MODERN TECHNOLOGIES AND METHODS OF DATA COLLECTION IN THE FUNCTION OF MAKING BETTER TRAFFIC ANALYSIS OF FORENSIC TRAFFIC EXPERTS

Rok Kamnik [1*], Darja Topolšek [2], Stanko Laković [1]
[1] *University of Maribor, Faculty of Civil Engineering, Transportation Engineering and Architecture, SI-2000, Maribor, Slovenia*
[2] *Univeristy of Maribor, Faculty of Logistics, SI-2000, Maribor, Slovenia*
*E-mail of corresponding author: rok.kamnik@um.si

Abstract: *Even though the European roads are among the safest in the world, the number of road accidents is still a cause for concern. To reduce their number and consequences, many studies are being conducted, including knowledge of the factors that influence the occurrence of accidents. Forensic traffic experts are also part of the treatment of traffic accidents, and they often must base their conclusions on proven incomplete studies of data collected by police officers. In some cases, traffic accident data are still collected in classical ways and with classical measuring equipment. This is often a source of error. This paper defines these errors and offers solutions that are shown primarily through data capture using 3D scanners and photogrammetry. In this way, we can perfectly recreate the situation in the event of a traffic accident through 3D models, thus eliminating many shortcomings of police drawings and records. The article also proposes a central database of traffic accidents as an additional solution to gain a deeper insight into the causes and consequences of traffic accidents.*

Keywords: traffic accidents, forensic experts, traffic accident data errors, 3D laser scanner, photogrammetry, database

Received: 14.06.2022. / Accepted: 30.06.2022.
Published online: 20.12.2022.

Original scientific paper
DOI:10.37023/ee.9.1-2.1

1. INTRODUCTION

The number of vehicles on the roads worldwide is constantly increasing, so there is a greater possibility of accidents. More than 90% of the world's road casualties occur in low- and middle-income countries, although about 54% of the world's vehicles are located there. Drivers between the ages of 15 and 44 are responsible for 48% of all deaths (WHO, no date). In 2020, 18,800 people (European Commission, no date) died in road accidents in the European Union, which is why the European Union is encouraging the establishment of long-term and system-oriented measures taken both within the Union and at the national level.

European roads remain one of the safest globally, with 42 road casualties per million people in the EU, compared to 174 per million worldwide (OECD/ITF, 2020). While the average reduction in road casualties in the EU-27 from 2010 to 2020 was as high as 33%, this percentage is only 10% on average from 2019 to 2020. Of course, some countries have progressed much more than others, such as Malta with 31%, Bulgaria with 26% and Italy and Hungary with 25% (Javna Agencija RS za varnost prometa, 2021).

In Slovenia, we have 555 registered passenger cars per 1,000 population. Their average age is 10.1 years, and all registered vehicles in Slovenia are 1,617,217 (RS, Statistični urad, no date). In 2020, 14,971 traffic accidents occurred in Slovenia (the number is not the most realistic due to the three-month Covid-19 lock-down measures). The highest number of deaths in traffic accidents in 2020 was in the age group over 64 - 16 deaths (the group had 28 deaths in 2018); following the age group from 45 to 54 and 55 to 64 (15 deaths each). Compared to 2019, the most significant increase is in the youngest participants, as six underage participants died last year (3 more than in 2019) (Javna Agencija RS za varnost prometa, no date).

The highest number of traffic accidents in 2020, as in 2018 and 2019, was caused by participants in the age group between 25 and 34, namely 2,328. It is followed by ages between 35 and 44 - 2,317 traffic accidents. Most participants died in traffic accidents caused by perpetrators in the age group between 45 and 54 years of age and between 55 and 64 years of age, with 17 deaths in each age group. There were 14 deceased participants in the age group from 25 to 34 years.

Relative indicators of traffic safety for 2020 are shown as data from the European Commission (Javna Agencija RS za varnost prometa, 2021) and show that in Slovenia, there were 38 deaths per million inhabitants, while in the EU, the average was 43 deaths per million inhabitants (Eurostat, Statistics explained, no date). This places Slovenia in the group of countries with above-average traffic safety in the EU (according to this indicator). However, if we compare our statistics with the best European countries (Norway, Sweden, Malta, Iceland and Switzerland) -

Figure 1, we see that a lot still should be done to achieve road safety in these countries (18-26 fatalities per million inhabitants). In any case, we can say that the situation in Slovenia is significantly better than in 2010 (67 fatalities) or in 2019 (49 fatalities).

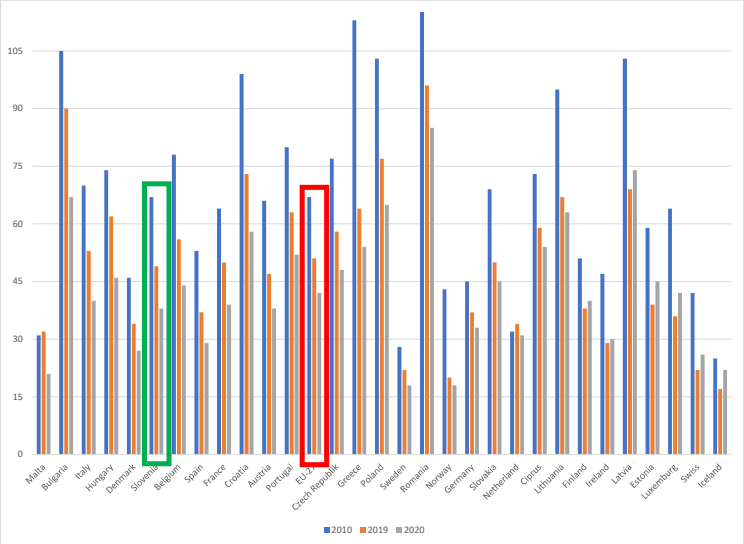

Figure 1. Fatalities per million population in the EU-27

2. TRAFFIC ACCIDENT STATISTICS IN SLOVENIA

The ratio between the number of adults convicted of criminal offences of negligence (PPNMM) and dangerous road traffic (NVCP) with serious body injuries and death and the number of fatalities and severe injuries in traffic accidents in the period 2014-2020 in Slovenia is shown on Figure 2. Data refer to both sexes. We can see that the number of convictions for PPNMM decreases at the expense of convictions for NVCP crime. At the same time, we see that the total number of convictions in 2017-2019 exceeded 350, and in 2020 dropped significantly to 271 (87 PPNMM and 184 NVCP) (RS, Statistični urad, no date).

Following the introduction of the amendment to the Slovenian Criminal Code KZ-1-NPB4 (2012), the crime of NVCP increased sharply compared to PPNMM, and in 2016 for the first time exceeded the acts of PPNMM 52.4% (Fig. 2). Since then, the ratio has been about 2:1, favouring PPNMM.

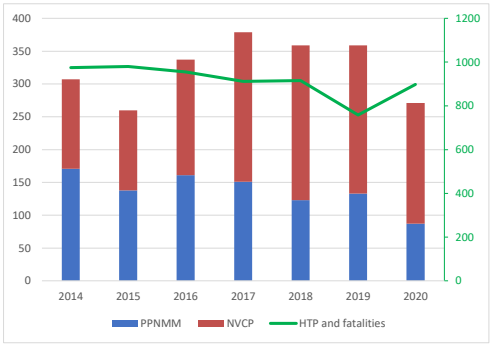

Figure 2. Ratio between the number of adults convicted of PPNMM and NVCP crimes and the number of deaths and severe injuries in traffic accidents in 2014-2020

The main penalties for the PPNMM offence for 2014-2020 and their trends are shown on Figure 3. Imprisonment from 2014 remains the primary measure imposed in the case of the PPNMM. In 2012, this share of prison sentences was only 11.5%. The trend line shows a drastic decline in these penalties from 148 (51.6% of all) to 48 (36.1%) in 2020. A similar but less steep trend has a suspended sentence, which declines from 40.4 % to 34.6% in 2020. In the same period, the fines imposed increased significantly from only 7.3% in 2014 to 29.3% in 2020. These three forms of measures thus remain the main ones and are now pretty much adjusted at about 1/3 each. Other actions (court reprimand, suspended sentence, and preventive measures without sentencing) are almost non-existent in these cases.

The main penalties for the NVCP crime for 2014-2020 and their trends are shown on Figure 4. Here, too, imprisonment since 2014 remains the primary measure. The trend line shows a decrease in these penalties after 2018 to 116 (48.7%) in 2020. Thus, the number of penalties is similar to 2014 (110). A very constant trend is observed in the case of suspended sentences, which averages around 67. However, in this case, there is a trend of increasing fines by more than twice, from 12.0% in 2014 to 28.6% in 2020. In this case, the other measures were negligibly small (one every two years).

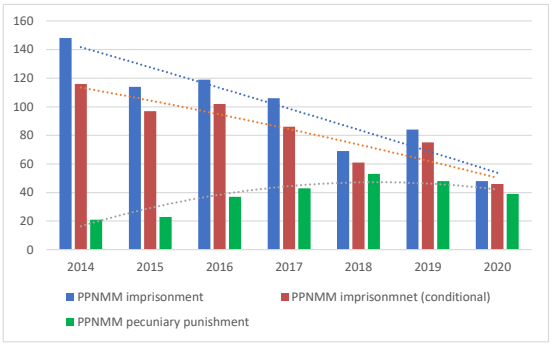

Figure 3. The main penalties for the crime of causing a traffic accident through negligence for the period 2006-2016

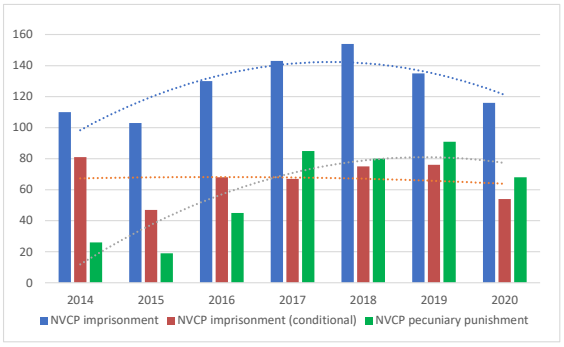

Figure 4. The main penalties for the NVCP offense for the period 2014-2020

Traffic accidents and their consequences in the Republic of Slovenia from 2016 to 2021 are shown in Table 1. 2020 certainly stands out due to the extraordinary epidemiological situation and a few month closures of public life. The table shows that the total number of traffic accidents in Slovenia has decreased. Nevertheless, it is unlikely that we will achieve the goals of the National Road Safety Program for 2022, that by the end of 2022, no more than 35 people per million people will die in traffic accidents and that no more than 230 persons per million inhabitants may be seriously injured.

Table 1. Traffic accidents in the Republic of Slovenia and consequences from 2016 to 2021 (Javna Agencija RS za varnost prometa, 2021)

Year	No. traffic accidents	No. of traffic accidents with injury or fatalities	Consequences (injuries)			Sum of injuries
			fatal	Severe injury	Minor injury	
2016	17931	6495	130	850	7606	8456
2017	17584	6185	104	851	7050	7901
2018	18248	6014	91	821	6867	7688
2019	18861	6025	102	814	6756	7570
2020	14971	4777	80	678	5017	5695
2021	17049	5330	114	784	5654	6438

In the event of an accident with significant material damage, minor and severe body injuries or the fatalities of a participant, the traffic accident ends in court. Table 2 shows the number of cases received in all courts in the Republic of Slovenia from 2016 to 2020, where we see a decline in cases (Slovenija and Pravosodje, 2021). Of these, an average of 6,746 cases (1.03% of all) are related to crimes against public transport safety, which, in addition to PPNMM and NVCP, include endangering special types of public transport and leaving the injured person in an accident without assistance. Still, the latter are in the vast minority. Figure 5 shows the trend in the number of criminal cases in the courts as a whole, compared to road traffic offences. We can see that the number of all criminal offences (Figure 5 - blue line) in the Republic of Slovenia has dropped dramatically since 2014 (by 51.2%), which is, of course, very good. The total number of offences against public transport safety is around 338 cases per year and represents 5% of all violations (Figure 5 - orange line). The largest share of this is NVCP, which is on an upward trend, while PPNMM is on a downward trend.

Table 2. Number of cases in courts and cases related to road traffic in the Republic of Slovenia between 2016-2020

year	2016	2017	2018	2019	2020

All cases	709743	682787	649392	647760	572450
Cases connected to traffic accidents	6687	6252	6098	6036	4814
percentage (%)	0,94	0,92	0,94	0,93	0,84

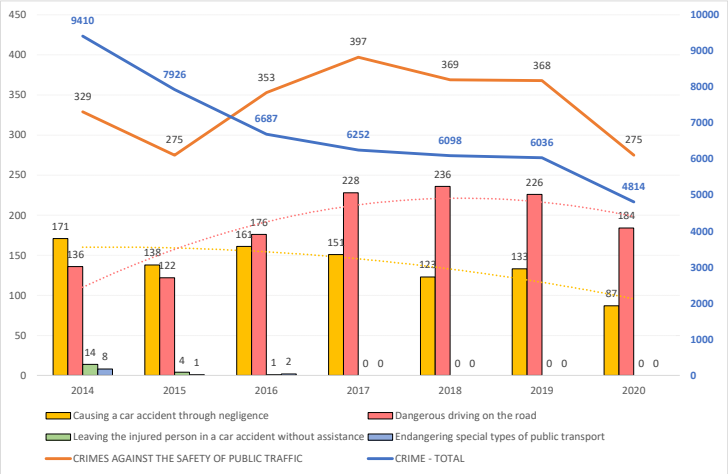

Figure 5. Trends in the number of road transport cases in 2014-2020

In general, the problem of traffic accidents in Slovenia is improving. The improvement of these statistics in Slovenia can be attributed to the following measures:

- new legislation,
- the work of the Ministry of Infrastructure and the Traffic Safety Agency,
- the work of the Councils for Prevention and Education in Road Traffic,
- work in kindergartens, primary and secondary schools with children and students,
- good work of driving schools,
- good work of safe driving schools,
- improved infrastructure,
- improved construction of vehicles,
- good police work,
- work of experts in transport (civil, logistics and traffic engineers, experts, etc.)

Some statistics on traffic accidents are presented in Chapter 2. Traffic accidents around the world are still mainly dealt with in the traditional way: with the help of police officers, measuring tapes and bicycles, and the production of hand sketches. This has certain shortcomings, which will be shown in Chapter 3. Chapter 4 presents some modern measurement methods and technologies that allow better and faster data capturing of traffic accidents and analysis of them even longer after the event.

3. THE WORK OF FORENSIC EXPERTS AND THEIR PROBLEM

Although we have highlighted only traffic accidents with body injury and fatal cases in criminal proceedings in the statistics, the handling of traffic accidents (maybe even the same) can end in court in other proceedings (misdemeanour, litigation and commercial). In many cases, the opinion of a forensic expert is required from time to time or even more than one forensic expert in the same proceedings. This prolongs the duration of the procedure and makes it more expensive. Criminal proceedings are relatively quick, but litigation is long, and its beginnings are usually much further away from the date of the accident than other proceedings. Thus, a forensic expert may have difficulties analysing a traffic accident, as there are no more physical traces on the roadway, and cars are usually already repaired. Thus, the forensic expert must mainly rely on (more or less) quality police records, photo documentation, witness statements and drawings.

Judicial experts are appointed based on a public call by the Minister responsible for justice for a specific professional field and subfield of expert work (ZDeb, 2019). The expert is ordered by a written order of the body conducting the procedure (usually, the expert is given 45 days to prepare an opinion). The order shall state which

facts to establish or judge and to whom the expert work should be entrusted. The order is also served to the parties. Before a forensic expert begins work assigned to him by a court or other state body, the forensic expert must carefully examine the scope and type of knowledge and experience required. To prepare an expert opinion, the Ministry of Justice prescribed general and individual guidelines (Ministrstvo za pravosodje, 2014) to prepare an opinion, which the Expert Council approved.

Difficulties in preparing expert opinions are usually identified during the re-inspection phase of the accident or during the opinion itself when comparing photo documentation and a sketch of the accident site and the record. In general, the problems of forensic experts in the field of transport are as follows:

- the police do not perform measurements of the slope of the carriageway (longitudinal and transverse),
- the police do not perform bend radio measurements,
- the accuracy of measurements with a measuring tape or by measuring wheel,
- photo studies are often missing, or images are inferior (black and white photocopies) - especially in litigation, where clients provide pictures.
- the police only perform rectangular measurements, which are often not accurate enough,
- the police do not establish vertical and horizontal band view,
- the certain starting point of measurements does not allow locating the place of collision,
- drawing a sketch in the field and redrawing it in the office is often a source of error,
- drawings are occasionally not to scale (we cannot use it in other programs, we cannot determine distances that are not explicitly quoted and measured),
- the sketch does not specify (measured) all the details drawn,
- the drawing does not show all the fallen parts from the vehicle, traces, etc., visible in the images.

Errors in accident data were well described in the paper (Ahmed et al., 2019), where mistakes were divided into errors in reporting accident data and recording accident data. Although data reporting does not depend so much on technology, much can be done in accident data recording.

Table 3. Percentage of errors in reporting traffic accidents (Ahmed et al. 2019)

Countries with	Percentage of reporting errors			
	Minor injuries	Severe injuries	Severe injury but no fatalities	Fatalities
high GDP	39 - 82	16 - 52	12 - 84	0 – 31
mid GDP	93 - 98	32,5 - 96	34 - 99	0,5 – 89,5
low GDP	n. a.	n. a.	69 - 80	0 - 61

The average error in the inventory of information related to the location of the accident was 27%, data on the victim 37%, vehicle 16% and circumstances 19%. Among the identified causes of errors in reporting accident data, the police system was highlighted as the most important. A total of 26 causes of mistakes in accident data were addressed, of which 12 were related to reporting and 14 to recording. The authors recommend reforming the police system and raising public awareness to reduce errors in accident data (Ahmed et al. 2019).

Between 2013 and 2021, 50 recent traffic accidents were selected from the personal database of expert opinions. Based on the analysis, we find that in 16 cases (32%), the expert work was challenging due to a combination of the shortcomings listed below (the number of times the problem is repeated is given in parentheses). Among the selected cases were five accidents with material damage, 33 accidents with minor injuries, ten accidents with severe injuries and two fatal accidents. Of these, 41 were heard in civil proceedings and 9 in criminal proceedings.

Identified deficiencies are incorrectly determined data or entered values or could not be determine precisely:

- distances from the place of collision to the stopped vehicle (4x),
- exact location of the collision (12x),
- the sketch made by the police did not cover all the traces visible at the scene of the accident (8x),
- lost details as the drawing were black and white or poorly photocopied (3x),
- details of the accident (when re-examining the scene of the accident), especially in bends and roundabouts, because the tracks, objects, parts of the vehicle or the stopping place of cars were not correctly located (6x),
- there were significant errors in redrawing the sketch of the draftsman at the police station (2x),
- images of the place did not show the situation at the time of the accident (due to the time delay of the arrival of police officers at the scene of the accident and the beginning of the viewing / photographing of the event) (3x),
- sketches are not in scale (7x).

A visit to the scene of a traffic accident by a forensic traffic expert causes delays in the duration of the proceedings and the entire court proceedings are more expensive, but it is necessary if the expert does not have all the required information from the scene of the accident (police work).

4. PROPOSAL TO IMPROVE THE STATE OF IMPLEMENTATION OF TRAFFIC ACCIDENT ANALYSIS

4.1. Use of modern measurement techniques

The use of a 3D scanner and an unmanned aerial vehicle (UAV-drone) is already in everyday practice in some places today, and its advantages are obvious (Kamnik et al. 2020). Laser scanning and photogrammetry with drone images are also used for 3D modelling of outdoor crime (Cunha et al., 2022) and other forensic investigations (Renduchintala et al., 2019; Desmoulin et al. 2022); Authors like Mohd Daud et al. (Mohd Daud et al., 2022) discussed using drones for challenge purposes in recording mass casualties.

There are also investigations of road safety infrastructure (Zhang, 2008; Caroti, Martínez-Espejo et al. 2015; Sarsam et al. 2015; Inzerillo et al. 2018) and road engineering structures (Mandirola et al., 2022) using 3D reconstructions according to traditional or modern routes using 3D modelling and drones. Analyses of traffic flows are already more or less well analysed through drones (Salvo et al. 2014; Garcia-Aunon et al. 2019).

Currently, the Slovenian Police has eight scanners (one traffic police station one), with which they deal with all traffic accidents of the 3rd and 4th category (with fatal outcome or severe injuries). In certain situations, also the 2nd category (with injuries). Given that one scanner covers an extensive area (a total of 111 police stations), it would make sense to consider purchasing additional scanners (e. g. for the needs of motorway police).

4.2. Capturing of images according to photogrammetric principles

Most of the images taken today are taken unsystematically, and it is impossible to make stereo pairs and stereo models from them. Thus, images should be taken according to the basic photogrammetry approaches, and relative orientation should be performed. It is about establishing a similar relative relationship between the shots at the time of the exposure. Stereo-pair are two shots taken from different points of view and partially overlapping by at least 50%. The stereo model is a relatively oriented stereo pair. Thus, we can obtain a 3D model of a traffic accident event, which can always be inspected, additional measurements can be performed, the model can be rotated, the situation can be viewed from different angles, etc. This should be done for all traffic accidents.

Images can be taken from the ground (terrestrial photogrammetry) and/or from the air (aero photogrammetry). That adds a new angle of view to the crash site that may not be visible from the ground. Aerial photogrammetry is now available with very accessible drones for free use for police purposes and without significant restrictions.

The benefits of photogrammetry for data collection in traffic accidents and analysis are discussed by some authors worldwide (Osman & Tahar, 2016; Stáňa et al., 2017; Pérez et al., 2019; Matys et al. 2021; Stehel et al. 2021).

When we have measurements performed in a modern way, many problems disappear. We have opportunities we didn't have before. Figure 6 - Figure 9 shows some possibilities of additional measurement by cloud point or models obtained from scanning data or images: measurements of a longitudinal slope, transverse slope, bend radius, and non-rectangular distances. Of course, there are many more possibilities here, depending on the needs and purpose. The Slovenian police do not use drone traffic data (aero photogrammetry) to capture data. 3D scanning can also be complex in some cases (heavy rain, snow, etc.). We can always take a photo, so in such cases, it is crucial to use the photogrammetric method and obtain a 3D model from the appropriate images.

Figure 6. Longitudinal slope measurement

Figure 7. Transverse slope measurement

Figure 8. Bending radius measurement

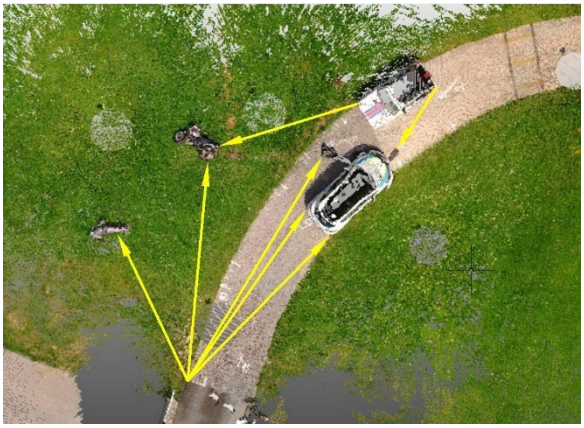

Figure 9. Measurement of non-rectangular distances

4.3. Education of stakeholders involved

With the introduction of new technologies, the education of all stakeholders involved in data acquisition, possible redrawing, data processing, analysis, and reporting must also play a key role. Software packages for image processing and stereo pairs (models) are user-friendly and so called, "Black box" thinking can occur, and over-reliance on the program itself.

It is essential to educate and teach staff who use modern procedures to capture and process data, how to prepare input data well, what are the crucial components of the capturing process, what to pay special attention to, what should be the accuracy of image capturing and where could be sources of error. It is necessary to be aware that insufficient input data result in poor output and, consequently, erroneous conclusions.

4.4. Central database

The primary source of data on traffic accidents today is still primarily the work of the police and statistical office. In any case, it would be necessary to establish a central database, which would be filled in by other stakeholders related to the treatment of traffic accidents (Figure 10).

Additional data sources are mainly insurance companies, which deal with many damage cases that do not reach the police, as the parties manage to agree on their own and when the issue is only minor material damage. In any case, this data would increase/decrease the number of accident black zones and their importance.

One of the most important stakeholders is also road maintenance workers, who have an excellent insight into the state of infrastructure. An essential part of the central database would also be the data of medical personnel, which deals with injuries and the duration of treatment, sick leave, etc.

Research and educational institutions often urgently need input data for the analyses and syntheses that follow from this data. The conclusions could be returned to the central base. Other important stakeholders are the Health Insurance Institute of Slovenia (ZZZS) and the National Institute of Public Health (NIJZ), as they keep data on sick leave, injuries, etc.

The central database should be established by the competent Ministries and regulated through appropriate legislation. At the moment, we see the Traffic Safety Agency as the leading manager of the database.

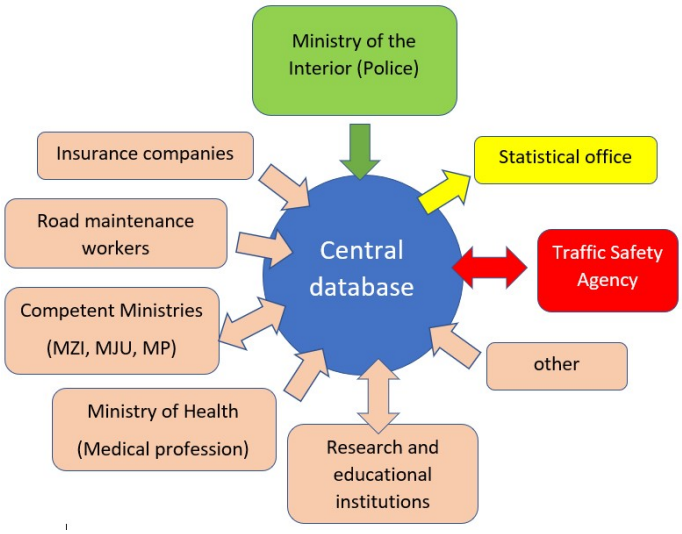

Figure 10. Schematic representation of the establishment of a central database on traffic accidents

5. CONCLUSION

Statistics of traffic accidents worldwide in Europe and Slovenia are relentless, and the numbers remain high. Values have practically halved in recent years at the expense of improved infrastructure and all other measures. Still, any material damage, body injuries and fatal casualties can be a tragedy. However, European roads remain the safest globally, with 42 road deaths per million inhabitants in the EU, compared to 174 deaths per million inhabitants worldwide. In 2020, the number of deaths per million inhabitants in Slovenia due to traffic accidents was 38 (despite the closure of public life).

The number of adults convicted of causing a traffic accident through negligence is declining at the expense of convictions for the crime of dangerous driving. The total number of convictions has been declining since 2017.

Imprisonment since 2014 remains the primary measure imposed in the case of negligent traffic accidents. Still, the trend in the number of such sentences is fortunately negative and fell from 148 (in 2014) to 48 (in 2020). A similar but less steep trend has also imposed a suspended sentence. However, the level of fines imposed is increasing. These are the primary forms of measures and are regulated by proportions of about 1/3 each.

The trend in the number of dangerous driving penalties after 2018 is declining (it was growing until 2018). A constant trend is reflected in the case of suspended sentences, and the trend of increasing fines by more than twice since 2014 is visible.

The number of court cases and issues related to road traffic in the Republic of Slovenia has been declining recently and has almost halved since 2014. The number of criminal offences against public transport safety represents 5% of all criminal offences in the Republic of Slovenia.

The issue of traffic accidents in Slovenia is improving. The improvement of these statistics in Slovenia can be attributed mainly to new legislation, the work of competent services, the improvement of infrastructure, etc.

In many cases of dealing with a traffic accident in court, the opinion of a forensic expert is required from time to time by even more forensic experts in the same proceedings. This prolongs the duration of the procedure and raises the costs. Since it has usually been a long time since the need for an expert opinion and the actual traffic accident, forensic experts can have considerable difficulty gathering additional facts for analysis. Thus, a forensic expert must rely mainly on (more or less) quality police records.

In general, the problems of forensic experts in the field of traffic are related to the lack or even incorrect data of the police, incomplete accident drawings or other errors that occur in capturing and presenting the facts of the accident. According to research, the average number of errors in the inventory of information related to the accident location is 27%, data on the victim 37%, vehicle 16% and circumstances 19%.

Between 2013 and 2021, 50 more recent traffic accidents were selected from our database of processed cases. In 16 cases (32%), expert work was challenging due to one or more shortcomings. Among the selected cases were five accidents with material damage, 33 accidents with minor injuries, ten accidents with severe injuries and two fatal accidents. Of these, 41 were heard in civil proceedings and 9 in criminal proceedings.

Solutions using modern measurement techniques such as 3D laser scanning and photogrammetry (aero and terrestrial) are presented. In this way, measurements, and insights into the situation at the time of the accident can be obtained. This would greatly simplify and improve the work of the forensic traffic expert and speed up and reduce the cost.

It would be excellent for the police to capture images according to the principles of photogrammetry when capturing data in the field. This would enable 3D models to be made by experts who will process their data later, especially in difficult weather conditions).

We also propose appropriate training for all actors who cover accident data to get acquainted with the basic procedures, equipment, technology, and data collection methods in ways that enable better post-processing.

In doing so, it would be necessary to establish a single database not only of the police but also of all other stakeholders who are otherwise involved in dealing with the consequences of traffic accidents or the state of infrastructure. This would also require the necessary resources and regulations and the scope of stakeholders.

The use of modern measurement methods and technology could thus avoid many problems and errors in the collection of traffic accident data, such as: incorrect position measurements, incorrect location of the collision, incomplete collision traces, incorrect scale, missing length and radius measurements and many others.

6. REFERENCES

Ahmed, A., Sadullah, A. F. M. and Yahya, A. S. (2019) 'Errors in accident data, its types, causes and methods of rectification-analysis of the literature', *Accident Analysis and Prevention*. Elsevier, 130(July 2017), pp. 3–21. doi: 10.1016/j.aap.2017.07.018.

Caroti, G., Martínez-Espejo Zaragoza, I. and Piemonte, A. (2015) 'Accuracy assessment in structure from motion 3D reconstruction from UAV-born images: The influence of the data processing methods', *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, 40(1W4), pp. 103–109. doi: 10.5194/isprsarchives-XL-1-W4-103-2015.

Cunha, R. R., Arabal, C.T., Dantas, M.M., Bassanelli, H.R., (2022) 'Laser scanner and drone photogrammetry: A statistical comparison between 3-dimensional models and its impacts on outdoor crime scene registration', *Forensic Science International*. Elsevier, 330, p. 111100. doi: 10.1016/j.forsciint.2021.111100.

Desmoulin, G. T., Kalkat, M. and Milner, T. E. (2022) 'Forensic application of inverse and reverse projection photogrammetry to determine subject location and orientation when both camera and subject move relative to the scene', *Forensic Science International*. Elsevier, 331, p. 111145. doi: 10.1016/j.forsciint.2021.111145.

European Commission (no date) *Mobility & Transport - Road Safety*. Available at: https://ec.europa.eu/transport/road_safety/statistics-and-analysis/data-and-analysis_en.

Eurostat, Statistics explained (no date). Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Road_accident_fatalities_-_statistics_by_type_of_vehicle#In_2019.2C_Romania_had_96_persons_killed_per_million_inhabitants_in_road_accidents.2C_the_highest_in_the_EU.

Garcia-Aunon, P., Roldán, J. J. and Barrientos, A. (2019) 'Monitoring traffic in future cities with aerial swarms: Developing and optimizing a behavior-based surveillance algorithm', *Cognitive Systems Research*, 54, pp. 273–286. doi: 10.1016/j.cogsys.2018.10.031.

Inzerillo, L., Di Mino, G. and Roberts, R. (2018) 'Image-based 3D reconstruction using traditional and UAV datasets for analysis of road pavement distress', *Automation in Construction*. Elsevier, 96(October), pp. 457–469. doi: 10.1016/j.autcon.2018.10.010.

Javna Agencija RS za varnost prometa (2021) *Pregled stanja varnosti v cestnem prometu za leto 2020*. Available at: https://www.avp-rs.si/wp-content/uploads/2021/03/analiza-in-pregled-stanja-varnosti-cestnega-prometa-v-letu-2020.pdf.

Javna Agencija RS za varnost prometa (no date). Available at: https://www.avp-rs.si/varnost-cestnega-prometa-v-evropski-uniji-leta-2020-najmanj-smrtnih-zrtev-na-cestah-doslej/.

Kamnik, R., Nekrep Perc, M. and Topolšek, D. (2020) 'Using the scanners and drone for comparison of point cloud accuracy at traffic accident analysis', *Accident Analysis and Prevention*, 135. doi: 10.1016/j.aap.2019.105391.

Mandirola, M., Casarotti, C., Peloso, S., Lanese, I., Brunesi, E., Senaldi, I., (2022) 'Use of UAS for damage inspection and assessment of bridge infrastructures', *International Journal of Disaster Risk Reduction*. Elsevier Ltd, 72(January), p. 102824. doi: 10.1016/j.ijdrr.2022.102824.

Matys, M., Krajcovic, M. and Gabajova, G. (2021) 'Creating 3D models of transportation vehicles using photogrammetry', *Transportation Research Procedia*. Elsevier B.V., 55, pp. 584–591. doi: 10.1016/j.trpro.2021.07.025.

Ministrstvo za pravosodje (2014) 'Smernice za izdelavo izvedenskega mnenja oz. cenitve na preizkusu strokovnosti za sodne izvedence oz. sodne cenilce', p. 2. Available at: https://cip.gov.si/media/1334/21-5_2014_smernice.pdf.

Mohd, D., Sharifah, M.S., Mohd, Y., Mohd, Y.P., Heo, C.C., Khoo, L.S., Chainchel, S., Mansharan, K., Mahmood, M.S., Nawawi, H., (2022) 'Applications of drone in disaster management: A scoping review', *Science and Justice*. Elsevier B.V., 62(1), pp. 30–42. doi: 10.1016/j.scijus.2021.11.002.

OECD/ITF, I. T. S. D. and A. G. I. (2020) *Road Safety Annual Report 2020*. Paris.

Osman, M. R. and Tahar, K. N. (2016) '3D accident reconstruction using low-cost imaging technique', *Advances in Engineering Software*. Elsevier Ltd, 100, pp. 231–237. doi: 10.1016/j.advengsoft.2016.07.007.

Pérez, J. A., Gonçalves, G.R., Rangel, J.M.G., Ortega, P.F., (2019) 'Accuracy and effectiveness of orthophotos obtained from low cost UASs video imagery for traffic accident scenes documentation', *Advances in Engineering Software*. Elsevier, 132(March), pp. 47–54. doi: 10.1016/j.advengsoft.2019.03.010.
Renduchintala, A., Jahan, F., Khanna, R., Javaid, A.Y., (2019) 'A comprehensive micro unmanned aerial vehicle (UAV/Drone) forensic framework', *Digital Investigation*. Elsevier Ltd, 30(2019), pp. 52–72. doi: 10.1016/j.diin.2019.07.002.
RS, Statistični urad (no date a). Available at: https://pxweb.stat.si/SiStat/sl/Podrocja/Index/48/transport.
RS, Statistični urad (no date b). Available at: https://pxweb.stat.si/SiStatData/pxweb/sl/Data/-/1360303S.PX.
Salvo, G., Caruso, L. and Scordo, A. (2014) 'Urban Traffic Analysis through an UAV', *Procedia - Social and Behavioral Sciences*. Elsevier B.V., 111, pp. 1083–1091. doi: 10.1016/j.sbspro.2014.01.143.
Sarsam, S., Daham, A. and Ali, A. M. (2015) 'Implementation of Close Range Photogrammetry to Evaluate Distresses at Asphalt Pavement Surface', *International Journal of Transportation Engineering and Traffic System*, 1(1), pp. 31–44. Available at: http://civil.journalspub.info/index.php?journal=JTETS&page=article&op=view&path%5B%5D=25.
Slovenija, R. and Pravosodje, M. Z. A. (2021) *Sodna statistika 2020*. Ljubljana. Available at: https://podatki.gov.si/dataset/43606a24-b254-40ef-846d-2b7df3db22ed/resource/7b005a8e-b174-4c26-8ad3-6ee21cfd0eff/download/sodnastatistika2020.pdf.
Stáňa, I., Tokař, S., Bucsuházy, K., Bilik, M., (2017) 'Comparison of Utilization of Conventional and Advanced Methods for Traffic Accidents Scene Documentation in the Czech Republic', *Procedia Engineering*, 187, pp. 471–476. doi: 10.1016/j.proeng.2017.04.402.
Stehel, S., Vertal, P. and Demcáková, L. (2021) 'Application of Close-Range Photogrammetry in Documenting the Location of an Accident', *Transportation Research Procedia*. Elsevier B.V., 55, pp. 1657–1664. doi: 10.1016/j.trpro.2021.07.156.
WHO (no date) *Road traffic injuries*. Available at: https://www.who.int/news-room/fact-sheets/detail/road-traffic-injuries.
ZDeb, U. R. št. 22/18 in 3/22-Zd. (2019) 'ZSICT, Zakon o sodnih izvedencih, sodnih cenilcih in sodnih tolmačih'. Available at: http://www.pisrs.si/Pis.web/pregledPredpisa?id=ZAKO7726.
Zhang, C. (2008) 'An UAV-based photogrammetric mapping system for road condition assessment', *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences.*, pp. 627–632. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.150.8490&rep=rep1&type=pdf.