

SAFETY ANALYSIS OF TRAM AND BUS PASSENGER TRANSPORT IN THE CITY OF ZAGREB

Marko Slavulj¹, Dino Šojat², Matija Sikirić³, Zlatko Boros²

Abstract: Public passenger transport is often considered a safe mode of travel compared to other modes, such as the private car. However, safety is one of the fundamental features of any transport system, including public transport, both from the point of view of passengers and operators. The paper contains an analysis of traffic accidents in the area of the City of Zagreb, based on the database of the local city public transport operator, Zagreb Electric Tram - ZET, for a period of ten years. Traffic accidents in the tram and bus system were analysed according to: type, place and time of occurrence, their frequency on individual tram and bus lines, working hours and the age of the driver. The aim of the work is to create a statistical analysis based on historical data on traffic accidents that will be used to define the degree of safety or risk of an accident, with regard to all traffic indicators, and accordingly define the necessary measures for the prevention and reduction of the number of traffic accidents involving public transport vehicles.

Keywords: safety indicators, traffic accident, tram system, bus system, safety level

1. INTRODUCTION

Traffic is a very complex phenomenon that leads to many conflicting situations. In order to increase traffic safety, it is necessary to implement numerous measures, the aim of which is to eliminate or reduce the danger. Traffic safety is a fundamental characteristic of every transport system, and especially of public city transport as a modality of sustainable passenger transport.

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The reasons are evident in the fact that the reliability of public city transport from the point of view of safety must be in the first place, because regularity and punctuality depend on it, and thus its efficiency.

The classical concept of safety in public city transport implies conditioning of five groups of factors in the environment in which these factors are located (Cerovac, 2001):

- a person, i.e. a tram/bus driver (working hours, driving experience, driver's age), a passenger or a pedestrian,
- roads (road condition, quality of lighting, weather conditions),
- vehicles (technical capabilities of the vehicle, technical correctness of the vehicle),
- traffic flows in the network,
- incident factors (they are characterized by unsystematic and unexpected occurrences – sudden changes in road conditions or weather conditions).

In general, safety as a feature of the transport system is complex and is best described by the number of traffic accidents that can be measured in time, according to the road covered or the number of vehicles, depending on the aspect of safety that is to be highlighted. A traffic accident is defined as an event in which at least one vehicle was involved, and in which at least one person died or was injured or caused material damage (Zakon o sigurnosti prometa na cestama).

At the EU level, the need for investment in intermodal passenger transport has been recognized. Policies must recognize that there are large differences between the risk of traffic accidents depending on the mode of travel. Walking and cycling safety also needs to be improved to optimize public transport safety, due to the high risk of required walking and/or cycling in the 'before and after' stages of these journeys. For the average passenger trip in the EU, bus travel has a 10 times lower fatality risk than car travel, while rail (including tram transport) represents the safest mode per distance travelled. (European Transport Safety Council)

2. RESEARCH METHODOLOGY

Traffic accidents are processed according to: type, place and time of occurrence, their frequency on individual tram or bus lines, working hours, driver's age and driving experience in ZET and driver employment services.

For the purpose of statistical analysis, a database on traffic accidents was used, based on the processing of statistical sheets for the record of traffic accidents filled out by the competent persons in the field, and then processed by the expert services in ZET. Statistical monitoring of phenomena over a period of several years is a sure indicator of certain laws that can be of great help in identifying the causes of traffic accidents.

The paper analyzes:

- statistical data on the number of traffic accidents in the ten-year period for the tram and bus system;
 - classification of traffic accidents by category and type;
 - classification of traffic accidents according to severity of injury;
 - frequencies of traffic accidents, as well as frequencies by accident category;
 - spatial characteristics of accidents;
 - temporal dispersion of accidents (monthly, weekly, hourly);
 - driver characteristics (experience, age, hourly load).
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Depending on the needs and availability of data, historical data on traffic accidents from the ZET database were used for individual indicators. That is, historical data were used for a period of 10, 5, 2 or one year. The analysis covered a total of 19 tram lines (15 day and 4 night) and 153 bus lines (145 day, 4 night and 4 special), operated by ZET.

3. STATISTICAL ANALYSIS RESULTS

For the purposes of the analysis, a longer observation period was taken, depending on the needs of an individual indicator, while the comparative year of observation is 2021. During 2021, ZET trams and buses covered a total of 40.730.576 km, which is 14,88% more than in 2020, when 35.455.587 km were covered. In the observed period, 556 traffic accidents occurred, which compared to 2020 (438) represents an increase of 26,94%. Public passenger transport vehicles travelled 111.591 km per day, with 1.52 traffic accidents. For every 100.000 kilometres travelled, 1.36 traffic accidents occurred, or 10,57% more than in the previous year, 2020. During the year 2021, a total of 126 people were injured in traffic accidents, which is 6,78% more than the previous year 2020, when 118 people were injured.

Figure 1 shows the number of traffic accidents in the ten-year period from 2012 to 2021. Traffic accidents are shown collectively and individually for the tram and bus system.

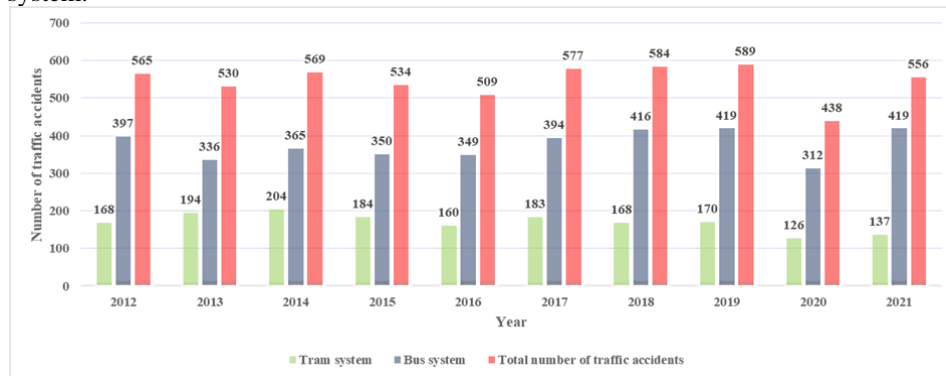


Figure 1. Total number of traffic accidents in the last 10 years

It is evident from the presentation that the number of traffic accidents is almost constant throughout the observed period, except for the year 2020. The reason for the significantly lower number of traffic accidents is the conditions caused by the Covid-19 pandemic, where there was a decrease in the traffic intensity of all modes of travel. In the following, a detailed analysis of traffic accidents of the ZET tram and bus system is presented.

3.1. Tram system accident analysis

The tram network extends over a length of 116.843 m, of which 62.534 m or 53,52% takes place on separate areas from other traffic, while 54.309 m or 46,48% of the track is on common areas. Of the total length of the tram network, 23.180 m or 19,84% are separated by lanes reserved for public passenger traffic (yellow lanes).

3.1.1. Type of accident

Table 1 shows the number of traffic accidents by type: collisions; vehicle damage (mostly minor material damage); other accidents.

Table 1. The number of traffic accidents in the period from 2017 to 2021

<i>Type of accident</i>	<i>Number of traffic accidents</i>				
	<i>2017</i>	<i>2018</i>	<i>2019</i>	<i>2020</i>	<i>2021</i>
Collisions	79	69	80	59	52
Vehicle damage	64	57	43	32	48
Other accidents	40	42	47	35	37
<i>Total</i>	<i>183</i>	<i>168</i>	<i>170</i>	<i>126</i>	<i>137</i>

When we look at the "collisions" category in 2021, the most common type of accident includes a collision between a tram and a motor vehicle (45), followed by a collision between a tram and a tram (5), and a collision between a tram and a motorcycle/bicycle (2). In the "vehicle damage" category, the most common type is collisions between trams and motor vehicles (44), followed by collisions between trams and trams (2), and collisions involving trams and buses (2). In the "other accidents" category, the most common type includes the fall of tram passengers (20), followed by collisions with pedestrians (12), and tram derailments (5).

The following table (Table 2) shows the categorization of injuries of persons who participated in traffic accidents.

Table 2. Number of injured in the period from 2017 to 2021

<i>Severity of injury</i>	<i>Number of traffic accidents</i>				
	<i>2017</i>	<i>2018</i>	<i>2019</i>	<i>2020</i>	<i>2021</i>
Minor injuries	63	69	66	36	35
Severe injuries	5	8	7	8	6
Fatalities	1	2	2	0	1
<i>Total</i>	<i>69</i>	<i>79</i>	<i>75</i>	<i>44</i>	<i>42</i>

The first thing that is noticeable from the table is the significantly lower number (a decrease of approximately 43,5%) of those injured in traffic accidents in 2021, compared to the average from 2017 to 2019. Of the injured, the majority refer to minor injuries (approximately 83,3%), followed by severe injuries (approximately 14,3%) and 1 fatality (approximately 2,3%).

3.1.2. Frequency of accidents

The frequency of traffic accidents is usually the best indicator of traffic safety. Figure 2 shows the number of accidents that occurred per 100.000 vehicle kilometres travelled. A period of 5 years (2017 to 2021) was observed. The yellow colour indicates the trend of traffic accidents with respect to the number of kilometres travelled, while the green, blue, and red colours indicate the same with regard to the type of accident.

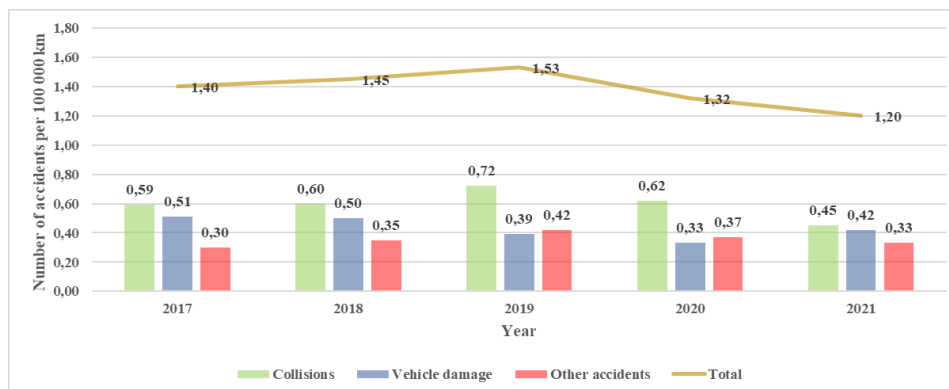


Figure 2. Number of traffic accidents per 100.000 km in the period from 2017 to 2021

The display shows that the highest frequency of traffic accidents was recorded in 2019 (1,53), while a significant decrease was recorded in 2021 (1,20). When we look at the injuries of persons involved in traffic accidents in 2021, the frequency corresponds to 0,37 according to the same criterion. Of the above, the frequency of 0,31 corresponds to the occurrence of accidents with minor injuries, 0,05 to severe injuries, and 0,01 to fatalities.

3.1.3. Spatial analysis

Table 3 shows the number of traffic accidents with respect to the line that operates, and the corresponding accident frequency coefficients.

Table 3. Number of traffic accidents by tram lines

Line number	Line name	Total number of accidents	Total accidents per 100 000 km
1	Zapadni kolodvor - Borongaj	6	2,47
2	Črnomerec - Savišće	18	2,20
3	Ljubljaniica - Savišće	5	1,28
4	Savski most - Dubec	14	1,52
5	Prečko - Dubrava	7	1,59
6	Črnomerec - Sopot	20	2,03
7	Arena Zagreb - Dubec	14	1,12
8	Mihaljevac - Zaprude	4	1,25
9	Ljubljaniica - Borongaj	8	1,29
11	Črnomerec - Dubec	16	2,27
12	Ljubljaniica - Dubrava	7	1,70
13	Žitnjak - Kvaternikov trg	4	0,64
14	Mihaljevac - Savski most	7	0,64
15	Mihaljevac - Gračansko dolje	1	0,50
17	Prečko - Borongaj	6	1,44
Total		137	1,20

No traffic accidents were recorded on lines number 31, 32, 33, 34, and for this reason they are not shown in the table above.

When we look at the locations of traffic accidents, taking the criteria of 3 or more traffic accidents, the following locations stand out as the most frequent:

1. roads: Savska (8 accidents); Ilica (5 accidents), Maksimirska (4 accidents); Ozeljska (4 accidents)
2. intersections: Branimirova-Erdodyeva (3 accidents); Ilica-Čavićeva (3 accidents); Šubićeva-Martićeva (3 accidents); Savska-Tratinska (3 accidents)
3. squares: Kvaternikov square (5 accidents); Trg žrtava fašizma (3 accidents)

63 traffic accidents or 46,00% occurred on traffic areas where tram and other traffic take place on a common body, while 16 or 11,67% occurred on tram routes separated from other traffic, in the pedestrian zone 2 or 1,46%, and on lanes reserved for public transport (yellow lanes) 56 or 40,87%.

On lanes reserved for public passenger transport traffic (yellow lanes), the following occurred: 24 collisions between trams and motor vehicles, 17 side collisions, 3 head-on collisions, 4 collisions with pedestrians, 6 falls of passengers in trams, 2 collisions with motor vehicles.

3.1.4. Temporal analysis

Figure 3 shows the distribution of traffic accidents with respect to the months in which they occurred. Data from 2020 and 2021 were used for the analysis.

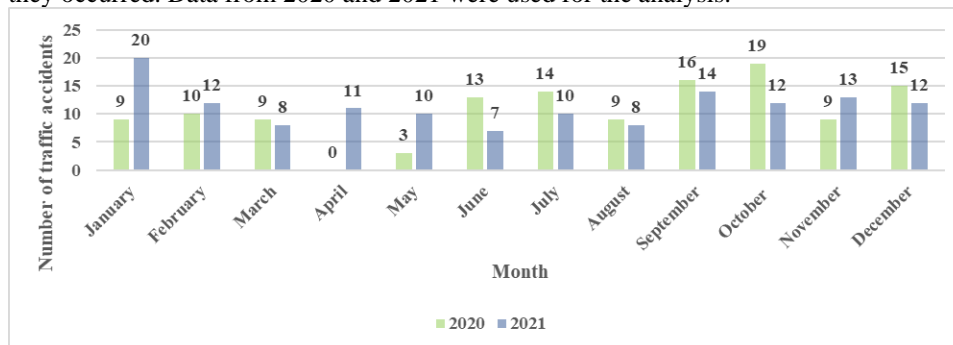


Figure 3. Number of traffic accidents per month for 2020 and 2021

The largest number of accidents was recorded in January 2021 (20 accidents) and October 2020 (19 accidents), while the rest of the year is equally distributed, with a slightly higher number in the period from September to February.

Figure 4 shows the dispersion of the number of traffic accidents according to the day of the week when they occurred.

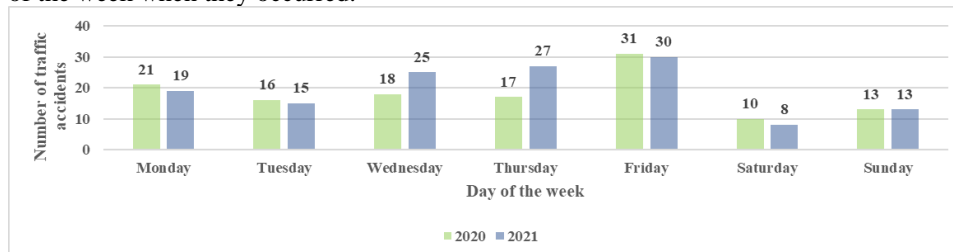


Figure 4. Number of traffic accidents per day of the week for 2020 and 2021

The dispersion of traffic accidents largely coincides for the two analyzed years, where the highest number of accidents was recorded on Fridays (31 in 2020, 30 in 2021), while the lowest frequency is on weekends, which also corresponds to the intensity of traffic and trips made by public transport.

Figure 5 shows the dispersion of traffic accidents with regard to the period of the day (range of hours) in which the traffic accidents occurred.

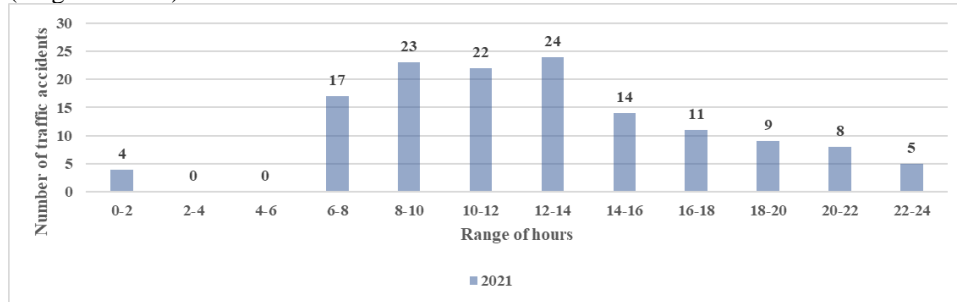


Figure 5. The number of traffic accidents per hour per day for the year 2021

Based on the analyzed data according to Figure 5, the most traffic accidents - 24 or 17,52% - occurred in the period between 12 - 14 hours. During daylight hours, 111 accidents or 81,00% occurred, while in the night period there were 26 accidents or 19,00%.

3.1.5. Driver characteristics

The driver is a very important factor in the occurrence of a traffic accident. In this segment, the effects of length of service (experience), age and fatigue, i.e. working hours in traffic, are analyzed. Figure 6 shows the analysis of the number of traffic accidents with regard to the driver's experience.

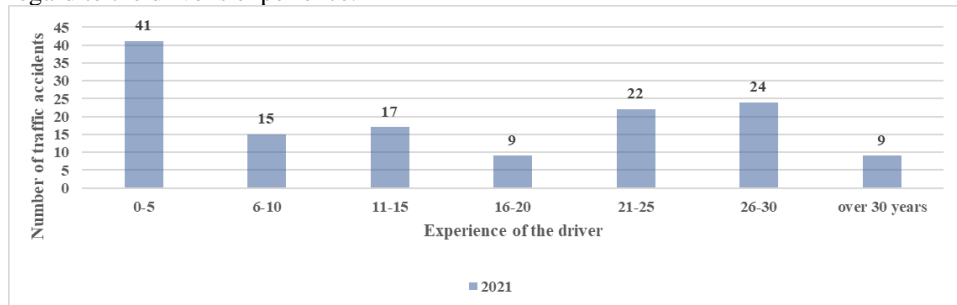


Figure 6. The number of traffic accidents in 2021 with regard to driver experience

Based on the data from Figure 6, it is evident that drivers with up to 5 years of driving experience participated in the most traffic accidents (41 or 29,93%), while drivers with a driving experience of 16-20 and over 30 years participated in the fewest traffic accidents. An increased number of traffic accidents was also recorded among drivers with work experience of 21 to 30 years. When we look at the age of drivers, the highest number of accidents was recorded among drivers aged 51-55 (29 accidents or 21,17%), followed by drivers aged 36-40 (25 accidents), over 55 years old (25 accidents), 46-50 (18 accidents), 41-45 (16 accidents).

A significantly lower number of accidents was recorded among drivers aged 26-30 and 31-35 (11 accidents), while the number of accidents was the lowest among drivers under 25 years of age (2 accidents), which is understandable given that the share of these drivers is the smallest.

Figure 7 shows the analysis of the number of traffic accidents with respect to the driver's hours of work.

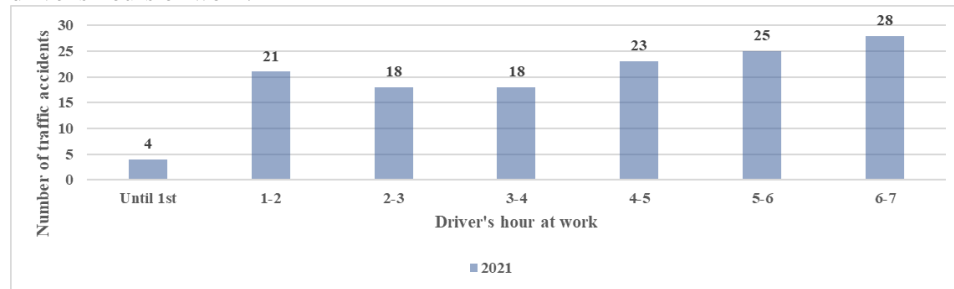


Figure 7. The number of traffic accidents in 2021 in relation to the driver's hours of work

Considering the hours of work until the accident, it is evident that most traffic accidents occurred in the period of 6-7 hours of driver work, 28 or 20,44%. During the first hour of work, the fewest traffic accidents occurred - 4 or 2,92%. The number of accidents increases as the driver works more, while the anomaly appears in the period of 1 to 2 hours of work.

3.2. Bus system accident analysis

In the area of the City of Zagreb in 2021, bus passenger transport consists of 153 lines (145 day, 4 night and 4 special), with a total length of the bus network of 1,424 km.

3.2.1. Type of accident

Table 4 shows the number of traffic accidents by type: collisions; vehicle damage (mostly minor material damage); other accidents.

Table 4. The number of traffic accidents in the period from 2017 to 2021

Type of accident	Number of traffic accidents				
	2017	2018	2019	2020	2021
Collisions	102	104	87	71	93
Vehicle damage	216	234	234	190	253
Other accidents	76	78	98	51	73
<i>Total</i>	<i>394</i>	<i>416</i>	<i>419</i>	<i>312</i>	<i>419</i>

When we look at the "collisions" category in 2021, the most common type of accident includes a collision between a bus and a motor vehicle (85), followed by a collision between a bus and a bus (6), and a collision between a bus and a motorcycle/bicycle (2). In the "vehicle damage" category, the most common type is collisions between buses and motor vehicles (214), followed by collisions between a bus and a stationary object (34), collision between a bus and a bus (3), and collisions involving buses and trams (2).

In the "other accidents" category, the most common type includes the fall of tram passengers (54), followed by buses hitting a stationary object (14), collisions with pedestrians (4), and bus derailments (1).

Table 5 shows the categorization of injuries of persons who participated in traffic accidents.

Table 5. Number of injured in the period from 2017 to 2021

Severity of injury	Number of traffic accidents				
	2017	2018	2019	2020	2021
Minor injuries	108	99	111	65	80
Severe injuries	3	4	7	9	4
Fatalities	1	0	0	0	0
Total	112	103	118	74	84

As in the case of tram traffic, there was a significant reduction in numbers (a decrease of approximately 24,5%) of those injured in traffic accidents in 2021, compared to the average from 2017 to 2019. Of the injured, the majority refer to minor injuries (approximately 95,2%), followed by severe injuries (approximately 4,7%), while no fatalities were recorded.

3.2.2. Frequency of accidents

The actual state of bus traffic safety is obtained through relative values by relating the number of traffic accidents to 100.000 vehicle kilometres travelled. Figure 8 shows the number of accidents that occurred per 100.000 vehicle kilometres travelled. A period of 5 years (2017 to 2021) was observed. The yellow colour indicates the trend of traffic accidents with respect to the number of kilometres travelled, while the green, blue, and red colours indicate the same with regard to the type of accident.

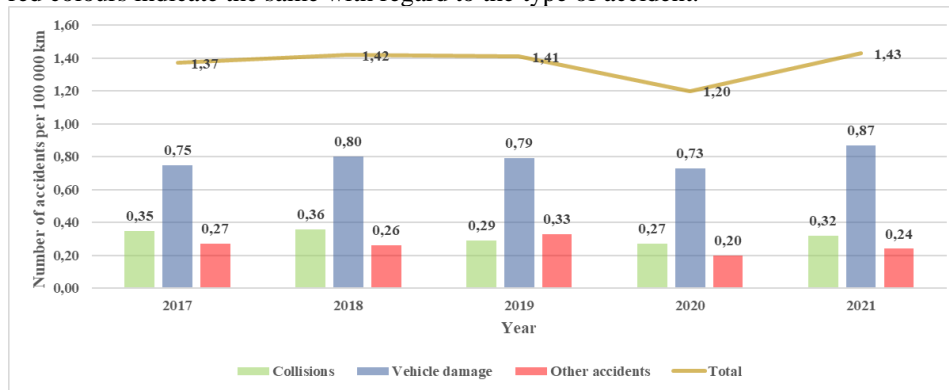


Figure 8. Number of traffic accidents per 100.000 km in the period from 2017 to 2021

From the data presented Figure 8, values are obtained based on which it is evident that in 2021, 1,43 traffic accidents occurred per 100.000 kilometers traveled, which represents an increase of 19,16% compared to 2020. The number of injured persons is the same in the observed years. Also, it should be noted that 2020 is not a completely representative year considering the previously mentioned conditions. Comparing 2021 with the previous years, it can be concluded that there is no major shift, that is, the frequency is at a minimum growth.

3.2.3. Spatial analysis

Table 6 shows the number of traffic accidents with respect to the line that operates, and the corresponding accident frequency coefficients.

Table 6. Number of traffic accidents by tram lines

Line number	Line name	Total number of accidents	Total accidents per 100 000 km
109	Črnomerec - Dugave	23	2,84
215	Kvaternikov trg - Trnava	12	2,71
238	Gl. Kolodvor - V. Gorica	10	2,53
209	Dubrava - G. Čučurje	10	0,95

As shown in Table 6, it is evident that the most traffic accidents - (absolute and relative number) occurred on bus line 109 Črnomerec - Dugave - 23 accidents. When we look at the locations of traffic accidents, taking the criteria of 5 or more traffic accidents on roads and 3 or more traffic accidents at intersections or terminals, the following locations stand out as the most frequent:

1. roads: Ilica (14 accidents); Zagrebačka (14 accidents); Selska cesta (7 accidents); Av. Dubrava (7 accidents); Vrapčanska (7 accidents); Vukomerička (6 accidents)
2. intersections: Ilica-Selska (5 accidents)
3. terminals: Terminal Glavni kolodvor (4 accidents); Terminal Savski most (3 accidents)

During 2021, the largest number of accidents (in absolute terms) occurred on Ilica (14 accidents). Long-term monitoring of traffic accidents has shown that Ilica is the most critical road in the City of Zagreb due to the high frequency of both bus and other traffic, and due to the insufficient length of the separate traffic lane for public transport vehicles (the length of the "yellow lane" on Ilica is 872m). The most critical terminal is the Main Station with 4 accidents. This state of affairs at the Main Station terminal is caused by the high frequency of ZET bus traffic, and the movement of passengers and delivery vehicles across the terminal area.

3.2.4. Temporal analysis

Figure 9 shows the distribution of traffic accidents with respect to the months in which they occurred. Data from 2020 and 2021 were used for the analysis.

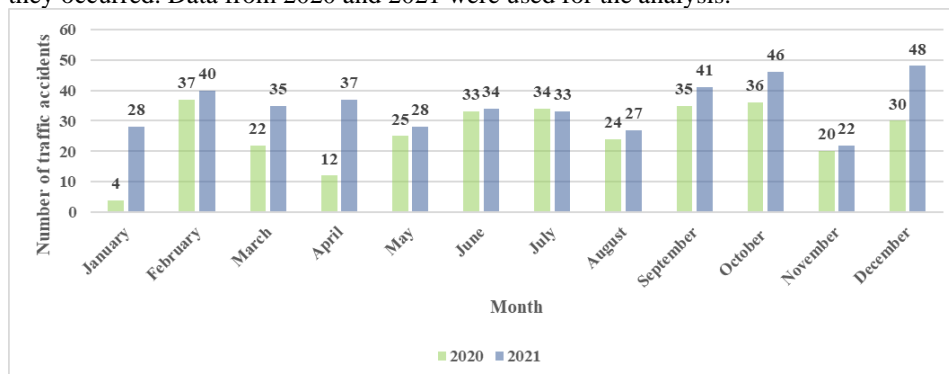


Figure 9. Number of traffic accidents per month for 2020 and 2021

The largest number of accidents was recorded in December 2021 (48 accidents), October 2021 (46 accidents) and February 2021 (40 accidents), while the rest of the year is equally distributed, with the lowest numbers in November (22 accidents).

Figure 10 shows the dispersion of the number of traffic accidents according to the day of the week when they occurred.

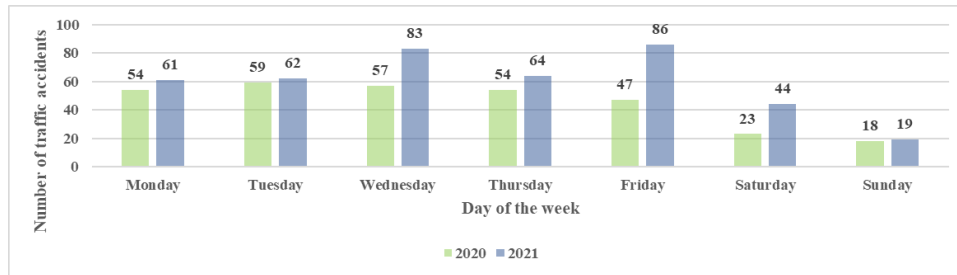


Figure 10. Number of traffic accidents per day of the week for 2020 and 2021

The dispersion of traffic accidents throughout the week is largely the same for 2021 and 2020. The highest number of accidents was recorded on Fridays (86 accidents in 2021), and a very high number of accidents on Wednesdays (83 accidents in 2021). The weekend, as in the case of trams, is the period with the lowest number of accidents, although in 2021 there was a significant increase in the number of accidents on Saturdays (44 accidents in 2021 versus 23 in 2020).

Figure 11 shows the dispersion of traffic accidents with regard to the period of the day (range of hours) in which the traffic accidents occurred.

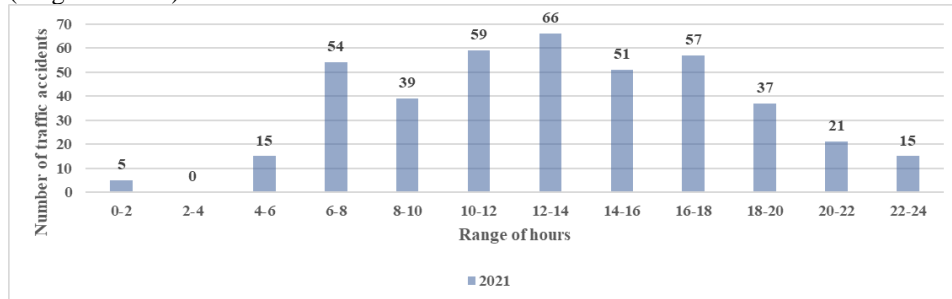


Figure 11. The number of traffic accidents per hour per day for the year 2021

Most traffic accidents occurred between 12:00 and 2:00 p.m., 66 accidents or 15,75%. In the daylight period from 6:00 a.m. to 6:00 p.m., 326 accidents or 77,80% occurred, and in the night period 93 accidents or 22,19%.

3.2.5. Driver characteristics

Figure 12 shows the analysis of the number of traffic accidents with regard to the driver's experience.

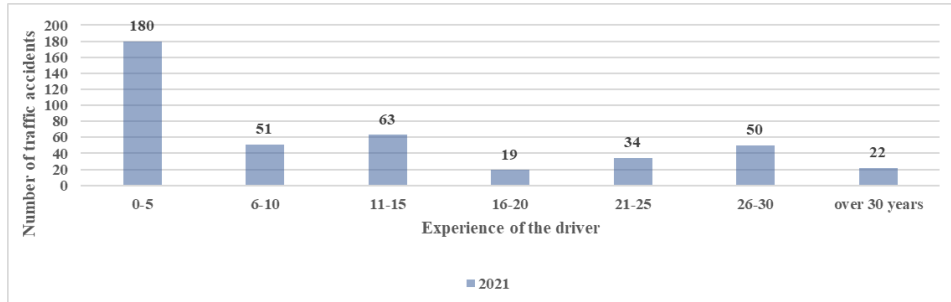


Figure 12. The number of traffic accidents in 2021 with regard to driver experience

Figure 12 shows the consistency with data from tram traffic. In the case of bus accidents, the highest number of traffic accidents was also recorded in the case of drivers with 5 or less years of experience (180 or 42,96%). Drivers over 30 years of age participated in the fewest traffic accidents, in 22 accidents or 5,25%. A greater number of accidents were recorded among drivers with 11-15 years of experience (63 accidents) and 26-30 years of experience (50 accidents). When we look at the age of drivers, the highest number of accidents was recorded among drivers aged over 55 years old (81 accidents or 19,33%), followed by drivers aged 36-40 (66 accidents), 46-50 (61 accidents), 31-35 (59 accidents), 51-55 (57 accidents). A significantly lower number of accidents was recorded among drivers aged 26-30 (38 accidents) and 41-45 (42 accidents), while the number of accidents was the lowest among drivers under 25 years of age (15 accidents), which is understandable given that the share of these drivers is the smallest.

Figure 13 shows the analysis of the number of traffic accidents with respect to the driver's hours of work.

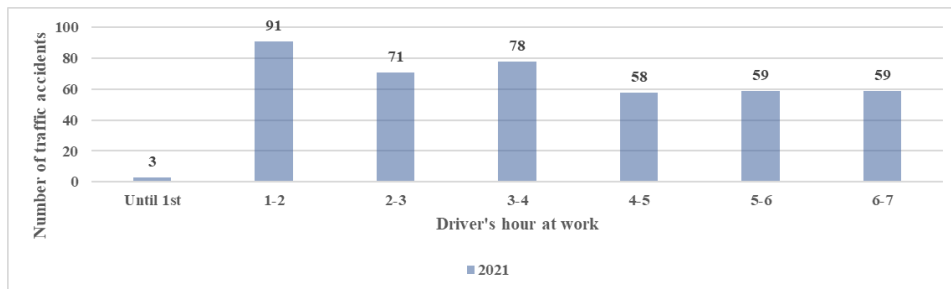


Figure 13. The number of traffic accidents in 2021 in relation to the driver's hours of work

Considering the hours of work until the accident, it is evident that the most traffic accidents occur in the period from the 1st to the 2nd hour of work - 91 accidents or 21,72%, and from the 3rd to the 4th hour of work 78 accidents or 18,62%. From the data presented, it can be concluded that the lowest number of accidents occurs during the first hour of work, 3 traffic accidents or 0.72%.

4. DISCUSSION

During 2021, significantly more kilometers were traveled in public passenger transport compared to 2020 due to the reduction or cancellation of certain bus and tram lines from 22.3. – 13.05. 2020. This resulted in the occurrence of a greater number of traffic accidents in absolute terms in 2021.

During 2021, 137 traffic accidents occurred in tram traffic, which is an increase of 8.73% compared to the previous year, when 126 accidents occurred. 0.37 traffic accidents occurred per day, and an average of 31.333,52 km were traveled. Most accidents (8) occurred on Savska cesta and tram line number 6 (20 accidents). The number of traffic accidents per 100.000 kilometers traveled decreased from 1,32 to 1,20 events or by 9,01%. Comparing 2020 and 2021, the number of tram-tram collisions increased from 4 to 5 events or by 25,00% (category "Collisions"). The number of tram collisions with other participants has increased by 50%. An increase was recorded in the category "Vehicle damage", type of collisions with trams and trams (from 1 to 2 events or by 100%) and collisions with trams and motorcycles. vehicles (31 out of 44 events or for 41,93%). There was an increase in the category "Other accidents", tram collisions with pedestrians (from 10 to 12 events or by 20%) and a decrease in tram passengers (from 18 to 20 events or by 11,11%).

In 2021, there were 419 traffic accidents in bus traffic, which is an increase of 34,29% compared to the previous year, when 312 accidents occurred. There were 1,15 traffic accidents per day, and the average distance traveled was 80.257 km. Most accidents occurred on Ilica street (14) and bus line 109 (23 accidents). The number of traffic accidents per 100.000 kilometers traveled increased from 1,20 to 1,43 events or by 19,16%. An increase in the number of collisions was recorded in the following "Collision" categories: collisions between ZET buses (from 3 to 7 events or by 133%) and buses with motor vehicles (from 62 to 84 events or by 35,48%). During 2021, a total of 253 accidents occurred in the "Vehicle damage" category of bus collisions, which is an increase of 33,16%. An increase in the number of traffic accidents in the category of collisions of buses with motor vehicles and collisions of buses with unknown objects was determined. The total number of traffic accidents under the category "Other accidents" increased from 51 to 73 events or by 43,14%. There was an increase in the number of injured passengers on the bus from 37 to 52 people or by 40,54%, then the number of injured pedestrians from 2 to 4 people or by 100% and the number of bus collisions with stationary objects from 11 to 14 events or by 27,27 %.

It should be noted that the current number of traffic accidents is significantly influenced by the state of the roadway, that is, the entire accompanying traffic infrastructure. It is to be assumed that by improving the conditions on certain roads, installing additional or adequate traffic signals and establishing the coordinated operation of traffic lights and controlling compliance with yellow lanes, the degree of safety would be significantly increased.

5. CONCLUSION

Based on the presented data, it is evident that the number of traffic accidents in 2021 compared to 2020 has increased in absolute (by 26,94%) and relative (by 10,57%) amounts.

The analysis of the total number of traffic accidents during the period from 2012 to 2021 determined that the absolute and relative number of traffic accidents depends mainly on the degree of motorization in the City of Zagreb. The relative number of traffic accidents during the week is proportional to the total traffic volume during the day, the consequence of which is a higher proportion of traffic accidents on weekdays than on weekends, with peaks on Friday. The relative number of traffic accidents in periods during the day is a direct consequence of vehicle flow oscillations, with the highest value in the afternoon peak load, so it is more influenced by the duration of the load, and less influenced by the intensity of the traffic flow. Driver fatigue also contributes to the higher number of accidents in the afternoon peak load.

In the city of Zagreb, there are less than 1% of yellow lanes on the street network, and they do not exist on roads with a high intensity of bus traffic (Ilica, Selska cesta). By increasing the proportion of yellow lanes, that is, by separating the path of public transport vehicles from other traffic, the number of incident situations, and ultimately the expected number of traffic accidents, would decrease.

The reduction in the number of traffic accidents cannot be influenced by reducing the number of vehicles at work, but only by traffic or construction interventions on the network of lines, which are carried out based on the analysis of dangerous places on the bus network. For the analysis of dangerous places, it is necessary to create a database of traffic accidents based on accurate data obtained in GIS (GIS - geographic information system), especially for locating dangerous places on mountain lines.

Such a database should create a prerequisite for researching the causes of traffic accidents such as meteorological conditions, or by researching characteristic groups of road users who have died. A more detailed investigation of the causes of traffic accidents, with the proposed database, would create a prerequisite for detecting the causality of the occurrence of traffic accidents, and determine more precise measures to increase the safety of bus traffic.

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