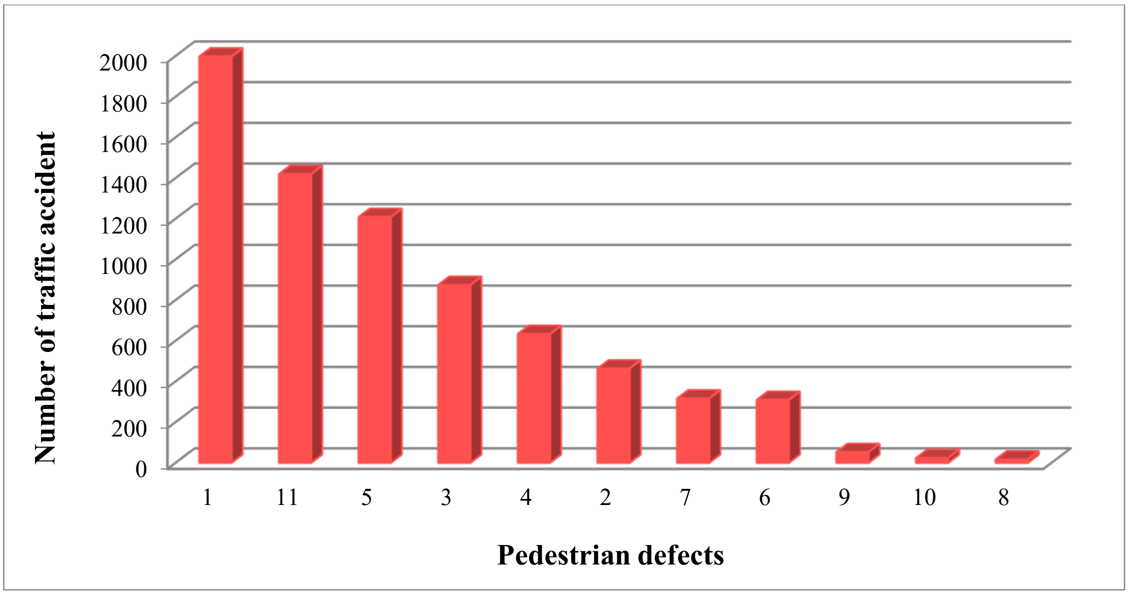

Figure 4. *Number of pedestrian defects [6]*

When the pedestrian defects in traffic accidents are analyzed in Figure 4, the top five defects in the number of accidents are "Not complying with the rules of passing in places where there are no crossings and intersections", "Other pedestrian defects", "Going to the highway", "Taking actions that endanger traffic on the vehicle road" and "Failure to obey crossing rules", respectively.

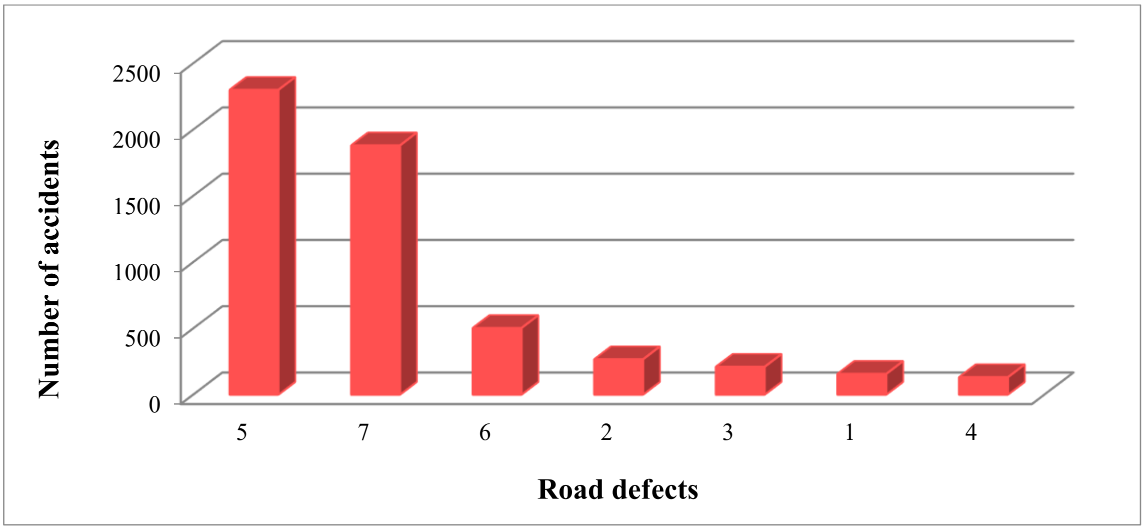

Figure 5. *Number of road defects [6]*

When the effect of road defects on traffic accidents is analyzed in Figure 5, it is seen that "Loose material on the road surface", "Other road defects", "Pothole on the road", "Lane collapse" and "Collapse" are among the top five road defects in traffic accidents.

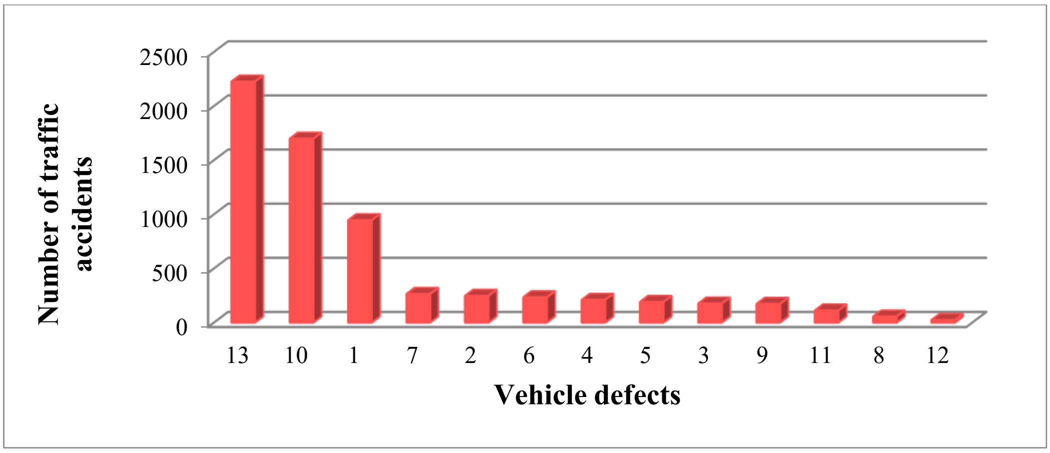

Figure 6. *Number of vehicle defects [6]*

When vehicle defects are ranked among the 13 sub-defects in Figure 6, the defect that causes the most accidents is "Other defects of the vehicle", which ranks first. The second and third most common defects are "Tire burst" and "Defective brake", respectively. This order is followed by "Rear lights" and "Defective rod".

4. STATISTICAL ANALYSIS OF DEFECTS IN TRAFFIC ACCIDENTS

In this section, the binary relationship between each of the sub-defects of the five main defects consisting of "Vehicle", "Driver", "Pedestrian", "Road" and "Passenger" defects in traffic accidents with fatalities and injuries was analyzed using One Way Anova and Kruskal Wallis methods according to whether the defects show normal distribution or not. In the tables, the "*" sign indicates that there is a significant relationship between two variables at 0.01, while the "X" sign indicates that there is no significant relationship.

4.1. Statistical Analysis of Driver Defects

Since the analysis is not normally distributed, the Kruskal Wallis method is applied in this section. Figures 7 and 8 show the box plot and the pairwise comparison of driver defects, respectively.

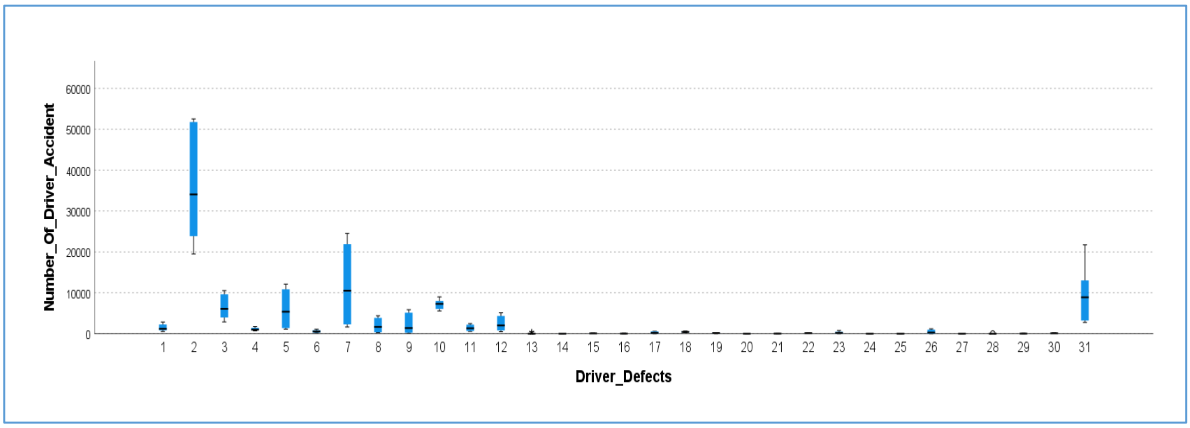

Figure 7. *Box plot of driver defects*

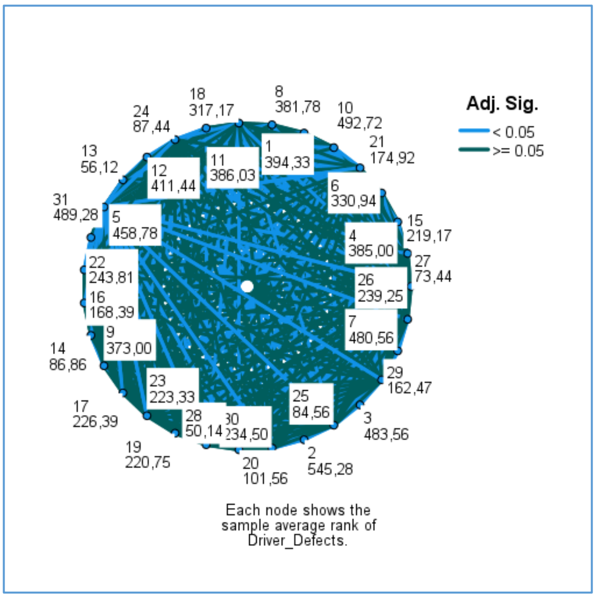

Figure 8. *Pairwise comparison of driver defects*

The box plot in Figure 7 shows that the 2nd, 5th, 7th and 31st defects are more heterogeneous than the others. The detailed representation of Figure 8 is given in Table 2. Table 2 shows the binary relationship between the "Driver" defects.

When Table 2 is taken into consideration, a significant relationship is obtained between the defects indicated with "*". On the other hand, a significant relationship could not be obtained between the defects indicated with "X". When Table 2 is analyzed, it is seen that a significant relationship was obtained between many driver defects. For example, there is a significant relationship between the 1st and 2nd defects. There is a significant relationship between the defects ("Driving under the influence of alcohol" and "Not adjusting the vehicle speed according to the conditions required by the road, weather and traffic").

4.2. Statistical Analysis of Passenger Defects

Since the analysis was not normally distributed, the Kruskal-Wallis method was applied. Figures 9 and 10 show the box plot and the pairwise comparison of road defects, respectively.

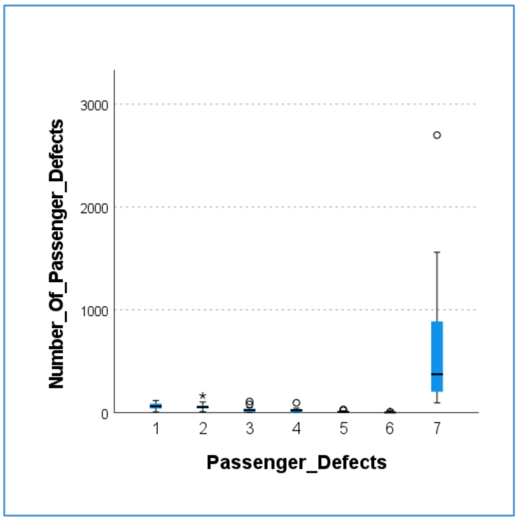

Figure 9. *Box plot of passenger defects*

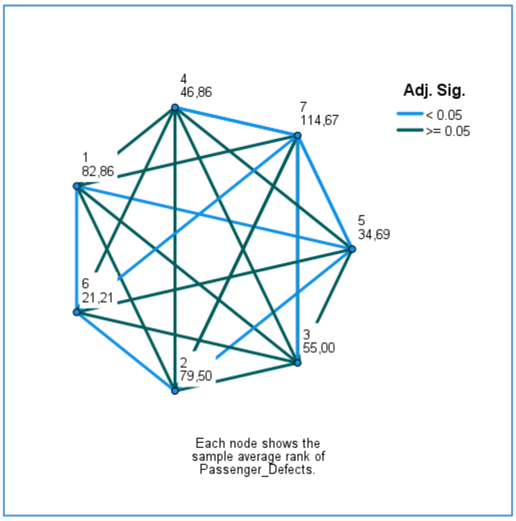

Figure 10. *Pairwise comparison of passenger defects*

Table 2. *The relationship between driver defects*

Driver Defects	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
1	-	*	*	X	*	*	*	*	X	*	X	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
2	*	-	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
3	*	*	-	*	X	*	*	*	*	X	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	X
4	X	*	*	-	*	X	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	X	*	*	*	*	*
5	*	*	X	*	-	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	X
6	*	*	*	X	*	-	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	X	*	*	*	*	*
7	*	*	*	*	*	*	-	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	X
8	*	*	*	*	*	*	*	-	X	*	*	X	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
9	X	*	*	*	*	*	*	X	-	X	X	X	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
10	*	*	X	*	*	*	*	<	X	-	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
11	X	*	*	*	*	*	*	*	X	*	-	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
12	*	*	*	*	*	*	*	X	X	*	*	-	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
13	*	*	*	*	*	*	*	*	*	*	*	*	-	X	X	X	*	*	X	X	X	X	*	X	X	*	X	X	X	X	*
14	*	*	*	*	*	*	*	*	*	*	*	*	X	-	*	*	*	*	X	*	X	*	*	X	X	*	X	X	*	*	*
15	*	*	*	*	*	*	*	*	*	*	*	*	X	*	-	X	*	*	X	*	*	X	*	*	*	*	*	*	X	X	*
16	*	*	*	*	*	*	*	*	*	*	*	*	X	*	X	-	*	*	X	*	X	*	*	*	*	*	*	*	X	*	*
17	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	-	*	*	*	*	*	X	*	*	X	*	*	*	*	*
18	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	-	*	*	*	*	X	*	*	*	*	*	*	*	*
19	*	*	*	*	*	*	*	*	*	*	*	*	X	X	X	X	*	*	-	X	X	X	*	X	X	*	X	X	X	X	*
20	*	*	*	*	*	*	*	*	*	*	*	*	X	*	*	*	*	*	X	-	X	*	*	X	X	*	X	X	X	*	*
21	*	*	*	*	*	*	*	*	*	*	*	*	X	X	*	X	*	*	X	X	-	*	*	X	X	*	X	X	X	*	*
22	*	*	*	*	*	*	*	*	*	*	*	*	X	*	X	*	*	*	X	*	*	-	*	*	*	*	*	*	*	X	*
23	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	X	X	*	*	*	*	-	*	*	X	*	*	*	*	*
24	*	*	*	*	*	*	*	*	*	*	*	*	X	X	*	*	*	*	X	X	X	*	*	-	X	*	X	X	X	*	*
25	*	*	*	*	*	*	*	*	*	*	*	*	X	X	*	*	*	*	X	X	X	*	*	X	-	*	X	X	X	*	*
26	*	*	*	X	*	X	*	*	*	*	*	*	*	*	*	*	X	*	*	*	*	*	X	*	*	-	*	*	*	*	*
27	*	*	*	*	*	*	*	*	*	*	*	*	X	X	*	*	*	*	X	X	X	*	*	X	X	*	-	X	X	*	*
28	*	*	*	*	*	*	*	*	*	*	*	*	X	X	*	*	*	*	X	X	X	*	*	X	X	*	X	-	*	*	*
29	*	*	*	*	*	*	*	*	*	*	*	*	X	*	X	X	*	*	X	X	X	*	*	X	X	*	X	*	-	X	*
30	*	*	*	*	*	*	*	*	*	*	*	*	X	*	X	*	*	*	X	*	*	X	*	*	*	*	*	*	X	-	*
31	*	*	X	*	X	*	X	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	-

The box plot in Figure 9 shows that the 7th defect is more heterogeneous than the others. A detailed representation of Figure 10 is given in Table 3. A significant relationship is obtained between the defects indicated with "*". On the other hand, a significant relationship could not be obtained between the defects indicated with "X".

Table 3. *The relationship between passenger defects*

Passenger Defects	1	2	3	4	5	6	7
1	-	X	*	*	*	*	X
2	X	-	X	*	*	*	X
3	*	X	-	X	*	*	X
4	*	*	X	-	X	X	X
5	*	*	*	X	-	X	X
6	*	*	*	X	X	-	X
7	X	X	X	X	X	X	-

Table 3 shows the relationships between the passenger defects. For example, there is a significant relationship between the 1st defect and the 3rd defect ("Not using a helmet" and "Getting on and off vehicles in an uncontrolled manner"). However, there is no significant relationship between the 1st and 2nd defects ("Not using a helmet" and "Not wearing a seat belt").

4.3. Statistical Analysis of Pedestrian Defects

Since the analysis was not normally distributed, the Kruskal Wallis method was applied. Figures 11 and 12 show the box plot and the pairwise comparison of pedestrian defects, respectively.

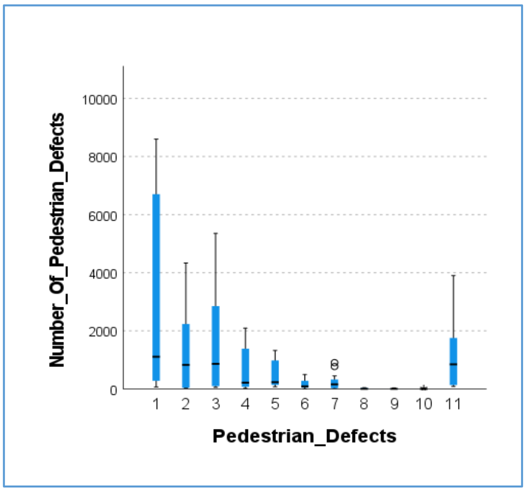

Figure 11. *Box plot of pedestrian defects*

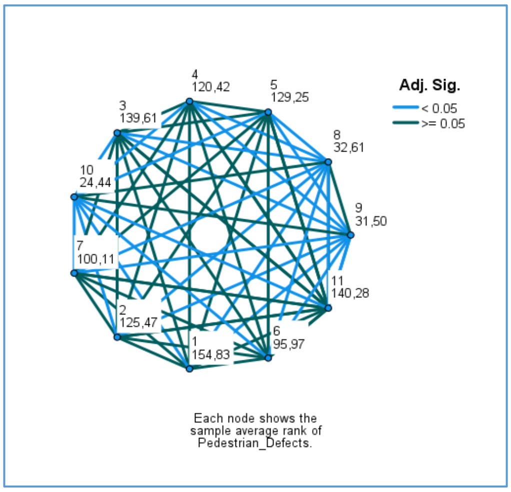

Figure 12. *Pairwise comparison of pedestrian defects*

The box plot in Figure 11 shows that the 1st defect is the most heterogeneous. A detailed representation of Figure 12 is given in Table 4. A significant relationship is obtained between the defects indicated with "*". On the other hand, a significant relationship could not be obtained between the defects indicated with "X". Table 4 shows the binary relationship between the "Pedestrian" defects.

Table 4. *The relationships between pedestrian defects*

Pedestrian Defects	1	2	3	4	5	6	7	8	9	10	11
1	-	X	X	X	*	*	*	*	*	*	X
2	X	-	X	X	*	*	*	*	*	*	X
3	X	X	-	X	*	*	*	*	*	*	X
4	X	X	X	-	X	*	X	*	*	*	X
5	*	*	*	X	-	*	X	*	*	*	X
6	*	*	*	*	*	-	X	*	*	*	*
7	*	*	*	X	X	X	-	*	*	*	*
8	*	*	*	*	*	*	*	-	X	X	*
9	*	*	*	*	*	*	*	X	-	X	*
10	*	*	*	*	*	*	*	X	X	-	*
11	X	X	X	X	X	*	*	*	*	*	-

When Table 4 is examined (i.e. defects 1 to 8), a significant relationship was found between “Not complying with the rules of passing in places where there are no crossings and intersections and Not stopping at the scene of an accident, not taking the necessary precautions”. No significant relationship was found between “Not complying with the rules of passing in places where there are no crossings and intersections or intersections and other pedestrian defects” (between defects 1 and 11).

4.4. Statistical Analysis of Road Defects

The One-Way Anova method was applied because the analysis showed a normal distribution. Figures 13 and 14 show the box plot and the pairwise comparison of road defects, respectively. Table 5 shows the pairwise relationship of “Road” defects with each other.

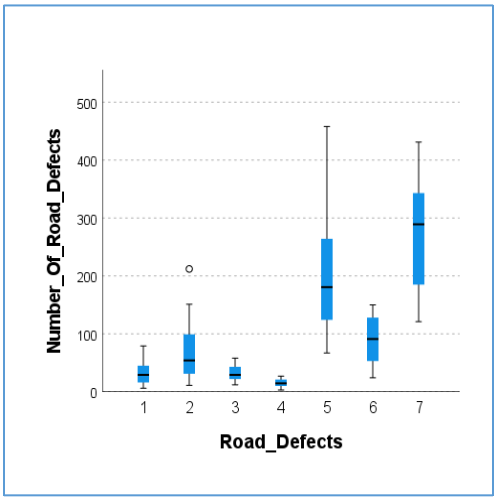

Figure 13. *Box plot of road defects*

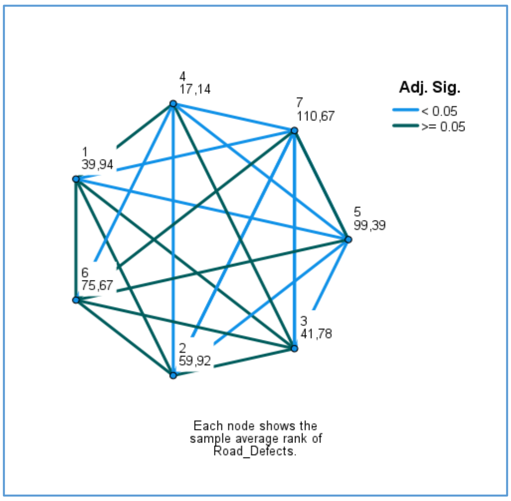

Figure 14. *Pairwise comparison of road defects*

The box plot in Figure 13 shows that the 5th and 7th defects are more heterogeneous than the others. A detailed representation of Figure 14 is given in Table 5.

Table 5. *Relationship between road defects*

Road Defects	1	2	3	4	5	6	7
1	-	X	X	X	*	X	*
2	X	-	X	X	*	X	*
3	X	X	-	X	*	X	*
4	X	X	X	-	*	*	*
5	*	*	*	*	-	*	*
6	X	X	X	*	*	-	*
7	*	*	*	*	*	*	-

A significant relationship is obtained between the defects indicated with "*". On the other hand, a significant relationship could not be obtained between the defects indicated with "X". Table 5 shows the relationships between the road defects. For example, there is a significant relationship between defects 1 and 5. There is a significant relationship between defects ("Sitting on the wheel track" and "Loose material on the road surface"). However, there is no significant relationship between defects 1 and 2 ("Sitting on the wheel track" and "Lane collapse").

4.5. Statistical Analysis of Vehicle Defects

The analysis did not show a normal distribution. Therefore, the Kruskal-Wallis method, one of the non-parametric methods, was applied. Figures 15 and 16 show the box plot and pairwise comparison of vehicle defects, respectively. Table 6 shows the relationship of the vehicle defects with each other.

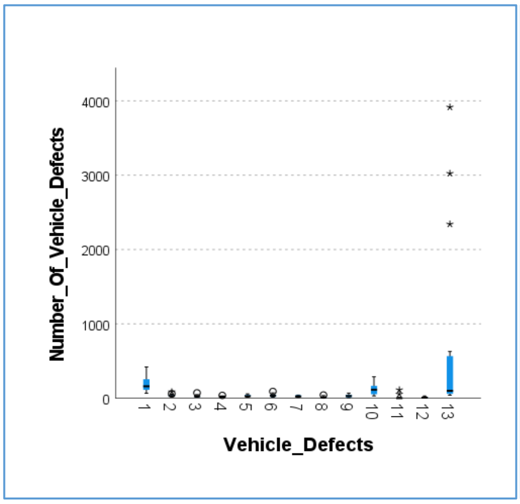

Figure 15. *Box plot of vehicle defects*

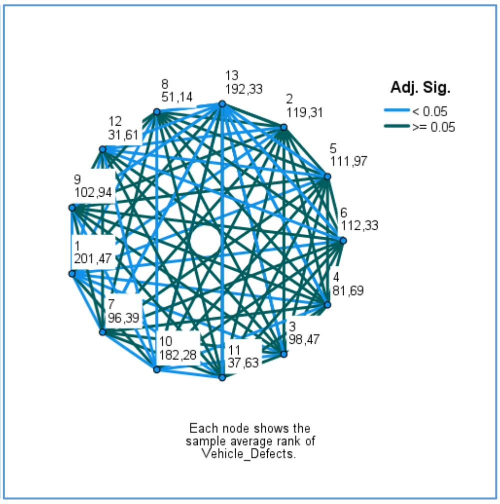

Figure 16. *Pairwise comparison of vehicle defects*

The box plot in Figure 15 shows that the 13th defect is more heterogeneous than the others. A detailed representation of Figure 16 is given in Table 6.

Table 6. *The relationship between vehicle defects*

Vehicle Defects	1	2	3	4	5	6	7	8	9	10	11	12	13
1	-	X	*	*	X	*	*	*	*	X	*	*	X
2	X	-	X	X	X	X	X	*	X	X	*	*	X
3	*	X	-	X	X	X	X	*	X	*	X	X	*
4	*	X	X	-	X	X	X	X	X	*	X	*	*
5	X	X	X	X	-	X	X	*	X	*	*	*	*
6	*	X	X	X	X	-	X	*	X	*	*	*	*
7	*	X	X	X	X	X	-	*	X	*	*	*	*
8	*	*	*	X	*	*	*	-	*	*	X	*	*
9	*	X	X	X	X	X	X	*	-	*	*	*	*
10	X	X	*	*	*	*	*	*	*	-	*	*	X
11	*	*	X	X	*	*	*	X	*	*	-	*	*
12	*	*	X	*	*	*	*	*	*	*	*	-	X
13	X	X	*	*	*	*	*	*	*	X	*	X	-

A significant relationship is obtained between the defects indicated with “*”. On the other hand, a significant relationship could not be obtained between the defects indicated with “X”. In Table 6, a significant relationship is obtained between defect 1 and defect 3, which are expressed as “Defective deceleration” and “Sheave, shaft, gearbox, gear failure” respectively, while no significant relationship is obtained between defect 1 and defect 5, which are expressed as “Defective deceleration” and “Defective steering”.

5. DISCUSSION

In the Road Traffic Safety Strategy Document of the Republic of Türkiye, the target of a 50% reduction of the number of deaths and serious injuries caused by traffic accidents until 2030 has been set [59]. In order to achieve this goal, every parameter that causes traffic accidents should be understood in the best way, and steps should be taken to ensure safe traffic. In this direction, there should be cooperation between educational programs, media programs and legislators, and individuals should be responsible forensuring safe traffic. In a study, it has been shown that public service announcements in the media of different countries, which are dominated by fear and sadness in order to show people the irreparable consequences of traffic accidents, will contribute to people's implementation of traffic rules [60].

To ensure road safety, sanctions should be imposed on road users, and measures should be taken. For example, sanctions should be imposed to prevent passenger defects such as not using seat belts and not using helmets, and people should raise awareness to implement these measures. In studies on seat belts, it has been observed that the decision of passengers in the same vehicle to use seat belts affects each other. This result shows that there are social dynamics among passengers [61]. The following distance warning systems can be used in vehicles to prevent rear-end accidents caused by close following [25]. In addition, reducing driver fatigue also plays an important role in reducing rear-end crashes [62]. In order to ensure the safety of pedestrians and cyclists who are vulnerable in traffic, it is necessary to increase the use of pedestrian crossings and to pay attention to signaling. If a vehicle traveling at 30 km/h hits a pedestrian, the probability of the pedestrian surviving can reach 90% or even 99%. For this reason, the construction of humps and mini-intersections before 40-50 meters from the pedestrian crossing, which will ensure that the speed of the drivers is reduced to 30 km or less at pedestrian crossings, are some of the effective methods to protect pedestrians and cyclists [63]. In a study conducted in Hungary to examine the safety of vulnerable road users in traffic, it was observed that the imposition of safety measures contributed to a reduction in pedestrian accidents. The study found that pedestrians behaved more erratically at roundabouts and crossed more regularly at crossings with flashing yellow lights, median islands and traffic lights. In this direction, it is concluded that highway safety measures have a strong effect on accidents caused by pedestrians [64].

In order to eliminate traffic accidents caused by road defects, it has been observed that applications such as new construction productions (sunken-overlap application), overpass applications, embankment applications on the middle sidewalk to control pedestrian crossing, and road geometry arrangement have been developed [42]. Designing appropriate asphalt according to the seasons and road conditions can contribute to the reduction of road-related traffic accidents. Preventive measures need to be strengthened to ensure traffic safety. Elements where accidents occur more frequently should be controlled more strictly within the scope of the policy [44].

In this study, the main defects of “Driver”, “Passenger”, “Pedestrian”, “Road” and “Vehicle” and 69 sub-defects of these main defects that cause traffic accidents were investigated, the most common defects that cause traffic accidents were mentioned and the relationship between all defects was examined. When the defects that are effective in traffic accidents occurring between 2013 and 2021 in Türkiye are analyzed, it is seen that the defect with the highest rate is the driver defect. Pedestrian defects are in the second place. When the sub-defects of these main defects are analyzed, “Not adjusting the vehicle speed according to the conditions required by the road, weather and traffic” and “Failure to observe the priority of passage at intersections” were found to be the most frequently observed defects among driver defects. Among passenger defects, “Other defects of the passenger” and “Not wearing a seat belt” were the most common defects. Among pedestrian defects, “Not complying with the rules of passing in places where there are no crossings and intersections” and “Other pedestrian defects” were the most common defects. Among road defects, “Loose material on the road surface” and “Other road defects” are the most common road defects causing traffic accidents. Among vehicle defects, “Other defects of the vehicle” and “Tire burst” are among the most common defects.

The box plots analyzed in the study provide more detailed information about the data distribution. Among the driver defects, the box plots of the 2nd, 5th, 7th and 31st defects showed a more heterogeneous distribution than the others. Defect 2 refers to “Not adjusting the vehicle speed according to the conditions required by the road, weather and traffic”. The distribution of the 7th fault, namely “Failure to observe the priority of passage at intersections”, has more scattered data among the 31 faults examined. The maximum value of this defect was also found to be quite high compared to other defects. As a result of the box plot findings, among the driver faults that cause traffic accidents, the 2nd fault (not adjusting the vehicle speed according to road, weather and traffic conditions) and the 7th fault (not complying with the passing priority at intersections) should be given priority. When the causes of traffic accidents in Türkiye are examined, the faults of not complying with speed and intersection rules are 42% and 13% respectively [65]. These rates are high, and it is inevitable to intervene in these defects in order to reduce accidents. Within the scope of the global plan for traffic safety, it is aimed to halve the proportion of vehicles exceeding the established speed limit and reduce speed-related injuries and deaths by 2030. In this direction, it is necessary to ensure stricter inspections with applications such as cameras and radars for driving at the appropriate speed and complying with the priority of passing at intersections, to increase the deterrence of fines, and to raise public awareness from an early age. The global plan includes increasing the proportion of motorcyclists wearing a standard-compliant helmet to 100%, and increasing the proportion of motor vehicle occupants using seat belts or standard-compliant child restraint systems to 100% by 2030 [66].

When pedestrian faults in traffic accidents were examined, the widest range in the box plot results was found to belong to fault 1 (Not complying with the rules of passing in places where there are no crossings and intersections). The maximum value of this defect was found to be quite high among pedestrian defects. It has the feature of scattered data. Its average value is close to the 2nd, 3rd and 11th defects.

Among the road defects that cause traffic accidents, “other defects” were found to have the widest distribution and the highest average. This defect covers all defects found except other defects examined in the study. Among the examined road defects, the defect with scattered data feature was found to belong to the 5th defect, which is “loose material on the road surface”. This defect showed a more heterogeneous distribution compared to other defects. To prevent traffic accidents caused by this defect, asphalt planning should be done in the best way possible. Asphalt application should be carried out in accordance with the procedure. Technical standards must be met.

The study also examined the relationship between the 69 sub-faults under five main headings and their effects on traffic accidents. The absence of a significant relationship indicates that the defects are equal. The finding of a significant relationship as a result of pairwise comparison indicates that there are similar characteristics between the defects. However, despite the similarity, differences can be observed in the averages of the defects. Finding a positive or negative result provides information about the average number of defects. For example, in the table of passenger defects in the Annex, the average difference between the 6^{th} and 1^{st} defects was found to be 61.655 (test statistic), and the average difference between the 6^{th} and 7^{th} defects was found to be -93.461 (test statistic). In this case, the mean of the 6^{th} fault is greater than the mean of the 1^{st} fault, but less than the mean of the 7^{th} fault. According to the pairwise comparisons made for the 69 faults examined in the study, more detailed information can be obtained about the share of faults in traffic accidents and their effects on each other by examining the similarities between the faults and the averages of the faults.

6. CONCLUSION AND RECOMMENDATIONS

The Global Plan has been developed as a guidance document by the World Health Organization and the United Nations Regional Commissions, in collaboration with the United Nations Collaborating Partners on Road Traffic Safety and other stakeholders, to support the implementation of the Decade of Action for Road Safety 2021-2030 and in line with its objectives. UN General Assembly resolution 74/299 declared the Decade of Action for Road Safety 2021-2030 for Road Traffic Safety with the target of reducing road traffic-related deaths and injuries by at least 50%. This plan aims to encourage national and local governments and other stakeholders that can have an impact on road traffic safety (including civil society, academia, private sector, donors, community and youth leaders and other stakeholders) to develop national and local action plans, targeting the Decade of Action. Suggestions in this direction are given below [67].

* Multimodal transportation and land use planning
* Safe road infrastructure
* Vehicle safety
* Safe road use
* Post-accident response

The requirements for implementing these recommendations are identified as financing, legal frameworks, speed management, capacity building, ensuring a gender perspective in transport planning, harmonizing technologies with the safe system, and focusing on low- and middle-income countries. Responsibility for road traffic safety is shared by governments, academia, civil society and youth, the private sector, funders and the UN [67]. In this context, projects are also developed with funds for countries [68]. With this study prepared in this direction, all defects that cause traffic accidents are examined under the main and subheadings. In order to reduce traffic accidents, measures should be taken and sanctions should be imposed by taking into account the most common main defects and sub-defects of these main defects. In addition, new studies can be conducted for the defects that have a significant relationship with the two defects examined in this study. This may help reduce traffic accidents. This research study is expected to help authorities, professionals and planners develop appropriate practices for safe traffic.

Kruskal Wallis and One Way Anova are methods used to examine the parameters affecting traffic accidents [69-70]. The effects of factors on traffic accidents can be examined using different methods, such as logistic regression analysis and Bayesian networks [71-74].

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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