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FREQUENCY OF CO-RECORDING OF ROAD-RELATED CONTRIBUTORY FACTORS AND DRIVER BEHAVIOUR-RELATED CONTRIBUTORY FACTORS

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Abstract: Globally, the number of fatalities and injuries resulting from road traffic crashes remains unacceptably high despite numerous measures implemented to improve road safety. The development of such measures is, among other things, based on the analysis of contributory factors, which describe the reasons and circumstances that directly or indirectly led to the occurrence of a road traffic crash or influenced the severity of its consequences. Previous studies have primarily focused on analysing individual contributory factors, while their co-recording has received considerably less attention. The number of contributory factors identified in an individual road traffic crash depends not only on the crash circumstances but also on the knowledge and expertise of the police officers conducting the crash investigation. In road traffic crashes where at least two contributory factors have been identified, it is possible to analyse the frequency of their co-recording. The aim of this study is to compare the frequency of recording selected driver behaviour-related contributory factors in road traffic crashes with and without a recorded specific road-related contributory factor. The analysis was conducted using national fatal and injury road traffic crash data from the Republic of Serbia covering the period from 2016 to 2025. The results indicate differences in the frequency of recording individual driver behaviour-related factors in crashes with and without the specific road-related factors recorded. For example, malfunctioning traffic signals are frequently recorded together with failure to yield the right-of-way, while inappropriate speed is the driver behaviour-related contributory factor frequently recorded in combination with various road-related contributory factors. The findings may contribute to a better understanding of crash circumstances, provide a basis for improving the recording of contributory factors in road traffic crash databases, and support the development of road safety measures.

Keywords: Contributory factors, driver behaviour, road infrastructure

1. INTRODUCTION

The number of road traffic deaths worldwide decreased by 5% between 2010 and 2021, yet road traffic crashes remain the leading cause of death among children and young people aged 5–29 years (WHO, 2023). In the European Union, 20,017 people were killed in road traffic crashes in 2024, representing a decrease of only 2% compared with the previous year and progress considerably slower than required to achieve the target of halving road traffic deaths by 2030

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(ETSC, 2025). In the Western Balkans, 1,225 people were killed, corresponding to an average of 76 deaths per million inhabitants, which remains substantially higher than the European Union average. In the Republic of Serbia, more than 32,000 road traffic crashes were recorded in the same year, resulting in 514 deaths and more than 19,000 injuries (RTSA, 2025). A comparison of road traffic risk in Sweden and Serbia over an eight-year period (2014–2021) shows that the risk in Serbia was 4.1–5.8 times higher than in Sweden, with a slight upward trend in this disparity over the period examined (Nešić et al., 2023). These indicators confirm that road traffic crashes remain a serious societal and public health problem. Therefore, in addition to monitoring their number and consequences, a more detailed examination of the factors contributing to their occurrence is needed.

Of all fatal road traffic crashes that occurred in the United States in 2020, 28% were speeding-related (NHTSA, 2022). Although this figure highlights the importance of inappropriate or excessive speed, examining it in conjunction with other characteristics enables more precise identification of at-risk groups and the circumstances in which road traffic crashes occur. The same report states that speeding was recorded among 35% of male drivers aged 15–20 years involved in fatal road traffic crashes, identifying this group as particularly important for targeted prevention activities. Speeding was also recorded among 19% of drivers involved in fatal road traffic crashes on dry road surfaces, 21% on wet surfaces, 33% on surfaces covered with snow or slush, and 42% on surfaces covered with ice or frost (NHTSA, 2022). Drawing on research by other authors, the manual for the professional training of road safety inspectors and auditors emphasises that many driver errors arise from the interaction between road elements and the way drivers perceive the road and the traffic situation. Road geometry, lane width, sight distance, road surface condition, and the visual appearance of the road and its surroundings influence drivers' speed choice and responses. For example, a wide, straight carriageway may encourage speeds above the speed limit, whereas road narrowings, chicanes, and other geometric measures encourage drivers to choose lower speeds. A particular risk arises on small-radius curves and wet road surfaces, where the need for greater speed reduction increases the likelihood of misjudgement and loss of vehicle control (RTSA, 2023).

Through an analysis of 274 road traffic crashes at roundabouts, Montella (2011) identified a combination of multiple contributory factors in approximately 81% of crashes, with the factors identified by an expert team. He notes that, in some cases, the approach to identifying contributory factors differed from that adopted by police officers, who primarily investigated driver errors, whereas the expert team focused on the interaction between road users and road infrastructure. Montella (2011) also highlights the need to examine associations between contributory factors in addition to their individual frequencies, showing that failure to yield the right-of-way and entry path radius co-occurred 2.12 times more frequently than would have been expected if they had been independent.

In a later study, Montella et al. (2021) explain that driver behaviour cannot be fully separated from the conditions in which it occurs. They found that certain combinations of contributory factors were associated with a higher proportion of run-off-road crashes. Specifically, 93.8% of road traffic crashes in which both speeding and a wet road surface were recorded were run-off-road crashes.

By analysing 59 independent assessment reports on the contribution of the road to the occurrence and consequences of crashes involving a pedestrian fatality, Marković et al. (2021) found that the set of road-related contributory factors in the CADaS protocol was insufficient to adequately and comprehensively describe all situations in which the road contributed to crash occurrence or consequences. They report that road and human factors jointly contributed to 52.6% of the crashes analysed. However, their study does not present an analysis of associations between individual pairs of road-related and human-related contributory factors.

Previous research confirms that contributory factors related to the road and driver behaviour often co-occur and that examining them separately does not provide a complete understanding of the circumstances in which road traffic crashes occur. However, existing research in the Republic of Serbia addresses the contribution of individual contributory factors without examining associations between specific factors available to the public through the Road Traffic Safety Agency's Integrated Database of Road Safety Characteristics. This study aims to compare the frequency with which selected driver behaviour-related contributory factors are recorded in road traffic crashes with and without a given road-related contributory factor. It also considers the relevance of these data for interpreting crash circumstances and improving the recording of contributory factors.

2. METHODOLOGY

The study was based on data on fatal and injury road traffic crashes that occurred in the Republic of Serbia between 2016 and 2025. The data were obtained from the Road Traffic Safety Agency's Integrated Database of Road Safety Characteristics. Road traffic crash data are collected according to the CADaS protocol (Common Accident Data Set).

A contributory factor is a reason or circumstance that directly or indirectly contributed to the occurrence of a road traffic crash or influenced the severity of its consequences. One or more contributory factors may be recorded for a single road traffic crash. Police officers can select from 84 contributory factors classified into nine groups: 1. Road and road environment; 2. Vehicle defects; 3. Injudicious actions by drivers; 4. Incorrect execution of driving manoeuvres; 5. Driver errors due to impaired psychophysical condition or inattention; 6. Driver errors due to inexperience, inappropriate behaviour or traffic violations; 7. Driver errors due to inadequate visibility or sight distance; 8. Pedestrian errors; and 9. Special cases.

For the purposes of this study, road-related contributory factors comprised factors from the first group, "Road and road environment". Driver behaviour-related contributory factors comprised factors from the third, fourth, fifth, sixth and seventh groups.

Factors related to vehicle defects were not included in the analysis, as the study focuses on the association between road-related contributory factors and driver behaviour-related contributory factors (driver errors). For the same reason, pedestrian-related contributory factors were not included when forming factor pairs. Factors from the "Special cases" group were also excluded from the analysis. These include events such as driving a stolen vehicle, committing a criminal offence or involvement in a police pursuit, involvement of emergency service vehicles, opening vehicle doors, persons falling from or inside vehicles, failure to secure the crash scene, and other factors that cannot be assigned to another category.

Road traffic crashes in which at least one road-related contributory factor and at least one driver-related contributory factor were recorded were selected for forming factor pairs, regardless of the presence of other contributory factors. Multiple road-related and/or driver-related contributory factors may be recorded for a single road traffic crash. In such cases, all combinations of an individual road-related contributory factor and an individual driver-related contributory factor were formed. The analysis included combinations of contributory factors that were recorded together in at least five road traffic crashes, while the remaining combinations were excluded as exceptionally rare.

For each factor pair examined, the percentage of road traffic crashes in which the driver-related factor under consideration was recorded was compared between two groups: crashes in which the road-related factor under consideration was recorded and crashes in which it was not recorded. The following formulas were used:

Percentage of road traffic crashes with the driver-related factor under consideration among crashes in which the road-related factor under consideration was recorded:

$$P_1 = \frac{A}{A+B} \cdot 100\ [\%] \qquad (1)$$

Percentage of road traffic crashes with the driver-related factor under consideration among crashes in which the road-related factor under consideration was not recorded:

$$P_0 = \frac{C}{C+D} \cdot 100\ [\%] \qquad (2)$$

The symbols used in the formulas have the following meanings: A – the number of crashes in which both contributory factors under consideration were recorded (the road-related factor and the driver-related factor); B – the number of crashes in which the road-related factor under consideration was recorded, but the driver-related factor under consideration was not; C – the number of crashes in which the driver-related factor under consideration was recorded, but the road-related factor under consideration was not; and D – the number of crashes in which neither of the two contributory factors under consideration was recorded. The sum A+B+C+D represents a total of 137,597 road traffic crashes. A total of 7,819 road traffic crashes with at least one recorded road-related contributory factor and at least one recorded driver-related contributory factor were used to form and select factor pairs. The percentages for the selected pairs were calculated using the full sample of 137,597 fatal and injury road traffic crashes.

3. RESULTS

A total of 222,653 contributory factors were recorded in the 137,597 fatal and injury road traffic crashes that occurred between 2016 and 2025. On average, 1.62 contributory factors were recorded per road traffic crash, while at least two contributory factors were recorded in 53,021 crashes (38.53%). Driver-related contributory factors were recorded without factors from any other group in 82.81% of fatal and injury road traffic crashes. Road and road environment-related contributory factors were recorded alone in 0.90% of crashes, while vehicle-related contributory factors were recorded alone in 0.30%. Road-related and driver-related contributory factors were recorded together in 4.59% of crashes, while road-related, vehicle-related and driver-related contributory factors were recorded together in 0.48%. These two categories (the hatched area in Figure 1) account for a total of 5.07% of road traffic crashes and represent crashes in which both road-related and driver behaviour-related contributory factors were recorded. A further approximately 0.61% of crashes involved at least one pedestrian-related contributory factor and/or a factor from the “Special cases” group, in addition to at least one road-related and at least one driver-related contributory factor. Together, these categories account for 5.68%, or 7,819 road traffic crashes, from which pairs of road-related and driver-related contributory factors were identified.

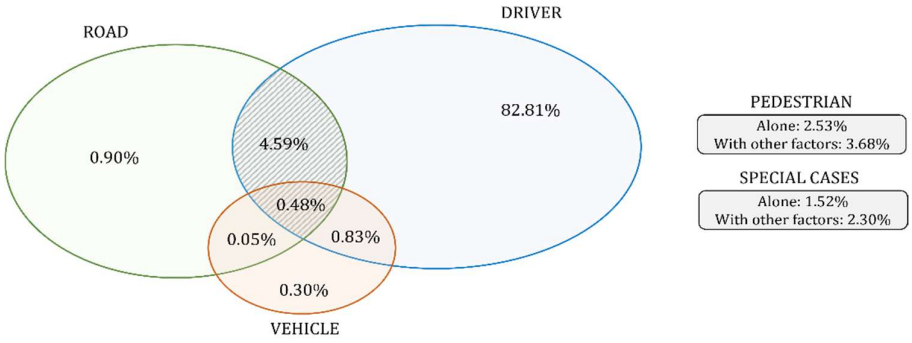


Figure 1. Distribution of road safety factors (groups of contributory factors) in fatal and injury road traffic crashes, 2016–2025.

Among individual road-related contributory factors, a slippery road surface due to weather conditions was the most frequently recorded, occurring in 3,468 road traffic crashes (2.52%). The effects of traffic calming measures were recorded least frequently, in 61 road traffic crashes (0.04%).

A total of 252 pairs of road-related contributory factors and contributory factors related to driver errors were identified. Table 1 presents selected pairs considered relevant to the interpretation of the results. The road factors column shows the number of road traffic crashes in which each road-related factor was recorded and its percentage of the total number of crashes. For each factor pair, the table shows the number of crashes in which both factors were recorded, the percentage of crashes with the specified road-related factor in which the driver-related factor was recorded (P_1), and the corresponding percentage among crashes without the specified road-related factor (P_0).

Inappropriate speed for traffic conditions and road conditions was recorded in 52.62% of road traffic crashes in which a slippery road surface due to weather conditions was recorded. In comparison, this speed-related factor was recorded in 24.96% of crashes in which a slippery road surface due to weather conditions was not recorded.

For the road alignment factor, the effect of road alignment on the driver's sight distance was recorded in 16.05% of crashes with this road-related factor and in 0.52% of crashes without it. Driver inexperience contributing to the crash was recorded in 8.60% of crashes with the road alignment factor, compared with 4.33% of crashes without it. Driving under the influence of alcohol was recorded as a contributory factor in 14.52% of crashes with the road alignment factor, compared with 11.64% of crashes without it.

The effect of vegetation (trees, hedges or other forms of vegetation) was recorded almost 11 times as frequently in road traffic crashes in which inadequate, missing or insufficiently conspicuous traffic signs, road markings and/or road equipment were also recorded: 2.75%, compared with 0.25% of crashes without this road-related factor.

Failure to yield the right-of-way as indicated by an authorised officer, traffic signs or traffic rules was recorded in 57.14% of road traffic crashes in which malfunctioning traffic signals were also recorded, compared with 15.3% of crashes without this road-related factor.

Incorrect assessment of the traffic situation was the most frequently co-recorded driver-related contributory factor in road traffic crashes involving the absence of a cycle track or cycle lane in a built-up area (22.97%).

Table 1. Frequency of selected driver-related contributory factors in road traffic crashes with and without a recorded road-related contributory factor

Road-related factor (n; %)	Driver-related factor	Both factors (n)	P_1 (%)	P_0 (%)
Poor or inadequately maintained road surface (1,438; 1.05%)	Loss of vehicle control	201	13.98	6.25
Road surface covered with oil, mud, etc. (249; 0.18%)	Inappropriate speed	110	44.18	25.63
	Loss of vehicle control	42	16.87	6.31
	Driver inexperience	18	7.23	4.36
Slippery road surface due to weather conditions (3,468; 2.52%)	Inappropriate speed	1,825	52.62	24.96
Inadequate, missing or insufficiently conspicuous traffic signs, road markings and/or road equipment (1,561; 1.13%)	Failure to yield the right-of-way	373	23.89	15.22
	Incorrect assessment of the traffic situation	360	23.06	18.24
	Effect of vegetation (trees, etc.)	43	2.75	0.25
Malfunctioning traffic signals (70; 0.05%)	Failure to yield the right-of-way	40	57.14	15.3
Temporary traffic signs and road markings (132; 0.10%)	Incorrect assessment of the traffic situation	34	25.76	18.29
	Loss of vehicle control	22	16.67	6.32
	Failure to yield the right-of-way	11	8.33	15.32
Effect of road alignment (1,302; 0.95%)	Crossing a solid centre line	89	6.84	3.01
	Driver inexperience contributing to the crash	112	8.6	4.33
	Effect of road alignment on the driver's sight distance	209	16.05	0.52
Animal or object on the carriageway (364; 0.26%)	Incorrect assessment of the traffic situation	21	5.77	18.33
	Driving under the influence of alcohol	9	2.47	11.69
Absence of a footway in a built-up area (540; 0.39%)	Passing too close to a pedestrian, cyclist or horse rider	71	13.15	1.58
	Glare from the headlights of an oncoming vehicle	19	3.52	0.25
Absence of a cycle track or cycle lane in a built-up area (1,071; 0.78%)	Incorrect assessment of the traffic situation	246	22.97	18.26
	Travelling on a surface not intended for that type of vehicle	64	5.98	0.71
	Cyclist wearing dark clothing	22	2.05	0.07

4. DISCUSSION

The results show that the frequency of individual driver behaviour-related contributory factors varies depending on whether a road-related contributory factor was identified in the road traffic crash. Factor pairs recorded together in fewer than five road traffic crashes were excluded from the analysis. Certain results should also be interpreted with caution, as the analysis was not conducted separately by crash type, vehicle category, number of road users involved, crash location or other characteristics. In other words, differences in the frequency of individual contributory factors may reflect differences in the composition of the crashes analysed. For example, factors related to cyclist errors, such as wearing dark clothing, may predominate in

crashes in which the absence of a cycle track or cycle lane in a built-up area was recorded. A further limitation concerns how contributory factors are recorded and linked to other crash data. Driver-related and pedestrian-related contributory factors are linked to the individual person in the database, whereas road-related factors are linked to the crash as a whole. This study did not specifically examine which driver each driver-related contributory factor referred to. Within the same crash, different contributory factors may refer to one or more drivers.

Certain road-related contributory factors and factors related to driver errors are closely related in meaning: the former describe a road characteristic, while the latter describe its effect on the driver. This applies to the group "Driver errors due to inadequate visibility, sight distance or overall visual perception of the road and traffic". The co-occurrence of the effect of road alignment (crests, cuttings, side-hill cuttings, etc.) and the effect of road alignment on the driver's sight distance (crests, curves, etc.) is expected, as road alignment can directly affect sight distance. This driver-related contributory factor was recorded in 16.05% of crashes with a recorded road alignment factor, compared with 0.52% of crashes without it. Nevertheless, examining their co-occurrence is relevant because it may provide insight into the reliability of contributory factor recording by police officers and thus inform the assessment of data quality.

Driving under the influence of alcohol was recorded as a contributory factor in 14.52% of crashes in which the effect of road alignment was also recorded, compared with 11.64% of crashes without this road-related factor. This finding may be related to an alcohol-impaired driver's reduced ability to assess road alignment. Before reaching the crash location, the driver may have travelled along several road sections without potentially challenging alignment features, such as curves or crests. These results further suggest that crash occurrence often needs to be considered in terms of the combined contribution of multiple factors within specific traffic circumstances. However, this interpretation requires further investigation incorporating other crash characteristics, such as road section characteristics, crash type and the driver's level of alcohol impairment.

Driver inexperience contributing to crash occurrence was recorded more frequently in road traffic crashes in which a road-related factor was also recorded. This may indicate that inexperienced drivers have greater difficulty anticipating and adapting to potentially more challenging conditions along a road, such as horizontal and vertical curves or mud on the road surface, through speed reduction, choice of vehicle position within the lane or other adjustments. This finding could therefore inform the content of theoretical and practical learner driver training, as well as the development of additional training programmes for inexperienced drivers.

The effect of vegetation (trees, hedges or other forms of vegetation) on sight distance was recorded more frequently in crashes involving inadequate, missing or insufficiently conspicuous traffic signs, road markings and/or road equipment. The co-recording of these two factors provides further detail beyond the general description of inadequate, missing or insufficiently conspicuous traffic signs and road markings, indicating that, in some cases, these conditions may be associated with vegetation obscuring them. This finding may also inform routine maintenance activities, particularly the planning of vegetation trimming near traffic signs and/or road equipment. Further analysis by month or season could show whether the pattern of co-occurrence is more pronounced during periods of more intensive vegetation growth.

5. CONCLUSION

The study showed that the co-recording of road-related and driver behaviour-related contributory factors remains an insufficiently recognised pattern in the database. Only 252 pairs of road-related and driver behaviour-related factors were identified over the period 2016–2025. This finding highlights the need to examine crash circumstances in an integrated manner rather than solely through individual contributory factors.

The results show marked differences in the frequency with which individual driver-related contributory factors were recorded in road traffic crashes with and without the road-related factor under consideration. This is particularly evident for inappropriate speed on slippery road surfaces, loss of vehicle control on inadequately maintained road surfaces, and combinations involving traffic signs and road markings, sight distance and road infrastructure characteristics. These findings indicate the potential value of analysing factor pairs to better understand the circumstances in which road traffic crashes occur and to target prevention activities more precisely.

Certain road-related contributory factors (road characteristics) may increase the demands placed on drivers, while their knowledge, attitudes, abilities, experience and behaviour determine how they respond under such conditions.

The results also indicate the meaningfulness of recording contributory factors, as road elements, represented by road-related contributory factors, and corresponding driver errors arising from them were identified together in numerous road traffic crashes. Nevertheless, the reported frequencies do not constitute evidence of direct causation. Rather, they provide a basis for a more comprehensive understanding of crash circumstances and for guiding measures that jointly address road infrastructure improvements, road maintenance, driver development systems and other activities, primarily those focused on prevention and awareness raising.

Future research should examine the co-recording of contributory factors in greater detail for specific crash types, vehicle categories and other crash characteristics for which recorded contributory factors may help explain how crashes occur. Associations between individual driver-related contributory factors should also be examined, such as driver inexperience and inappropriate speed, or alcohol impairment and incorrect assessment of the traffic situation. Such analyses could help identify characteristic patterns of crash occurrence, further guide preventive measures and activities, improve theoretical and practical learner driver training, and support road safety decision-making.

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