Acta Polytechnica CTU Proceedings **52**:136–143, 2025
https://doi.org/10.14311/APP.2025.52.0136

Published by the Czech Technical University in Prague

STATISTICAL ANALYSIS OF ACCIDENT DATA ON D1 MOTORWAY

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Abstract. This study analyses incidents on the D1 motorway over the period 2015–2023, with a focus on improving towing operations processes. The analysis includes a breakdown of incidents by type (accidents, technical failures), injuries and deaths, and considers seasonal variations and traffic conditions. The data show that traffic accidents account for most incidents, especially in sections with heavy traffic and difficult weather conditions. At the same time, there is an increase in the number of incidents in 2018 and 2019, while 2020 brings a temporary decrease due to the COVID-19 pandemic. This research is part of a long-term project aimed at optimizing and standardizing the processes of extrication and towing activities, with the aim of streamlining interventions, minimizing traffic complications and ensuring rapid traffic recovery on key roads. Subsequent steps will focus on designing new standards for towing interventions and improving current protocols.

Keywords: D1 motorway, incidents, traffic accidents, towing activities, process optimization, technical failures, intervention standardization, injuries, recovery activities, seasonal effects.

1. Introduction

The D1 motorway connecting Prague and Brno is the oldest and busiest motorway in the Czech Republic, as illustrated in Figure 1. Thanks to its strategic location and importance within the European transport network, it plays a key role in the transport of goods and passengers. The high frequency of traffic, especially trucks and cars, causes D1 to become a frequent site of traffic accidents that affect the flow of traffic [1]. Accidents on D1 are caused by various factors, including failure to adapt speed to road conditions, driver fatigue and technical defects in vehicles. In winter months, when road icing is frequent, the risk of accidents increases even more [2]. Statistics show that accidents occur most frequently in congested sections of the motorway, especially between kilometers 178 and 210, where traffic complications are common [3].

To ensure a quick response to accidents and to minimize traffic problems, a central dispatch of towing services has been established on D1, which is managed by the Directorate of Roads and Motorways (DRD) [1]. This dispatching center ensures the coordination of towing services, which are responsible for the removal of immobile vehicles from the roadway so that traffic can be restored as soon as possible. The towing services cooperating with the RCSD include companies such as Pretol, Jerex and WUKA, which have the necessary equipment to tow both cars and heavy goods vehicles [4].

According to Act No. 361/2000 Coll. on Road Traffic, it is the duty of the vehicle owner to remove the immobile vehicle from the road [2]. If the owner is unable or unwilling to do so, the central dispatching center may call a towing service at the owner's expense. This procedure is common, especially in accidents where the vehicle is an obstruction to traffic and must be removed quickly to avoid further complications [5].

In addition to accidents, towing is also carried out when a vehicle is unable to continue driving due to a technical fault or when it is incorrectly parked, for example in emergency parking lanes. Such vehicles can obstruct emergency services or significantly impede the flow of traffic on the motorway [4].

The aim of this paper is to analyze the data on accidents and other incidents on the D1 motorway. This analysis will focus on the number of accidents, the structure of those involved in accidents (cars, trucks, pedestrians) and the distribution of accidents by motorway section. Where available, intervention times will also be considered, allowing a better understanding of the nature of accidents and interventions on D1 motorway.

The research question is mainly to find out what types of incidents happen most often on D1 motorway, on which sections these incidents happen the most and what is specific to them, what kind of vehicles are involved in these incidents, how frequent are injuries and deaths of people and what is the distribution of incidents in years and months, or whether there are months that are more characteristic of accidents to happen or not.

The analysis of accident data on highways is an essential tool for identifying risk factors and improving road safety. Such analysis enables the planning of preventive measures and infrastructure optimization to reduce the likelihood of accidents. In the Czech Republic, the "Methodology for Managing the Consequences of Traffic Accidents" was developed by the

FIGURE 1. D1 motorway in its analyzed extent [6].

Directorate of Roads and Highways of the Czech Republic in cooperation with the Institute of Forensic Engineering at Brno University of Technology. This document provides a detailed guide on procedures for handling accident aftermath on highways and first-class roads, emphasizing the importance of a quick and coordinated response to minimize impacts on traffic flow and safety for road users [7].

In international literature, statistical methods and spatial analysis are commonly used to gain insights into the causes and effects of traffic accidents. A review of statistical approaches to crash frequency analysis highlights their critical role in modeling risk factors on highways [8]. Various approaches to assessing injury severity in accidents offer insight into how different conditions, such as speed and road type, impact accident outcomes [9].

Another important factor is unobserved heterogeneity, which means that certain factors influencing the likelihood of an accident may not be directly observable. Ignoring these hidden factors can lead to inaccurate conclusions and biased results [10]. Temporal instability in accident data also plays a significant role, as patterns of behaviour and traffic conditions may change over time, affecting the accuracy of predictive models [11].

Advances in machine learning enable the use of sophisticated algorithms for analyzing and predicting high-risk areas on highways. Machine learning has proven beneficial for improving the accuracy and adaptability of these models in various environments [12]. In the European context, factors such as traffic density and infrastructure quality have a crucial impact on road safety, highlighting the need for individualized approaches to enhance safety across different regions of Europe [13].

2. Solution methods

Accident and event data extraction and analysis from large CSV files were key steps in understanding the nature of traffic events across the country. Working with this data required a combination of several methods and techniques, including the use of Excel, VBA scripts and analytical techniques to extract relevant information. The data came from the period September 2015 to December 2022 and contained hundreds of thousands of records from across the country, which included various types of traffic events, accidents and road restrictions. The process began with importing this data from CSV files into Excel, where initial editing and data preparation was required. This data was often in the form of long supplementary text that contained key accident information such as the date and time of the event, road type, road number, accident location and other details that needed to be extracted.

Visual Basic for Applications (VBA) is a programming language developed by Microsoft that allows you to automate tasks in applications such as Excel, Access, and other Microsoft Office applications. VBA is an extension of Visual Basic and is integrated directly into these applications, allowing users to create macros and scripts for tasks that would otherwise require manual intervention.

One of the main challenges in working with this data was the need to extract specific information from the long text descriptions. For example, it was necessary to isolate the date and time of the accident from this text, which required splitting cells and finding specific formats such as date stamps or time stamps. To do this, we used various methods such as cell splitting using Excel functions or VBA scripts to automate the extraction of this data. In addition, we needed to

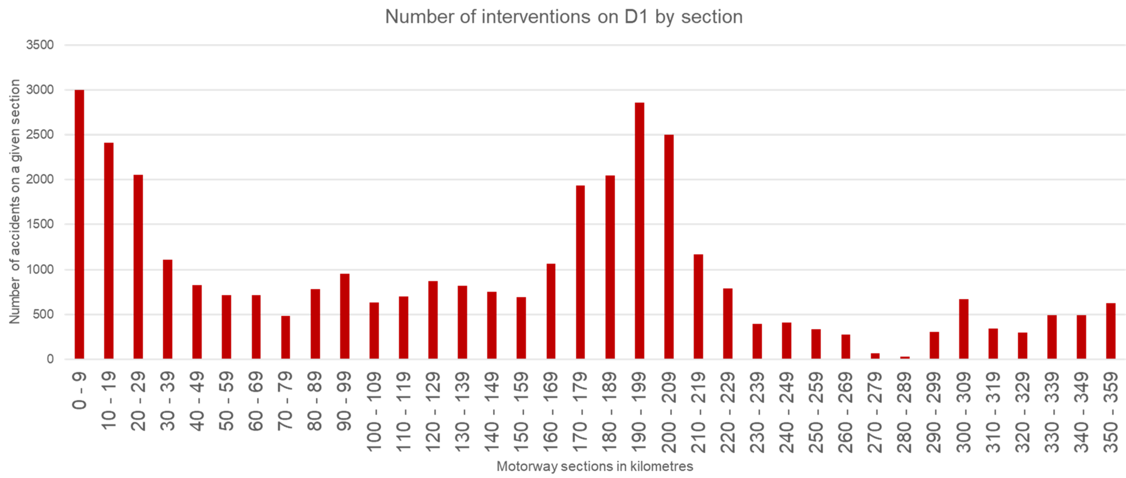

Figure 2. Number of interventions on D1 by section.

identify the type of road (e.g., highway, class 1 road) and its number, which often required text processing to find keywords and numbers.

In the context of data analysis, VBA provides efficient tools for manipulating large volumes of data. In this paper, VBA was used to process large-scale data on traffic events on the D1 motorway. VBA was used to automate various processes such as extracting data from long text descriptions, identifying accident types, splitting data by time stamps, or converting time data into a format usable for analysis in Excel. The use of VBA not only sped up data processing but also increased the accuracy of the results, which was crucial for a deeper understanding of accident patterns on the D1 motorway.

For more advanced analysis, VBA scripts written specifically for this purpose were used. These scripts made it possible to automate the identification and counting of the different types of vehicles mentioned in the text, such as cars ("OA"), trucks ("NA"), buses ("BUS"), motorcycles ("MOTO"), pedestrians ("CHODEC") and other categories such as animals or fixed obstacles, which were classified as OTHER. The scripts were designed to detect different forms and combinations of these categories, including cases where occurrences such as "2× OA" or "OA × NA" had to be accounted for, which meant one car and one truck.

Another challenge was to correctly analyze the duration of the events. For this purpose, the textual duration information, which was given as "2 hours 5 minutes" for example, was converted into a format that Excel would recognize and allow for further calculations such as summing or comparing times. These conversions were done using VBA scripts that decomposed the time data into hours and minutes and then converted it into a format usable for further work in Excel.

The whole process therefore involved a combination of different techniques and tools working together to extract, edit and analyze the accident data. The use of VBA was key in automating many steps that would otherwise have required manual work and allowed large amounts of data to be processed and analyzed efficiently. This approach not only sped up processing, but also increased the accuracy of the analyses, which was essential for drawing meaningful conclusions from the available information on crashes and road events.

3. Results and discussion

This analysis is part of a specific research aimed at creating an effective system of evidence for optimizing the processes of recovery and towing activities in the Czech Republic. The data will be used for a comprehensive progressive analysis of accidents and infrastructure data to improve standards and practices in the field of road obstruction removal.

Specifically, the analysis focuses on accidents on the D1 motorway in its entirety, from 1 January 2015 to 31 December 2023. This includes data on accidents on all sections of the motorway from Prague to the border with Poland. This data will be a key source for the creation of a traffic accident database that will be used for further research purposes within the project.

Due to technical problems three months of data from 2023 are not available, which is likely to have been caused by an error in data collection or transmission. Despite this gap, the available data can be used to analyze the trends and distribution of accidents on the D1 motorway.

3.1. Analysis of events on D1 by motorway sections

The number of incidents on the D1 motorway by kilometer section is illustrated in Figure 2, with data broken down by ten-kilometer intervals. Some sections show a significantly higher number of incidents than others, a trend influenced by factors such as traffic density, weather conditions, construction works, and the nature of the infrastructure. Incidents include not

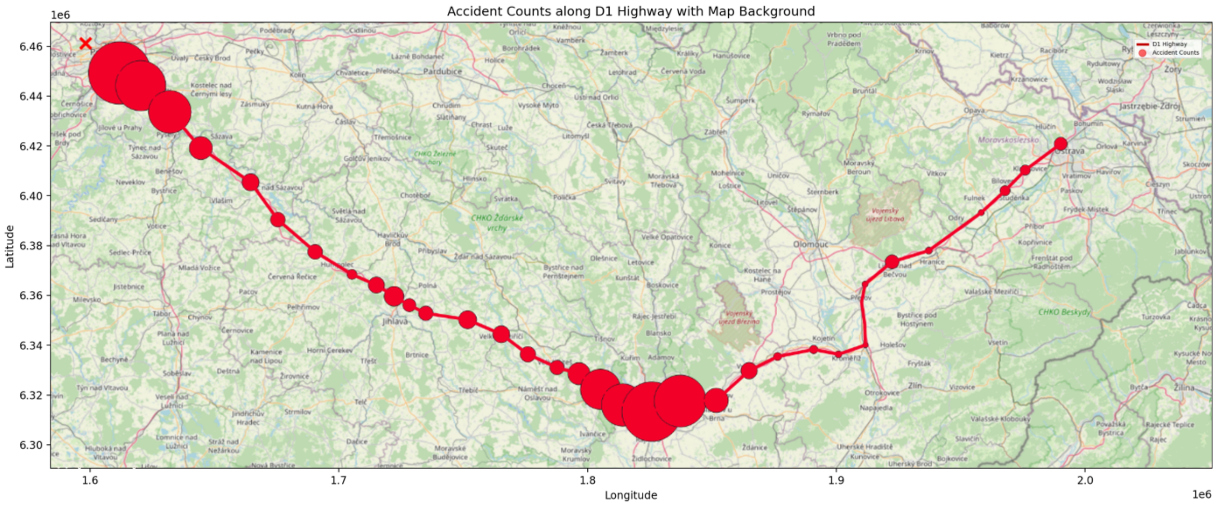

Figure 3. Accident counts along D1 highway with map background.

only accidents but also vehicle breakdowns and other events that required the use of a response vehicle.

Figure 3 shows a map of the D1 motorway with points marking the locations and frequency of accidents. The map was created based on geographical data on key points along the motorway and accident data highlighting areas of risk. Each red dot represents a 10 km stretch, with the size of the dot corresponding to the number of incidents. Initial coordinates were generated using the Python programming language to approximate the location of the incidents and then refined and visualized in QGIS to ensure an accurate alignment with the actual route of the D1 motorway.

The highest number of incidents occurs in the 0–9 km and 10–19 km sections, which are areas close to Prague. These sections are characterized by extreme traffic density, mainly due to the daily commute and the high number of cars and trucks. High traffic volumes and complex traffic situations such as city entrances and exits significantly increase the risk of incidents in this area. The combination of these factors results in a high incident rate at the start of the D1 motorway.

On the other hand, the 119–153 km sections (Highlands) are also characterized by a significant increase in the number of incidents. This section of the motorway is characterized by its variable terrain and frequent extreme weather conditions such as fog, snow and icing. These conditions are particularly dangerous during the winter months when traffic complications are frequent. In addition, there are regular construction works and closures on this stretch, which can contribute to further incidents.

The 190–199 km stretch is an example of an area where construction work is frequent, which together with heavy traffic leads to a high incident rate. Closures and changes in traffic arrangements increase the risk of collisions and other complications.

On the other hand, sections such as 270–279 km and 280–289 km have very low incident rates. These parts of the motorway are in less busy areas with lower traffic volumes. Therefore, there is less likelihood of incidents occurring here. The lower traffic volume in these sections and the absence of critical traffic points can be considered as the main reason for the lower incident rate.

Also of interest is the 30–39 km section where the number of incidents is elevated. This section is in the Mirošovice area, where traffic flow distribution and changes in traffic load occur. It is likely that traffic from the urban area meets the motorway network here, creating more complex traffic conditions and increasing the risk of incidents.

Conversely, the lower number of incidents in the 230–260 km sections may be due to lower traffic volumes and the absence of complex traffic situations. The lower traffic density in these sections contributes to a relatively lower intervention rate.

Based on the graph and data analysis, higher incident rates are often associated with heavy traffic, construction and challenging weather conditions, while sections with lower traffic volumes show lower intervention rates. These factors should be considered when designing effective measures to minimize incidents and improve safety on the D1 motorway.

3.2. Analysis of the type of events on D1

Figure 4 illustrates the ratio of traffic accidents to other incidents on the D1 motorway. The graph highlights that most recorded incidents are traffic accidents, as indicated by the red segment. These incidents frequently necessitate the intervention of towing services due to their severity and the urgent need to clear obstructions from the roadway.

A smaller proportion of incidents, shown in blue, represent other incidents, which primarily include technical vehicle breakdowns. Although these incidents

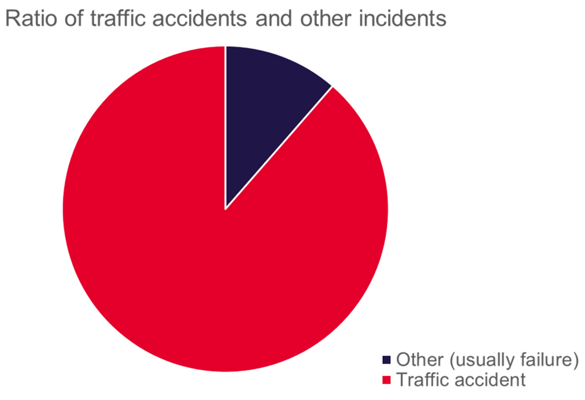

Figure 4. Ratio of traffic accidents and other incidents.

are less frequent than accidents, they still make up a significant proportion of interventions on the motorway. Compared to road accidents, these incidents tend to be less serious and can be quicker and easier to resolve, but this does not mean that they should be ignored.

3.3. Analysis of events in individual years and months

Figure 5 shows the number of incidents on the D1 motorway from 2015 to 2022, with the data broken down by month. This representation allows for the analysis of changes in the number of incidents both within each year and across the years.

In 2018 and 2019 there is a significant increase in the number of incidents, which reaches a peak. This trend may be due to several factors. One of them is the increasing volume of traffic on D1, which was extremely busy at this time. Another reason may be the frequent construction works that were taking place on various sections of the motorway, which led to traffic jams and a higher number of incidents requiring the intervention of towing services.

The year 2020, on the other hand, sees a decrease in the number of incidents, which is probably due to the global pandemic COVID-19. The restriction of movement and reduction in traffic volume led to fewer incidents, which is clearly visible in the graph. The significantly lower traffic density had a direct impact on the total number of interventions.

After 2020, incident numbers gradually stabilized, as shown by the trends in 2021 and 2022. Although in some month's incident numbers did not return to 2019 levels, they were close. This development may be related to the gradual return to normal traffic after the pandemic and the ongoing construction work on the D1 motorway.

The chart also shows seasonal fluctuations. For example, winter months such as December, January and February show a higher number of incidents, which is logical given the worsened weather conditions. Snow, ice and fog in winter increase the risk of traffic accidents and technical failures. Summer months, such as July and August, have a lower number of incidents in some years, probably due to better weather conditions and lower traffic congestion during the holidays.

In conclusion, the trend in the number of incidents on D1 over the years clearly indicates seasonal and long-term influences such as construction, pandemics and seasonal conditions. Winter months and periods of construction work bring higher numbers of incidents, while summer months and pandemics lead to a decrease.

3.4. Analysis of the types of vehicles involved in events

Figure 6 shows the distribution of incidents on the D1 motorway by type of participants. Each segment of the graph represents the share of each participant type in the total number of incidents. Key groups identified in the graph include cars, lorries, buses, motorcycles, pedestrians, and other categories such as cyclists, fixed obstacles, and animals.

The largest proportion of incidents, shown by the red segment, relate to cars. This is not surprising given that passenger cars make up most of the traffic on D1 motorway. The high volume of passenger traffic increases the likelihood that passenger cars will be frequent participants in accidents and other incidents.

The second largest segment, shown in blue, is trucks. Lorries make up a significant proportion of traffic on the D1 motorway and, although not as numerous as passenger traffic, their contribution to incidents is significant. This may be due to the greater risks associated with the handling and movement of heavy vehicles, particularly on sections with heavy traffic or poor weather conditions.

Buses are shown in the light blue segment and account for a smaller proportion of incidents. Although buses make up a smaller proportion of traffic, their contribution to incidents is important because of the potential consequences of these incidents, particularly in terms of passenger numbers and vehicle size.

Motorcycles, which account for a small proportion of the total number of incidents, may in some cases be under-reported in towing service intervention statistics since not all cases require a full tow truck intervention for a motorcycle. In some situations where the motorcycle is not a major road obstruction, it can be removed more quickly and easily without the need for heavy equipment. This factor contributes to the fact that incidents involving motorcycles are not always recorded as full-scale interventions, which may make their proportion of total incidents appear lower.

Small segments include motorcycles, pedestrians, and other users, which includes bicyclists, fixed obstacles, and animals. Incidents involving these participants are less frequent but can have serious consequences. Incidents involving pedestrians are particularly risky due to their vulnerability compared to vehicles.

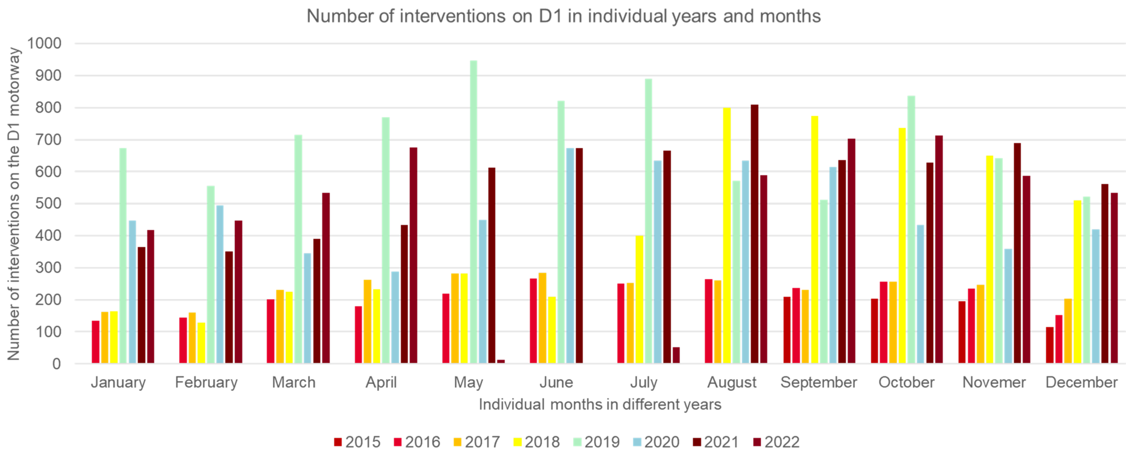

Figure 5. Number of interventions on D1 in individual years and months.

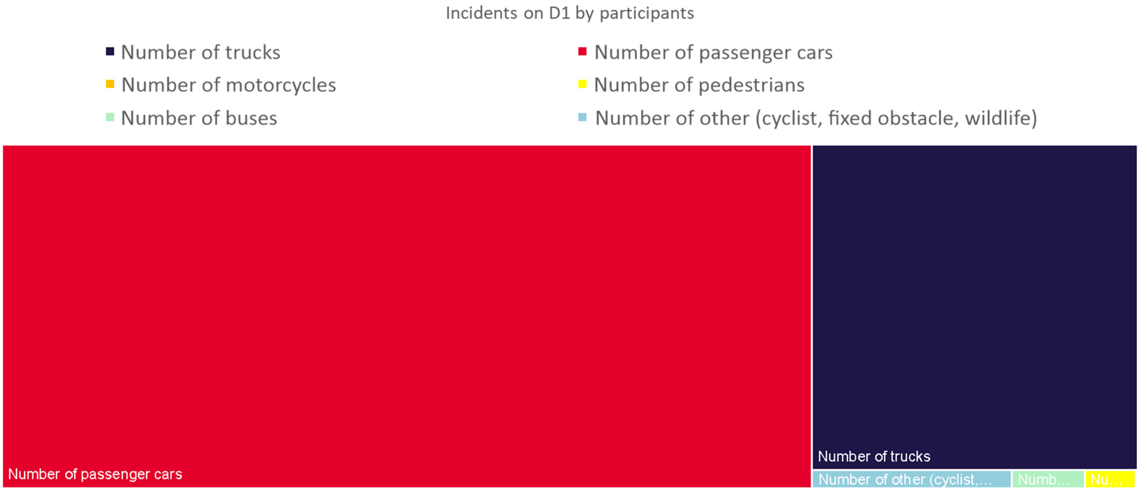

Figure 6. Incidents on D1 by participants.

Overall, the graph shows that cars and lorries make up the vast majority of those involved in incidents on D1 motorway. This is related to their dominance on the motorway and their greater numbers compared to other categories of users.

Figure 7 shows the number of people injured and killed in incidents on the D1 motorway. It is important to note that the proportion of incidents marked in blue as 'Not specified for towing purposes' include incidents where it was not necessary to specify injuries for towing purposes. This means that in these cases the injury is unlikely to have occurred at all or was not relevant to the towing vehicle intervention. Overall, there are over 19 000 cases with injuries and 24 tragic deaths, but this does not necessarily include all cases where towing service intervention was not required. This information is not always relevant to tow truck drivers unless the accident requires specific attention to these aspects.

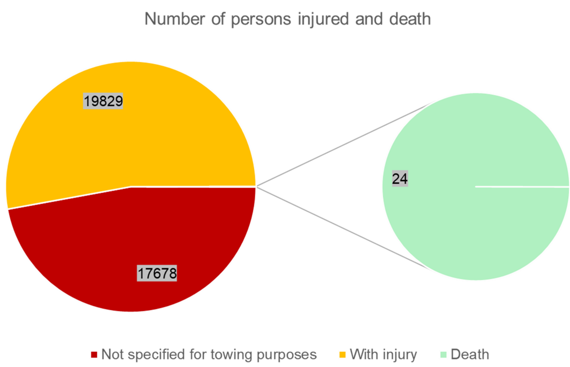

Figure 7. Number of persons injured and death.

3.5. Analysis of participant injuries and deaths

4. Conclusions

This analysis has provided a comprehensive overview of accidents on the D1 motorway between 2015 and 2023. From the available data we have found that road accidents make up most incidents. Vehicle breakdowns and other types of accidents are significantly less common but still make up a significant proportion of interventions on the motorway. Traffic crashes tend to be concentrated in certain sections of the highway and are influenced by several factors such as traffic volume, weather conditions, and roadway design.

From the graphs, we could also infer that there was an increase in the number of incidents in 2018 and 2019, which can be attributed to increasing traffic volumes and frequent maintenance and construction works on various sections of D1 motorway. The year 2020 brought a temporary decrease in the number of incidents due to the COVID-19 pandemic, which led to lower traffic volumes. After this hiatus, incidents gradually returned to the levels seen before the pandemic and again concentrated on critical sections of the motorway where traffic is densest or where weather and road conditions are more challenging.

Seasonal variations in incident rates show that winter months, when weather conditions are less favorable, pose a higher risk to drivers, while summer months have lower incident rates. This suggests that highway conditions play a major role in the incidence of crashes and other events requiring towing service intervention.

In the analysis of incident participants, it was found that cars and trucks make up the most of incident participants. Motorcycles and buses are represented to a lesser extent, and motorcycles may be statistically under-represented because it is not always necessary to call for tow trucks in their crashes. In such cases it is not necessary to record a full intervention, resulting in a lower proportion of these incidents in the statistics.

The analysis of injuries and deaths shows that although most incidents do not involve injuries, there are a significant number of cases with injuries and a few tragic deaths. These incidents have a significant impact on highway operations and require rapid and coordinated intervention to minimize the consequences not only to the participants but also to other drivers and traffic flow.

In terms of the ratio of accidents to technical failures, accidents significantly predominate. Technical failures, although less frequent, represent an important part of highway interventions and it is essential to ensure effective and rapid procedures for dealing with them to minimize disruption to traffic.

In conclusion, this analysis shows that incidents on the D1 motorway are influenced by a wide range of factors, ranging from traffic density to seasonal variations and weather conditions. These factors need to be carefully considered when developing strategies and standardized procedures for towing service interventions.

This analysis is an important step in research focusing on optimizing and standardizing the processes of salvage and towing operations. The research will continue toward finding ways to streamline highway interventions to ensure the quickest possible recovery and minimize traffic complications during incidents. The next step will involve developing new standards and protocols for response vehicles, including evaluating current processes and providing suggestions for improvement. Optimizing these processes aim to contribute to safer and smoother traffic on Czech motorways, not only on D1 motorway but also on other key roads in the country.

Acknowledgements

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