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# Road Crash Severity Level in Urban Areas. A Study on Traffic Crashes in the Romanian Cities

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**ABSTRACT**

Road traffic in urban areas is highly prone to the occurrence of road crashes, while crash severity level differs at the city level and in relation to the leading cause. In the case of urban sustainable environments, strategic planning and development measures have been implemented for safer mobility by effective traffic management and road user education. Still, in crowded cities, where mobility and transit traffic are major factors, road crashes are the antithesis of road safety and they occur in simple or complex circumstances mostly related to road users and road infrastructure. The aim of this study was to define the severity level of road traffic crashes in the cities of Romania during the reference period 2008 - 2019, before the COVID-19 pandemic, while highlighting the leading causes of road crashes in urban areas that determine their highest occurrence and severity level. Official crash data records provided by the general Directorate of the Romanian Police were employed. The general severity degree of road crashes was calculated, particularly in relation to the first five leading causes, and cities were ranked accordingly. Results are rendered at the local level, for all 319 cities and towns in Romania, by the five leading causes and by severity level, comparatively for the years 2008 and 2019. Synthetically, we pinpoint the Romanian cities that are most affected by this phenomenon. This could help local and national decision-makers direct their focus towards mitigating the negative effects of the frequent crash triggering factors, decrease road crash severity levels and create customized measures for better traffic management and increased road safety at the local level.

## 1. INTRODUCTION

For the numerous challenges urban road traffic has brought in the last decades due to the increase in the number of vehicles and the number of road users in progressively congested urban areas, both authorities at various levels and international scientific community have put together their efforts to come up with solutions and strategies to address them and diminish their negative effects. The safety and well-being of residents are directly impacted by road safety. By placing a high priority on road safety, the lives and physical well-being of urban road users can be protected. Road safety in urban areas has been approached in terms of strategic and innovative measures to be implemented to improve traffic management, drivers and other road users' behaviour, infrastructure and public transport. Road safety may be directly connected to urban sustainability through proper urban planning and strategic development. Cities need to comply with national and international regulations, standards, and guidelines. By focusing on road safety, cities can ensure adherence to the legal framework, establishing accountability and enhancing governance. Traffic crashes result in injuries, disabilities, and even fatalities. Road safety in cities is a crucial aim for sustainable urban development and for reducing the losses of lives, injuries and damage to

property (Joni et al., 2020), while road crashes with severe effects on the people involved has been a major issue worldwide because the number of traffic fatalities has remained extremely high (WHO, 2018). The identification of the leading causes of road traffic crashes, particularly human–related (depending on driver and other user behaviour) is fundamental for designing measures to increase awareness and improve driving education and eventually enhance road safety (Zotic et al., 2020). Therefore, the need for customized road safety measures and urban mobility strategies to mitigate the impact of road traffic crashes on urban communities remains current (Zotic et al., 2021). Specialists proposed road safety audits as part of road safety management tools, which have been examined to assess their efficiency and depict their challenges and limitations (Giuffrè et al., 2002; Raicu et al., 2014; Jun et al., 2021; Calderón Ramírez et al., 2023). Alam and Tabassum (2023) proposed the use of GIS techniques to find the relation between place topography and other factors and the location of crashes so as to identify and rank crash hotspot areas. Cities are experiencing rapid urbanization and population growth. With more people living and commuting within cities, there is an increased risk of road accidents. Focusing on road safety becomes imperative to cope with the growing number of vehicles and pedestrians. There have been efforts to improve city mobility by bringing up smart solutions and create the foundation for urban sustainable and smart mobility for all road users.

Vulnerable road users like pedestrians, cyclists, children, and the elderly are disproportionately affected by traffic accidents. By prioritizing road safety, cities can ensure that urban infrastructure and transportation systems provide equitable access and safety for all residents. More than half of the global road traffic deaths are amongst vulnerable road users (pedestrians, cyclists and motorcyclists), especially children and young adults, who are still often neglected in road traffic system design in many countries (WHO, 2018). The need for a comprehensive approach that would focus on all road users, including the most vulnerable ones, such as pedestrians, cyclists and motorists is a component of road safety improvement strategy in urban areas, in relation to street design, pedestrian-friendly road infrastructure, assisted road intersections, traffic calming measures and active and green transport - measures. Detailed studies have been conducted on pedestrian safety in urban areas, analysing various factors such as pedestrian behaviour, street design, traffic control measures, and their impacts on pedestrian safety. Findings show recommendations for improving pedestrian safety in urban environments. The design of the roadway and development of different land uses can either increase or reduce pedestrian road traffic injury (Stoker et al., 2015). Designing safe, accessible, and comprehensive facilities for pedestrians is vital to reducing pedestrian crashes because pedestrians are most at risk in urban areas due in part to the large amount of pedestrian and vehicle activity (Zegeer and Bushell, 2010). Planners need to design or modify the built environment to minimize risk for pedestrians (Stoker et al., 2015) and pedestrian preferences and perceptions should be considered when designing efficient and pedestrian friendly facilities and minimize pedestrian–vehicle conflicts (Sisiopiku and Akin, 2003).

Road safety is closely connected to traffic events and their degree of severity, whilst the severity level of road crashes is interrelated with road users' behaviour and traffic conditions (weather-related and infrastructure-related). It is important to reflect on the severity level by analysing the primary causes triggering road crash occurrence.

Recent researches have focused on investigating the circumstances and risk factors for road crash occurrence and severity. Traffic crash severity analyses have been performed to observe the influence of various characteristics related to infrastructure, environment, road users on the severity level of road crashes because it is important to specifically identify the primary or supplementary conditions of the event to be able to provide customized solutions for reducing the frequency of crash occurrence and enhance traffic safety.

The critical features of the vulnerable road users were analysed by measuring the partial dependency of road crash features with the severity levels by employing machine learning-based classification approaches (Komol et al., 2021). While considering different conditions such as lighting, weather, road infrastructure, human factors, vehicle category, and vehicle colour Rodionova et al. (2022) concluded that all kinds of conditions have an impact on the crash severity. Trivedi and Shah (2022) aimed to evaluate the severity of road crashes by considering all types of crashes (i.e., fatal injury, grievous injury, minor injury, and non-injury) and to develop a novel severity ranking approach, by employing the MCDM methods. The study conducted by Bekelcho et al. (2023) aimed to assess injury severity levels induced by road traffic crashes, concluding that the pedestrians share the highest number of severe to fatal crash injuries, mainly in the summer and autumn seasons and crashes occurring in dark light conditions highly contributed to crash injury severity levels compared with crash accidents occurring in good light conditions. Joni et al (2020) employed a logistic model to indicate the three factors affecting severity of collision crashes (site, vehicle body type and crash cause), which could be useful for developing traffic rules in order to reduce the rate of crashes, especially the high-severity ones (Joni et al., 2020). After performing a comprehensive mapping

of the types of inattention that contribute to fatal road crashes Sundfør et al. (2019) concluded that inattention among at-fault drivers of motor vehicles was found to contribute to almost one out of three fatal road crashes in the studies area.

The identification of primary and supplementary crash triggering factors is needed to reducing traffic crash rate and enhance road safety. Factors contributing to crash severity in urban road intersections were investigated by Mussone et al. (2017). Other analyses were conducted to reveal the different effects that could have certain factors such as road, environment, driver behaviour characterizing the accident on its severity by considering the different road crashes (two-vehicle, front/side collision versus rear-end collision and impact with an obstacle) (Eboli et al., 2020; Eboli and Forciniti, 2020). Bhuiyan et al. (2022) identified the significant contributing factors of road crashes by considering three different road crash severity levels (non□fatal, severe, and extremely severe), namely driver characteristics, vehicle characteristics, road characteristics, environmental conditions and injury localization. Using the Classification and Regression Tree (CART) and Chi-square Automatic Interaction Detector (CHAID) techniques, Zamzuri and Qi (2023) identified the main factors that enhance the occurrence of road accidents and their effects and concluded that the main factors that determine the severity of the accident are the type of vehicle, the type of violation, lighting, and severity of the driver's injuries. The relationship between the severity of road crashes and the level of traffic congestion using disaggregated crash records and a measure of traffic congestion while controlling for other contributory factors was investigated by Quddus et al. (2009) and the results suggested that the level of traffic congestion does not affect the severity of road crashes, but factors such as three-lane stretches of the motorway, single-vehicle crash and weekdays result in high severe crashes. A disaggregate model of road accident severity based on sequential logit models was presented by Nassar et al. (1994) to reveal the factors that affect the level of damage experienced by individuals involved in single-vehicle, two-vehicle and multi-vehicle road crashes, namely: accident dynamics, seating position, vehicle condition, vehicle size, driver condition, and driver action. Dissanayake and Roy (2014) employed binary logit models to prove that different driver, vehicle, road, crash, and environment related factors influence crash severity, concluding that run-off-road crashes typically tend to be more severe than other types of crashes. Similarly, Okafor et al. (2023) found that single-vehicle left run-off crashes are more likely to result in severe crashes compared to right single-vehicle left run-off and that male drivers, Driving Under Influence (DUI), motorcycles, and dry road surfaces were significant contributing factors to their severities. Champahom et al. (2023) sought to examine the factors that influence injury severity among young adult motorcyclists on local roads by contrasting urban and rural roadways, under various circumstance, arguing that in developing nations, motorcycles contribute to a substantial frequency of traffic accidents and fatalities, and concluded that speed and behaviour of motorcyclists are influenced by the traffic density and law enforcement. Rifaat and Chin (2010) sought to identify the contributing factors affecting crash severity with broad considerations of driver characteristics, roadway features, vehicle types, pedestrian characteristics and crash characteristics using an ordered probit model. Among the considered factors, vehicle type, road type, collision type, location type, pedestrian age, time of day of accident occurrence were found to be significantly associated with injury severity. Taheri et al. (2022) used the descriptive logit model family to identify what factors influence the severity of crashes on suburban roads in order to reduce the likelihood of occurrence, and argued in favour of using multisource data related to geometric design, time, weather and environmental conditions, land use, traffic features, vehicle characteristics and driver characteristics in defining factors impacting crash severity.

Therefore, by identifying the crash triggering factors, quantifying the frequency and the severity degree of road crashes in urban areas, could help directing the focus towards the most affected areas and creating customized measures in accordance with the particular needs and circumstances.

At the national level, cities are found to have particular traffic conditions and road infrastructure, highly different number of road crashes, yet with various severity degree of crash injuries, while the dominant triggering factors may remain the same. With about 18,000 people involved annually in car crashes, urban areas in Romania have been acknowledged as hotspots of traffic crashes incidence in the period 2008-2019, while the average number of persons involved in car crashes was of about 60 people/city every year (Zotic et al., 2021). The aim of this study was to define the severity level of road traffic crashes in the cities of Romania during the reference period 2008-2019, as an expression of urban mobility safety and sustainability. To achieve this aim, the first objective was to identify and rank the primary causes that determine the highest negative effects in case of crash occurrence and observe the differences between the years 2008 and 2019 in relation to the number of crashes, spatially distributed in urban and rural environments at the national level. Secondly, we proposed to quantify and assess the degree of severity of road traffic crashes occurring in the urban areas in Romania, regardless of their cause, for the end years of the period, in 2008 and 2019. For this, we chose a new perspective for determining the level of security in road traffic and for calculating the

general degree of severity of accidents and particularly in relation with the first five dominant causes determining the high number of crashes in the cities. Then, we proposed to investigate the spatial distribution of urban road crashes determined by the top five causes and by the degrees of crash severity. In the end, we ranked the Romanian cities by the general road crash severity degree, comparatively for the years 2008 and 2019, highlighting the most affected cities by the magnitude of this phenomenon.

## 2. THEORY AND METHODOLOGY

### 2.1. Road safety in the European and national context

In European countries, road safety in urban areas is a major concern, and several policies and regulations are in place to address this issue. In order to increase road safety in their urban areas, member states have benefited greatly from the shared standards and guidelines established by the European Union. European policy for urban road safety includes a range of measures and initiatives aimed at reducing accidents, injuries, and fatalities on urban roads. Because of the substantial impact that road traffic risks have on communities, several road safety initiatives have been launched by the European Union in the last 20 years, containing specific measures intended to enhance road safety and diminish the road crash severity. If the main aim of the 4th Road Safety Programme (2011–2020) was to reduce road mortality in half by 2020 throughout Europe, focusing on increasing vehicle and infrastructure safety and improving road users' behaviour (European Commission, 2010), in the case of the 5th Road Safety Programme (2020–2030) new strategic objectives are added to stimulate the implementation of measures to alleviate discrepancies between the results achieved by the member states, improve road safety initiatives, and lower the number of people who suffer serious injuries in traffic crashes (European Transport Safety Council, 2018). Directives were introduced to enhance EU-wide road safety management (*Directive 2008/96/EC on road infrastructure safety management* further amended by the *Road Traffic Safety Management Directive 2019/1936*): Their purpose was to place a strong emphasis on a data-driven strategy and that member states should gather, evaluate, and create national targets as well as road safety plans (European Parliament, 2008, 2019). The latter directive also consists of actions concerning the safety of urban roads for death and serious injuries in road crashes are largely preventable and argues in favour of shared responsibility by encouraging the development of pedestrian-friendly infrastructure and lowering speed limits in cities (European Parliament, 2019). Furthermore, the goal of the EU's Vision Zero initiative is to completely eradicate fatalities and serious injuries on European roadways by the year 2050 (European Commission, 2021a). Currently, the new EU Urban Mobility Framework aims to promote sustainable urban mobility options, lessen traffic congestion, and increase the safety of cyclists and pedestrians because cities are still faced with the negative consequences of transport for their communities, including traffic congestion and fatalities resulted from highly severe road crashes (European Commission, 2021b). Therefore, as tools for the local authorities, the Sustainable Urban Mobility Plans, initiated in 2013 at the European level, are encouraged to be reformulated and continuously monitored to address the most challenging aspects of urban mobility.

In accordance with the European Zero Vision initiative, in Romania, the new National Strategy for Road Safety for the period 2022-2030 was elaborated and put into action in 2022 with the main aim to decrease the severity degree of road crashes in Romania by 2030 compared to the reference year 2019, namely to reduce fatalities by 50% and the number of seriously injured people by 50% (Government of Romania, 2022). This strategy comes as an updated version of the first National Strategy for Road Safety in Romania for the period 2016-2020 that aimed primarily to decrease the number of fatalities and increase road safety at the national level (Government of Romania, 2016), as it was reflected by the high values of mortality index and road crash severity level recorded in Romania after the year 2003 (General Directorate of the Romanian Police, 2012), further monitored for the next years to observe the trends (General Directorate of the Romanian Police, 2020).

### 2.2. Leading causes for road crashes

Both within and outside cities, road traffic sometimes involves events such as crashes on public and private roads or streets. Crashes occur as a result of an accumulation of factors, of which one, at least, is dominant. Their effects consist of material destruction of the vehicles involved, degradation and destruction of road infrastructure and light or serious injuries or even deaths, as direct consequences for the people involved. These three health-related consequences that affect the road users involved in crashes are the most dramatic, most of the time very difficult or impossible to remedy (in the case of death). In order to observe the size of these effects and to reduce their incidence on roads, it is first necessary to know the magnitude of the phenomenon on a spatial and temporal scale. From a spatial perspective, road crashes are concentrated mainly within the administrative border of settlements, mostly urban, where several favourable conditions for their occurrence are present: agglomeration, high traffic values, pedestrians and vehicles traffic overlapping at

intersections, undersized roadways, large number of inexperienced drivers, reduced traffic discipline, various distractions in traffic etc. This proves that, especially in large urban agglomerations, the safety of road traffic decreases, and the number of crashes and their effects increase. Knowing the size and spatial distribution of the analysed phenomenon, measures can be taken to reduce or eliminate them by means of traffic studies and public policies. In this study, a number of 47 triggering factors for road crashes at the national level were considered; they are related to drivers, vehicles or other road users (Table 1).

Table 1. Leading causes and number of road crashes in Romania in 2008 and 2019.

| No. | Leading cause for road crashes | Road crashes | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2008 | | | | | 2019 | | | | |
| | | Total | Urban | | Rural | | Total | Urban | | Rural | |
| | | | no. | % | no. | % | | no. | % | no. | % |
| 1 | Animals or other objects on the road | - | - | - | - | - | 54 | 10 | 18.52 | 44 | 81.48 |
| 2 | Falling asleep while driving | 147 | 29 | 19.73 | 118 | 80.27 | 225 | 50 | 22.22 | 175 | 77.78 |
| 3 | Offences related to drivers of animal-drawn vehicles | 429 | 88 | 20.51 | 341 | 79.49 | 601 | 68 | 11.31 | 533 | 88.69 |
| 4 | Offences related to drivers of other vehicles | 32 | 8 | 25.00 | 24 | 75.00 | 47 | 2 | 4.26 | 45 | 95.74 |
| 5 | Offences of bike-riders | 854 | 402 | 47.07 | 452 | 52.93 | 2860 | 1209 | 42.27 | 1651 | 57.73 |
| 6 | Offences of road users (passengers, travellers, | - | - | - | - | - | 524 | 472 | 90.08 | 52 | 9.92 |
| 7 | Other offences of pedestrians | 114 | 60 | 52.63 | 54 | 47.37 | 127 | 63 | 49.61 | 64 | 50.39 |
| 8 | Other offences of drivers | 419 | 298 | 71.12 | 121 | 28.88 | 760 | 454 | 59.74 | 306 | 40.26 |
| 9 | Other road-related causes | 19 | 12 | 63.16 | 7 | 36.84 | 11 | 9 | 81.82 | 2 | 18.18 |
| 10 | Other distracting actions | - | - | - | - | - | 633 | 249 | 39.34 | 384 | 60.66 |
| 11 | Wrong-way driving | 489 | 227 | 46.42 | 262 | 53.58 | 247 | 100 | 40.49 | 147 | 59.51 |
| 12 | Driving without a licence | 303 | 107 | 35.31 | 196 | 64.69 | 334 | 78 | 23.35 | 256 | 76.65 |
| 13 | Reckless driving | 1625 | 649 | 39.94 | 976 | 60.06 | - | - | - | - | - |
| 14 | Aggressive driving | - | - | - | - | - | 3 | 2 | 66.67 | 1 | 33.33 |
| 15 | Driving under the influence of alcohol | 622 | 258 | 41.48 | 364 | 58.52 | 761 | 242 | 31.80 | 519 | 68.20 |
| 16 | Driving under the influence of drugs | - | - | - | - | - | 8 | 6 | 75.00 | 2 | 25.00 |
| 17 | Vehicle mechanical failure | 57 | 26 | 45.61 | 31 | 54.39 | 41 | 11 | 26.83 | 30 | 73.17 |
| 18 | Overloaded vehicle | 6 | 2 | 33.33 | 4 | 66.67 | 2 | 1 | 50.00 | 1 | 50.00 |
| 19 | Illegal overtaking | 659 | 270 | 40.97 | 389 | 59.03 | 617 | 202 | 32.74 | 415 | 67.26 |
| 20 | Damaged road or road under construction | 5 | 0 | 0.00 | 5 | 100.00 | 8 | 6 | 75.00 | 2 | 25.00 |
| 21 | Low driving experience | 92 | 32 | 34.78 | 60 | 65.22 | - | - | - | - | - |
| 22 | Inappropriate use of lights or of other signalling means | 2 | 1 | 50.00 | 1 | 50.00 | 1 | 1 | 100.00 | 0 | 0.00 |
| 23 | Children imprudent behaviour (7-14 y.o.) | 532 | 268 | 50.38 | 264 | 49.62 | - | - | - | - | - |
| 24 | Teenagers imprudent behaviour (15-18 y.o.) | 87 | 55 | 63.22 | 32 | 36.78 | - | - | - | - | - |
| 25 | Disabilities or other medical conditions | 9 | 5 | 55.56 | 4 | 44.44 | 24 | 12 | 50.00 | 12 | 50.00 |
| 26 | Improper turning | - | - | - | - | - | 172 | 95 | 55.23 | 77 | 44.77 |
| 27 | Lack of devices for road safety | 4 | 4 | 100.00 | 0 | 0.00 | 3 | 3 | 100.00 | 0 | 0.00 |
| 28 | Failure to give right-of -way to pedestrians | 2678 | 2449 | 91.45 | 229 | 8.55 | 2863 | 2603 | 90.92 | 260 | 9.08 |
| 29 | Failure to give right-of -way to vehicles | 3378 | 2770 | 82.00 | 608 | 18.00 | 3688 | 2796 | 75.81 | 892 | 24.19 |
| 30 | Lack of supervision of children (0-6 years old) | 408 | 195 | 47.79 | 213 | 52.21 | - | - | - | - | - |
| 31 | Lack of supervision of minors | - | - | - | - | - | 51 | 23 | 45.10 | 28 | 54.90 |
| 32 | Reckless driving when changing direction | - | - | - | - | - | 1176 | 746 | 63.44 | 430 | 36.56 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 33 | Reckless driving in reverse | 307 | 226 | 73.62 | 81 | 26.38 | 727 | 490 | 67.40 | 237 | 32.60 |
| 34 | Driver inattention when changing lanes | 1344 | 987 | 73.44 | 357 | 26.56 | 232 | 222 | 95.69 | 10 | 4.31 |
| 35 | Unstable load on vehicle | 23 | 10 | 43.48 | 13 | 56.52 | 8 | 4 | 50.00 | 4 | 50.00 |
| 36 | Not maintaining safe distance between vehicles | 1200 | 835 | 69.58 | 365 | 30.42 | 2283 | 1477 | 64.70 | 806 | 35.30 |
| 37 | Ignoring road warning signs | 58 | 55 | 94.83 | 3 | 5.17 | 43 | 39 | 90.70 | 4 | 9.30 |
| 38 | Ignoring traffic lights | 300 | 298 | 99.33 | 2 | 0.67 | 214 | 214 | 100.00 | 0 | 0.00 |
| 39 | Ignoring rules of railway crossing | 48 | 27 | 56.25 | 21 | 43.75 | 24 | 8 | 33.33 | 16 | 66.67 |
| 40 | Unsignalled obstacle on the road | 13 | 2 | 15.38 | 11 | 84.62 | 5 | 3 | 60.00 | 2 | 40.00 |
| 41 | Illegal stopping or standing the vehicle | 14 | 11 | 78.57 | 3 | 21.43 | 6 | 2 | 33.33 | 4 | 66.67 |
| 42 | Pedestrians on the road | 594 | 256 | 43.10 | 338 | 56.90 | 981 | 492 | 50.15 | 489 | 49.85 |
| 43 | Incomplete road signalling | 9 | 9 | 100.00 | 0 | 0.00 | 15 | 14 | 93.33 | 1 | 6.67 |
| 44 | Jaywalking | 4567 | 3289 | 72.02 | 1281 | 28.05 | 2751 | 1802 | 65.50 | 949 | 34.50 |
| 45 | Inappropriate speed in adverse conditions | 2706 | 1205 | 44.53 | 1501 | 55.47 | 2463 | 1051 | 42.67 | 1412 | 57.33 |
| 46 | Over speeding | 615 | 369 | 60.00 | 246 | 40.00 | 144 | 52 | 36.11 | 92 | 63.89 |
| 47 | Low visibility | 3 | 0 | 0.00 | 3 | 100.00 | - | - | - | - | - |
| **48** | **Total no. of crashes** | **24774** | **15794** | **63.76** | **8980** | **36.25** | **25737** | **15383** | **59.77** | **10390** | **40.37** |

*Source: computed based on data from the General Directorate for Public Safety Police, Traffic Police Directorate*

From this extended list, we can note that, between 2008 and 2019, the number and type of dominant causes changed. For instance, if in 2008 about 39 dominant causes generating crashes were monitored, in 2019 their number increased to 41. Also, if in 2008 the causes associated with the lack of supervision or imprudence of children and teenagers were monitored, in 2019 these three causes were merged into a single one, namely the lack of supervision of minors. Also, several other causes that were monitored in 2008, were excluded in 2019 (reckless driving, low driving experience or low visibility) and new ones were introduced (animals or other obstacles on the road, offences of passengers and accompanying persons, other distractions, aggressive driving, driving under the influence of drugs or alcohol, illegal U-turning, reckless driving when changing direction). Considering all these changes brought to the list of causes causing road crashes, it can be observed that, some of these causes are at the top of the list at the national level, with very high values of the number of resulting road crashes (Table 2).

Table 2. Top ten causes ranked based on the related number of road crashes in 2008 and 2019, at the national level.

| Rank | Leading cause for road crashes | Road crashes | | | | |
|---|---|---|---|---|---|---|
| | | Total | Urban | | Rural | |
| | | | no. | % | no. | % |
| **2008** | | | | | | |
| 1 | Jaywalking | 4567 | 3289 | 72.02 | 1281 | 28.05 |
| 2 | Failure to yield right-of-way to vehicles | 3378 | 2770 | 82.00 | 608 | 18.00 |
| 3 | Inappropriate speed in adverse conditions | 2706 | 1205 | 44.53 | 1501 | 55.47 |
| 4 | Failure to yield right-of-way to pedestrians | 2678 | 2449 | 91.45 | 229 | 8.55 |
| 5 | Reckless driving when changing lanes | 1344 | 987 | 73.44 | 357 | 26.56 |
| 6 | Not maintaining safe distance between vehicles | 1200 | 835 | 69.58 | 365 | 30.42 |
| 7 | Bicycle offences | 854 | 402 | 47.07 | 452 | 52.93 |
| 8 | Illegal overtaking | 659 | 270 | 40.97 | 389 | 59.03 |
| 9 | Driving under the influence of alcohol | 622 | 258 | 41.48 | 364 | 58.52 |
| 10 | Over speeding | 615 | 369 | 60.00 | 246 | 40.00 |
| **2019** | | | | | | |
| 1 | Failure to yield right-of-way to vehicles | 3688 | 2796 | 75.81 | 892 | 24.19 |
| 2 | Failure to yield right-of-way to pedestrians | 2863 | 2603 | 90.92 | 260 | 9.08 |
| 3 | Bicycle offences | 2860 | 1209 | 42.27 | 1651 | 57.73 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 4 | Jaywalking | 2751 | 1802 | 65.50 | 949 | 34.50 |
| 5 | Inappropriate speed in adverse conditions | 2463 | 1051 | 42.67 | 1412 | 57.33 |
| 6 | Not maintaining safe distance between vehicles | 2283 | 1477 | 64.70 | 806 | 35.30 |
| 7 | Driving under the influence of alcohol | 761 | 242 | 31.80 | 519 | 68.20 |
| 8 | Illegal overtaking | 617 | 202 | 32.74 | 415 | 67.26 |
| 9 | Reckless driving when changing lanes | 232 | 222 | 95.69 | 10 | 4.31 |
| 10 | Over speeding | 144 | 52 | 36.11 | 92 | 63.89 |

*Source: computed based on data from the General Directorate for Public Safety Police, Traffic Police Directorate*

According to official data, in 2008, *jaywalking* was the main cause of road crashes in Romania (a total number of 4,576), of which 72% were recorded in urban areas; however, in 2019, this cause was only third in ranking (Table 2). *The failure to give right-of-way to vehicles* is ranked first, as the leading cause for about 3,688 crashes, of which over 75% in urban areas, whilst the *failure to give right-of-way to pedestrians* is ranked second, as the cause for 2,863 crashes, of which over 90% in urban areas. *Reckless bike riding*, which generated some 2,860 road crashes of which 42.67% in urban areas, is ranked third. The ranking showed in Table 2 changes over time as a result of changes in the behaviour of road users as well as due to the improvement of road infrastructure and other traffic conditions. Nevertheless, certain leading causes of road crashes have a higher incidence in the urban than in the extra-urban areas (Table 3). Therefore, the aim of this study to depict the severity degree of road crashes at the city level in Romania is undoubtedly suitable, while the illustration of the spatial distribution of road crashes by the leading cause and severity level for all of the cities in Romania would be a fundamental tool for the decision-makers in their attempts for better urban traffic management.

Table 3. Spatial distribution of road crashes at the county level (urban and rural areas).

| No. | County | Road crashes in 2008 | | | | | Road crashes in 2019 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | County (total) | Urban (total) | | Rural (total) | | County (total) | Urban (total) | | Rural (total) | |
| | | no. | no. | % | no. | % | no. | no. | % | no. | % |
| 1 | Alba | 236 | 135 | 57.20 | 101 | 42.80 | 267 | 164 | 61.42 | 103 | 38.58 |
| 2 | Arad | 344 | 237 | 68.90 | 107 | 31.10 | 402 | 267 | 66.42 | 135 | 33.58 |
| 3 | Argeş | 762 | 284 | 37.27 | 478 | 62.73 | 885 | 404 | 45.65 | 481 | 54.35 |
| 4 | Bacău | 723 | 370 | 51.18 | 353 | 48.82 | 777 | 390 | 50.19 | 387 | 49.81 |
| 5 | Bihor | 481 | 303 | 62.99 | 178 | 37.01 | 415 | 232 | 55.90 | 183 | 44.10 |
| 6 | Bistriţa-Năsăud | 284 | 97 | 34.15 | 187 | 65.85 | 529 | 196 | 37.05 | 333 | 62.95 |
| 7 | Botoşani | 358 | 194 | 54.19 | 164 | 45.81 | 370 | 168 | 45.41 | 202 | 54.59 |
| 8 | Brăila | 247 | 196 | 79.35 | 51 | 20.65 | 256 | 177 | 69.14 | 79 | 30.86 |
| 9 | Braşov | 835 | 652 | 78.08 | 183 | 21.92 | 592 | 477 | 80.57 | 115 | 19.43 |
| 10 | Buzău | 621 | 220 | 35.43 | 401 | 64.57 | 427 | 171 | 40.05 | 256 | 59.95 |
| 11 | Călăraşi | 315 | 132 | 41.90 | 183 | 58.10 | 280 | 108 | 38.57 | 172 | 61.43 |
| 12 | Caraş-Severin | 217 | 153 | 70.51 | 64 | 29.49 | 243 | 158 | 65.02 | 85 | 34.98 |
| 13 | Cluj | 804 | 549 | 68.28 | 255 | 31.72 | 1063 | 705 | 66.32 | 358 | 33.68 |
| 14 | Constanţa | 1102 | 909 | 82.49 | 193 | 17.51 | 849 | 634 | 74.68 | 215 | 25.32 |
| 15 | Covasna | 103 | 56 | 54.37 | 47 | 45.63 | 165 | 81 | 49.09 | 84 | 50.91 |
| 16 | Dâmboviţa | 515 | 180 | 34.95 | 335 | 65.05 | 663 | 216 | 32.58 | 447 | 67.42 |
| 17 | Dolj | 482 | 233 | 48.34 | 249 | 51.66 | 754 | 469 | 62.20 | 285 | 37.80 |
| 18 | Galaţi | 639 | 363 | 56.81 | 276 | 43.19 | 648 | 349 | 53.86 | 299 | 46.14 |
| 19 | Giurgiu | 203 | 72 | 35.47 | 131 | 64.53 | 319 | 96 | 30.09 | 223 | 69.91 |
| 20 | Gorj | 376 | 139 | 36.97 | 237 | 63.03 | 428 | 152 | 35.51 | 276 | 64.49 |
| 21 | Harghita | 286 | 116 | 40.56 | 170 | 59.44 | 323 | 147 | 45.51 | 176 | 54.49 |
| 22 | Hunedoara | 474 | 323 | 68.14 | 151 | 31.86 | 520 | 341 | 65.58 | 179 | 34.42 |
| 23 | Ialomiţa | 199 | 83 | 41.71 | 116 | 58.29 | 268 | 115 | 42.91 | 153 | 57.09 |
| 24 | Iaşi | 879 | 516 | 58.70 | 363 | 41.30 | 1098 | 697 | 63.48 | 401 | 36.52 |
| 25 | Ilfov | 1101 | 469 | 42.60 | 632 | 57.40 | 749 | 314 | 41.92 | 435 | 58.08 |
| 26 | Maramureş | 529 | 306 | 57.84 | 223 | 42.16 | 489 | 258 | 52.76 | 231 | 47.24 |
| 27 | Mehedinţi | 294 | 215 | 73.13 | 79 | 26.87 | 402 | 202 | 50.25 | 200 | 49.75 |
| 28 | Mureş | 380 | 238 | 62.63 | 142 | 37.37 | 752 | 391 | 51.99 | 361 | 48.01 |
| 29 | Neamţ | 503 | 189 | 37.57 | 314 | 62.43 | 624 | 220 | 35.26 | 404 | 64.74 |
| 30 | Olt | 371 | 168 | 45.28 | 203 | 54.72 | 497 | 225 | 45.27 | 272 | 54.73 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 31 | Prahova | 1031 | 454 | 44.03 | 577 | 55.97 | 1034 | 518 | 50.10 | 516 | 49.90 |
| 32 | Sălaj | 260 | 125 | 48.08 | 135 | 51.92 | 252 | 93 | 36.90 | 159 | 63.10 |
| 33 | Satu Mare | 203 | 115 | 56.65 | 88 | 43.35 | 256 | 129 | 50.39 | 127 | 49.61 |
| 34 | Sibiu | 338 | 268 | 79.29 | 70 | 20.71 | 368 | 255 | 69.29 | 113 | 30.71 |
| 35 | Suceava | 767 | 374 | 48.76 | 393 | 51.24 | 974 | 406 | 41.68 | 568 | 58.32 |
| 36 | Teleorman | 439 | 164 | 37.36 | 275 | 62.64 | 366 | 147 | 40.16 | 219 | 59.84 |
| 37 | Timiș | 689 | 525 | 76.20 | 164 | 23.80 | 702 | 520 | 74.07 | 182 | 25.93 |
| 38 | Tulcea | 153 | 98 | 64.05 | 55 | 35.95 | 189 | 137 | 72.49 | 52 | 27.51 |
| 39 | Vâlcea | 560 | 278 | 49.64 | 282 | 50.36 | 623 | 284 | 45.59 | 339 | 54.41 |
| 40 | Vaslui | 274 | 130 | 47.45 | 144 | 52.55 | 585 | 273 | 46.67 | 312 | 53.33 |
| 41 | Vrancea | 390 | 164 | 42.05 | 226 | 57.95 | 371 | 143 | 38.54 | 228 | 61.46 |
| 42 | București | 5010 | 5010 | 100.00 | 0 | 0.00 | 3963 | 3963 | 100.00 | 0 | 0.00 |

*Source: computed based on data from the General Directorate for Public Safety Police, Traffic Police Directorate.*

### 2.3. Road crash severity level

Traffic data provided by the General Directorate for Public Safety Police, Traffic Police Directorate were used in this study. Traffic crash records included daily data on every event occurred on the road for the years 2008 and 2019, at the national level. The database also contained particular information on date, location and conditions of road crash occurrence, vehicles and road users involved, primary cause of occurrence and major effects expressed in three ways: no victims, slightly injured and deceased.

We computed the data on the number of accidents by categories of causes, which were grouped by the most important 32 causes generating road crashes for the years 2008 and 2019. The number of dead, seriously and slightly injured people was extracted for the 32 main causes for every of the 319 urban centres in Romania, for the years 2008 and 2019. The crash severity level was calculated by their main causes, and then weighted according to the equation:

$$G_s = (10 \times n_d) + (5 \times n_{svi}) + (2 \times n_{si}) \quad (1)$$

where:

$G_s$ – severity level of road crashes;

$n_d$ – number of deceased people;

$n_{svi}$ – number of seriously injured people;

$n_{si}$ – number of slightly injured people;

10, 5, 2 – weighting factors of the severity degree.

To weight the values of the severity degree, three weighting factors were set in relation to the severity of road crashes, in terms of their health-related effects on the people involved, without considering other material or financial consequences. As such, crashes involving slightly injured people were weighted by the factor 2, conventionally considering that the effects resulting from such an accident (direct and indirect costs associated with the management of slightly injured people: rescue intervention, general medical investigations, trips to hospital units, recovery treatment, medical leave, etc.) are twice as high as if the accident had no injured persons. Road crashes that involved seriously injured people were weighted by a factor of 5, conventionally considering that the effects resulting from such a crash (direct and indirect costs associated with the management of seriously injured people: rescue intervention, general and specialist medical investigations, hospitalization for a period of at least 10 days, physical and mental recovery treatment, medical leave, acquiring a disability, triggering other health problems, etc.) are five times higher than in the case the crash did not involve injured people. Crashes that ended in deaths were weighted by a factor of 10, conventionally considering that the effects resulting from such an accident (direct and indirect costs associated with the management of deaths: rescue intervention, general and specialized medical investigations, funeral costs, direct and indirect costs associated with the investments made in the deceased person, potential costs generated by the premature exit from the economic production system of the deceased person, etc.) are ten times higher compared to a crash that did not cause any injuries to the people involved.

To calculate the degree of severity of road crashes, absolute values were summed for each cause related to every urban locality. These values vary widely from 0 to ∞, depending on the number of injured people involved. Because the high range of values obtained did not allow for an effective comparative analysis, we transformed them into dimension values using the following equation:

$$G_s = (V_c - V_{min})/(V_{max} - V_{min}) \quad (2)$$

where:

$G_s$ – severity level of road crashes;

$V_c$ – the actual value;

$V_{max}$ – the maximum value within the statistical series;

$V_{min}$ – the minimum value within the statistical series.

After transforming the actual values into dimension values, we obtained indices with values on a scale of 0 to 1, whilst in extraordinary cases, values above the maximum 1 were obtained.

In order to rank the crash severity degree, the following classes of values were used: 0.000 – 0.100 – very low degree of severity; 0.101 – 0.200 – low degree of severity; 0.201 – 0.300 – low-medium degree of severity; 0.301 – 0.400 – medium degree of severity; 0.401 – 0.500 – medium-high degree of severity; 0.501 – 0.750 – high degree of severity; 0.751 – 1.000 – very high degree of severity; > 1.000 – exceptional degree of severity.

To enhance the perception on the intensity of the severity degree of road crashes, several colour shades were used in tables (Table 4). The same value classes were used to map the spatial distribution of severity degree of road crashes by the leading causes. Maps were created using ArcGis 8.2. software.

Table 4. Relation between value classes, intensity and colour shade assigned to every degree of road crash severity.

| | | | | | |
|---|---|---|---|---|---|
| | > 1.000 | Exceptional | | 0.401-0.600 | Medium |
| | 0.801-1.000 | Very high | | 0.201-0.400 | Low |
| | 0.601-0.800 | High | | 0.000-0.200 | Very low |

## 3. RESULTS AND DISCUSSION

The results obtained on the severity degree of road crashes were analysed at the city level in Romania. Cities were grouped by rank, according to the criteria provisioned by the Law 351 of July 6, 2001 (Romanian Parliament, 2001). According to this law, urban areas in Romania are ranked as follows: a) rank 0 – the capital city of Romania, city of European importance; b) rank 1 - city of national importance, with potential influence at the European level; c) rank 2 - city of inter-county or county importance, or with a balancing role in the network of localities; d) rank 3 - town.

### 3.1. Road crash severity degree at the city level

There are 11 rank 1 cities in Romania and, along with Bucharest, the capital city (rank 0), appear to be most affected by road traffic insecurity in terms of number of road crashes recorded and their severity degree (Table 5).

Bucharest recorded, by far, the highest severity degree of road crashes, with calculated values about 7 times higher than the value of the next ranked city in the hierarchy in 2008 and about 6 times higher in 2019. These extreme severity values are determined by the high number of vehicles in traffic, the very great values of both road and pedestrian traffic and most importantly, the lack of adaptation of the capacity of the road infrastructure to the continuously increasing traffic values. The small number of uneven intersections on the major roads, both within the city and especially at the exits, the low capacity and the precarious technical conditions of the current bypass (DJ 503), with the traffic capacity similar to that of a county road, the lack of a complete urban ring road, the small number of roundabouts or pedestrian underpasses, the insufficiency of parking spaces within the city, as well as Park and Rides on the outskirts of the city are the major causes for the dense traffic in the capital city, which generate these exceptional values of the severity degree of road crashes. This state of facts makes Bucharest the most unsafe city for traffic, and the place where the probability of road crashes resulting in material damage and casualties is the highest in Romania.

Table 5. Road crash severity degree calculated for rank 0 and rank 1 cities in Romania, in 2008 and 2019.

| No. | City | County | Severity degree | | No. | City | County | Severity degree | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 2008 | 2019 | | | | 2008 | 2019 |
| 1 | Bacău | Bacău | 0.059 | 0.246 | 7 | Craiova | Dolj | 0.000 | 0.540 |
| 2 | Oradea | Bihor | 0.105 | 0.030 | 8 | Galaţi | Galaţi | 0.234 | 0.317 |
| 3 | Brăila | Brăila | 0.001 | 0.000 | 9 | Iaşi | Iaşi | 0.507 | 1.000 |
| 4 | Braşov | Braşov | 0.805 | 0.505 | 10 | Ploieşti | Prahova | 0.096 | 0.365 |
| 5 | Cluj-Napoca | Cluj | 0.631 | 0.934 | 11 | Timişoara | Timiş | 0.585 | 0.599 |
| 6 | Constanţa | Constanţa | 1.000 | 0.541 | 12 | Bucureşti | Bucureşti | 7.246 | 5.931 |

All along, rank 1 cities recorded different severity degrees of road crashes. The values of this indicator vary between very low and very high, yet showing a general decrease tendency between 2008 and 2019. Accordingly, five out of the 11 cities of this rank recorded a very low severity degree of road crashes in 2008, compared to 2019, when only two of them maintained such values. This proves that even those cities that recorded low crash severity level in 2008 (Craiova, Brăila, Bacău, Ploieşti, Oradea) were impacted by the behavioural changes in traffic, leading to an increase in crash severity; thus, in 2019, only Brăila and Oradea still had very low severity degrees of road crashes; in opposition, we find the cities with high and very high severity degree of road crashes, including the regional urban poles of economic growth (Braşov, Constanţa, Cluj, and Iaşi). Accordingly, if in 2008 the highest degree of severity of road crashes was recorded in Constanţa, followed by Braşov and Cluj-Napoca, in 2019 the situation changed significantly, the city of Iaşi recording the highest severity degree of road crashes, followed by Cluj-Napoca, while Braşov and Constanţa regressed towards average severity values. This change in values is due, on the one hand, to the traffic improvement measures taken in the cities of Braşov and Constanţa, through the completion of bypass in the case

of Braşov and the A4 highway (Constanţa), which primarily eliminated transit traffic within the urban area, which was was a contributing factor for the very high number of road crashes. The city of Iaşi still has not completed the works on such bypasses, even up to now, a fact that is reflected in the increase to the maximum degree of severity, so that this is the urban area with the highest crash severity degree in Romania, after Bucharest. On the other hand, in line with the increase in economic investments and the intensification of traffic on the east-west direction, in 2019, Cluj-Napoca was ranked the third urban area in Romania in terms of crash severity, even if investments are made in the construction of bypasses but not having a complete ring road (in 2019, only the east bypass Vâlcele - Apahida with technical features of national road (DN 1N), was in operation).

Rank 2 cities also recorded different road crash severity degrees and the particular values calculated for each of the 92 cities in this category are shown Table 6.

Table 6. Road crash severity degree calculated for the rank 2 cities in Romania, in 2008 and 2019.

| No. | City | County | Severity degree | | No. | City | County | Severity degree | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 2008 | 2019 | | | | 2008 | 2019 |
| 1 | Aiud | Alba | 0.058 | 0.071 | 47 | Topliţa | Harghita | 0.123 | 0.090 |
| 2 | Alba Iulia | Alba | 0.370 | 0.325 | 48 | Brad | Hunedoara | 0.128 | 0.009 |
| 3 | Blaj | Alba | 0.030 | 0.000 | 49 | Deva | Hunedoara | 0.632 | 0.327 |
| 4 | Sebeş | Alba | 0.105 | 0.090 | 50 | Hunedoara | Hunedoara | 0.358 | 0.217 |
| 5 | Arad | Arad | 1.000 | 0.742 | 51 | Orăştie | Hunedoara | 0.105 | 0.091 |
| 6 | Câmpulung | Argeş | 0.135 | 0.092 | 52 | Petroşani | Hunedoara | 0.217 | 0.338 |
| 7 | Curtea de Arges | Argeş | 0.126 | 0.112 | 53 | Lupeni | Hunedoara | 0.069 | 0.045 |
| 8 | Piteşti | Argeş | 0.845 | 0.953 | 54 | Feteşti | Ialomiţa | 0.167 | 0.037 |
| 9 | Oneşti | Bacău | 0.174 | 0.213 | 55 | Slobozia | Ialomiţa | 0.089 | 0.169 |
| 10 | Moineşti | Bacău | 0.165 | 0.066 | 56 | Urziceni | Ialomiţa | 0.051 | 0.064 |
| 11 | Beiuş | Bihor | 0.039 | 0.022 | 57 | Paşcani | Iaşi | 0.150 | 0.131 |
| 12 | Marghita | Bihor | 0.032 | 0.033 | 58 | Baia Mare | Maramures | 0.903 | 0.469 |
| 13 | Salonta | Bihor | 0.082 | 0.046 | 59 | Sighetu Marmaţiei | Maramureş | 0.235 | 0.252 |
| 14 | Bistriţa | Bistriţa-Năsăud | 0.432 | 0.461 | 60 | Drobeta Tr. Severin | Mehedinţi | 0.857 | 0.697 |
| 15 | Botoşani | Botoşani | 0.653 | 0.462 | 61 | Orşova | Mehedinţi | 0.070 | 0.048 |
| 16 | Dorohoi | Botoşani | 0.101 | 0.080 | 62 | Reghin | Mureş | 0.140 | 0.121 |
| 17 | Flămânzi | Botoşani | 0.013 | 0.041 | 63 | Sighişoara | Mureş | 0.157 | 0.178 |
| 18 | Săveni | Botoşani | 0.000 | 0.009 | 64 | Târgu Mureş | Mureş | 0.636 | 1.000 |
| 19 | Codlea | Braşov | 0.076 | 0.088 | 65 | Târnăveni | Mureş | 0.024 | 0.025 |
| 20 | Făgăraş | Braşov | 0.107 | 0.103 | 66 | Piatra-Neamţ | Neamţ | 0.497 | 0.388 |
| 21 | Săcele | Braşov | 0.130 | 0.025 | 67 | Roman | Neamţ | 0.300 | 0.193 |
| 22 | Buzău | Buzău | 0.599 | 0.401 | 68 | Caracal | Olt | 0.059 | 0.171 |
| 23 | Râmnicu Sărat | Buzău | 0.186 | 0.180 | 69 | Slatina | Olt | 0.286 | 0.327 |
| 24 | Călăraşi | Călăraşi | 0.437 | 0.263 | 70 | Câmpina | Prahova | 0.175 | 0.116 |
| 25 | Oltenita | Călăraşi | 0.128 | 0.084 | 71 | Zalău | Sălaj | 0.445 | 0.322 |
| 26 | Caransebeş | Caraş-Severin | 0.088 | 0.086 | 72 | Carei | Satu-Mare | 0.065 | 0.092 |
| 27 | Reşiţa | Caraş-Severin | 0.355 | 0.363 | 73 | Satu Mare | Satu-Mare | 0.417 | 0.310 |
| 28 | Câmpia Turzii | Cluj | 0.139 | 0.046 | 74 | Mediaş | Sibiu | 0.286 | 0.166 |
| 29 | Dej | Cluj | 0.225 | 0.206 | 75 | Sibiu | Sibiu | 0.837 | 0.671 |
| 30 | Gherla | Cluj | 0.103 | 0.053 | 76 | Câmpulung Moldovenesc | Suceava | 0.173 | 0.106 |
| 31 | Turda | Cluj | 0.238 | 0.189 | 77 | Fălticeni | Suceava | 0.132 | 0.081 |
| 32 | Mangalia | Constanţa | 0.112 | 0.064 | 78 | Rădăuţi | Suceava | 0.212 | 0.196 |
| 33 | Medgidia | Constanţa | 0.157 | 0.147 | 79 | Suceava | Suceava | 0.837 | 0.478 |
| 34 | Sfântu Gheorghe | Covasna | 0.163 | 0.228 | 80 | Vatra Dornei | Suceava | 0.104 | 0.035 |
| 35 | Târgu Secuiesc | Covasna | 0.059 | 0.039 | 81 | Alexandria | Teleorman | 0.344 | 0.178 |
| 36 | Târgovişte | Dâmboviţa | 0.493 | 0.393 | 82 | Roşiori de Vede | Teleorman | 0.117 | 0.111 |
| 37 | Moreni | Dâmboviţa | 0.028 | 0.040 | 83 | Turnu Măgurele | Teleorman | 0.074 | 0.034 |
| 38 | Calafat | Dolj | 0.055 | 0.032 | 84 | Lugoj | Timiş | 0.220 | 0.112 |
| 39 | Băileşti | Dolj | 0.043 | 0.101 | 85 | Tulcea | Tulcea | 0.251 | 0.404 |
| 40 | Tecuci | Galaţi | 0.213 | 0.165 | 86 | Drăgăşani | Vâlcea | 0.082 | 0.131 |
| 41 | Giurgiu | Giurgiu | 0.306 | 0.274 | 87 | Râmnicu Vâlcea | Vâlcea | 0.928 | 0.584 |
| 42 | Motru | Gorj | 0.050 | 0.024 | 88 | Bârlad | Vaslui | 0.278 | 0.323 |
| 43 | Târgu Jiu | Gorj | 0.377 | 0.407 | 89 | Huşi | Vaslui | 0.116 | 0.110 |
| 44 | Miercurea Ciuc | Harghita | 0.170 | 0.138 | 90 | Vaslui | Vaslui | 0.232 | 0.330 |
| 45 | Odorheiu Secuiesc | Harghita | 0.159 | 0.125 | 91 | Adjud | Vrancea | 0.117 | 0.071 |
| 46 | Gheorgheni | Harghita | 0.026 | 0.037 | 92 | Focşani | Vrancea | 0.553 | 0.399 |

Still it should be noted that a large share of these cities recorded a very low degree of road crash severity, namely 59.78% in 2008 and about 65.21% in 2019. The increase in the number of urban areas with a very low crash severity degree is a positive aspect explained by the general trend of improving traffic conditions in more and more medium-size cities. However, there were ten urban areas with high and very

high values of road crash severity degree in 2008 (Arad, Râmnicu Vâlcea, Baia Mare, Drobeta Turnu Severin, Piteşti, Sibiu, Suceava, Botoşani, Târgu-Mureş, and Deva), only five of which remaining in this category in 2019 (Târgu-Mureş, Piteşti, Arad, Drobeta Turnu Severin, Sibiu). The general trend that can be observed is that of a reduction in the degree of severity against the background of the improvement of the general traffic conditions and the increase in the quality of the road infrastructure. Certain urban areas, however, remain hotspots of the severity of road crashes and require rapid reduction measures, among which, the most expected are bypasses and the construction of highway sectors that would eliminate transit traffic (e.g. Râmnicu Vâlcea, Piteşti, Târgu Mureş, and Arad). The road crash severity degree calculated for the rank 3 cities in Romania is presented in Table 7. Rank 3 cities (towns) also recorded different levels of road crash severity, most of them very low, both in 2008 (85.11%) and in 2019 (73.95%). There are however, certain towns that recorded a negative change in the values of the severity index in 2019 compared to 2019. This increase in the degree of severity of road crashes is a direct negative consequence of the general trend of continuously increasing traffic intensity in more and more small towns and their inability to improve the quality of road infrastructure, most of the times explained by the lack of funds.

Table 7. Road crash severity degree calculated for the rank 3 cities in Romania, in 2008 and 2019.

| No. | City | County | Severity degree | | No. | City | County | Severity degree | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 2008 | 2019 | | | | 2008 | 2019 |
| 1 | Abrud | Alba | 0.010 | 0.053 | 109 | Podu Iloaiei | Iaşi | 0.128 | 0.342 |
| 2 | Baia de Arieş | Alba | 0.034 | 0.008 | 110 | Târgu Frumos | Iaşi | 0.247 | 0.300 |
| 3 | Câmpeni | Alba | 0.068 | 0.023 | 111 | Bragadiru | Ilfov | 1.000 | 0.490 |
| 4 | Cugir | Alba | 0.146 | 0.095 | 112 | Buftea | Ilfov | 0.534 | 0.521 |
| 5 | Ocna Mureş | Alba | 0.029 | 0.087 | 113 | Chitila | Ilfov | 0.281 | 0.376 |
| 6 | Teiuş | Alba | 0.018 | 0.038 | 114 | Măgurele | Ilfov | 0.398 | 0.133 |
| 7 | Zlatna | Alba | 0.068 | 0.057 | 115 | Otopeni | Ilfov | 0.568 | 0.536 |
| 8 | Chişineu-Criş | Arad | 0.036 | 0.106 | 116 | Pantelimon | Ilfov | 0.740 | 0.582 |
| 9 | Curtici | Arad | 0.023 | 0.038 | 117 | Popeşti Leordeni | Ilfov | 0.719 | 0.563 |
| 10 | Ineu | Arad | 0.036 | 0.057 | 118 | Voluntari | Ilfov | 0.940 | 1.000 |
| 11 | Lipova | Arad | 0.063 | 0.388 | 119 | Baia Sprie | Maramureş | 0.190 | 0.278 |
| 12 | Nădlac | Arad | 0.102 | 0.072 | 120 | Borşa | Maramureş | 0.432 | 0.380 |
| 13 | Pâncota | Arad | 0.005 | 0.015 | 121 | Cavnic | Maramureş | 0.091 | 0.030 |
| 14 | Pecica | Arad | 0.089 | 0.106 | 122 | Dragomireşti | Maramureş | 0.031 | 0.015 |
| 15 | Sântana | Arad | 0.036 | 0.076 | 123 | Săliştea de Sus | Maramureş | 0.016 | 0.046 |
| 16 | Sebiş | Arad | 0.013 | 0.057 | 124 | Seini | Maramureş | 0.029 | 0.091 |
| 17 | Costeşti | Argeş | 0.112 | 0.160 | 125 | Şomcuta Mare | Maramureş | 0.055 | 0.095 |
| 18 | Mioveni | Argeş | 0.518 | 0.373 | 126 | Târgu Lăpus | Maramureş | 0.057 | 0.110 |
| 19 | Ştefăneşti | Argeş | 0.083 | 0.205 | 127 | Tăuţii-Măgherăuş | Maramureş | 0.073 | 0.065 |
| 20 | Topoloveni | Argeş | 0.138 | 0.087 | 128 | Ulmeni | Maramureş | 0.013 | 0.008 |
| 21 | Buhuşi | Bacău | 0.320 | 0.148 | 129 | Vişeu de Sus | Maramureş | 0.042 | 0.179 |
| 22 | Comăneşti | Bacău | 0.370 | 0.392 | 130 | Baia de Aramă | Mehedinţi | 0.034 | 0.034 |
| 23 | Dărmăneşti | Bacău | 0.242 | 0.198 | 131 | Strehaia | Mehedinţi | 0.096 | 0.236 |
| 24 | Slănic-Moldova | Bacău | 0.023 | 0.084 | 132 | Vânju Mare | Mehedinţi | 0.115 | 0.023 |
| 25 | Târgu Ocna | Bacău | 0.245 | 0.247 | 133 | Iernut | Mureş | 0.117 | 0.186 |
| 26 | Aleşd | Bihor | 0.065 | 0.114 | 134 | Luduş | Mureş | 0.063 | 0.152 |
| 27 | Nucet | Bihor | 0.010 | 0.019 | 135 | Miercurea Nirajului | Mureş | 0.000 | 0.046 |
| 28 | Săcueni | Bihor | 0.034 | 0.084 | 136 | Sângeorgiu de Pădure | Mureş | 0.026 | 0.080 |
| 29 | Ştei | Bihor | 0.044 | 0.042 | 137 | Sărmaşu | Mureş | 0.026 | 0.049 |
| 30 | Valea lui Mihai | Bihor | 0.042 | 0.167 | 138 | Sovata | Mureş | 0.047 | 0.133 |
| 31 | Vaşcău | Bihor | 0.005 | 0.015 | 139 | Ungheni | Mureş | 0.078 | 0.103 |
| 32 | Beclean | Bistriţa-Năsăud | 0.109 | 0.266 | 140 | Bicaz | Neamţ | 0.221 | 0.300 |
| 33 | Năsăud | Bistriţa-Năsăud | 0.086 | 0.380 | 141 | Roznov | Neamţ | 0.307 | 0.289 |
| 34 | Sângeorz-Băi | Bistriţa-Năsăud | 0.078 | 0.148 | 142 | Târgu Neamţ | Neamţ | 0.224 | 0.548 |
| 35 | Bucecea | Botoşani | 0.005 | 0.046 | 143 | Balş | Olt | 0.214 | 0.536 |
| 36 | Darabani | Botoşani | 0.010 | 0.118 | 144 | Corabia | Olt | 0.180 | 0.331 |
| 37 | Ştefăneşti | Botoşani | 0.005 | 0.027 | 145 | Draganeşti-Olt | Olt | 0.128 | 0.156 |
| 38 | Însurăţei | Brăila | 0.091 | 0.015 | 146 | Piatra-Olt | Olt | 0.076 | 0.099 |
| 39 | Făurei | Brăila | 0.049 | 0.042 | 147 | Potcoava | Olt | 0.034 | 0.084 |
| 40 | Ianca | Brăila | 0.188 | 0.080 | 148 | Scorniceşti | Olt | 0.203 | 0.205 |
| 41 | Ghimbav | Braşov | 0.135 | 0.129 | 149 | Azuga | Prahova | 0.180 | 0.076 |
| 42 | Predeal | Braşov | 0.273 | 0.099 | 150 | Băicoi | Prahova | 0.117 | 0.300 |
| 43 | Râşnov | Braşov | 0.271 | 0.148 | 151 | Boldeşti-Scăeni | Prahova | 0.294 | 0.224 |
| 44 | Rupea | Braşov | 0.120 | 0.042 | 152 | Breaza | Prahova | 0.128 | 0.270 |
| 45 | Victoria | Braşov | 0.036 | 0.015 | 153 | Buşteni | Prahova | 0.112 | 0.148 |
| 46 | Zărneşti | Braşov | 0.237 | 0.236 | 154 | Comarnic | Prahova | 0.307 | 0.266 |
| 47 | Nehoiu | Buzău | 0.052 | 0.030 | 155 | Mizil | Prahova | 0.135 | 0.217 |
| 48 | Pătârlagele | Buzău | 0.107 | 0.030 | 156 | Plopeni | Prahova | 0.115 | 0.057 |
| 49 | Pogoanele | Buzău | 0.128 | 0.030 | 157 | Sinaia | Prahova | 0.344 | 0.388 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 50 | Budeşti | Călăraşi | 0.057 | 0.015 | 158 | Slănic | Prahova | 0.115 | 0.042 |
| 51 | Fundulea | Călăraşi | 0.172 | 0.046 | 159 | Urlaţi | Prahova | 0.104 | 0.171 |
| 52 | Lehliu-Gară | Călăraşi | 0.130 | 0.179 | 160 | Vălenii de Munte | Prahova | 0.156 | 0.243 |
| 53 | Anina | Caraş-Severin | 0.115 | 0.080 | 161 | Cehu Silvaniei | Sălaj | 0.083 | 0.015 |
| 54 | Băile Herculane | Caraş-Severin | 0.057 | 0.030 | 162 | Jibou | Sălaj | 0.120 | 0.110 |
| 55 | Bocşa | Caraş-Severin | 0.188 | 0.167 | 163 | Şimleu Silvaniei | Sălaj | 0.242 | 0.156 |
| 56 | Moldova Nouă | Caraş-Severin | 0.029 | 0.046 | 164 | Ardud | Satu-Mare | 0.156 | 0.072 |
| 57 | Oraviţa | Caraş-Severin | 0.078 | 0.118 | 165 | Livada | Satu-Mare | 0.138 | 0.042 |
| 58 | Oţelu Roşu | Caraş-Severin | 0.190 | 0.175 | 166 | Negresti-Oaş | Satu-Mare | 0.161 | 0.274 |
| 59 | Huedin | Cluj | 0.099 | 0.152 | 167 | Tăşnad | Satu-Mare | 0.044 | 0.061 |
| 60 | Cernavoda | Constanţa | 0.154 | 0.144 | 168 | Agnita | Sibiu | 0.052 | 0.084 |
| 61 | Eforie | Constanţa | 0.000 | 0.015 | 169 | Avrig | Sibiu | 0.023 | 0.038 |
| 62 | Hârsova | Constanţa | 0.083 | 0.137 | 170 | Cisnădie | Sibiu | 0.086 | 0.232 |
| 63 | Murfatlar | Constanţa | 0.143 | 0.106 | 171 | Copşa Mică | Sibiu | 0.133 | 0.038 |
| 64 | Năvodari | Constanţa | 0.065 | 0.232 | 172 | Dumbrăveni | Sibiu | 0.055 | 0.030 |
| 65 | Negru Vodă | Constanţa | 0.013 | 0.091 | 173 | Miercurea Sibiului | Sibiu | 0.083 | 0.000 |
| 66 | Ovidiu | Constanţa | 0.107 | 0.152 | 174 | Ocna Sibiului | Sibiu | 0.026 | 0.015 |
| 67 | Techirghiol | Constanţa | 0.005 | 0.068 | 175 | Săliște | Sibiu | 0.065 | 0.042 |
| 68 | Întorsura Buzăului | Covasna | 0.083 | 0.129 | 176 | Tălmaciu | Sibiu | 0.063 | 0.046 |
| 69 | Baraolt | Covasna | 0.036 | 0.027 | 177 | Broşteni | Suceava | 0.076 | 0.110 |
| 70 | Covasna | Covasna | 0.029 | 0.095 | 178 | Cajvana | Suceava | 0.159 | 0.114 |
| 71 | Fieni | Dâmboviţa | 0.107 | 0.049 | 179 | Dolhasca | Suceava | 0.115 | 0.087 |
| 72 | Găeşti | Dâmboviţa | 0.146 | 0.300 | 180 | Frasin | Suceava | 0.117 | 0.087 |
| 73 | Pucioasa | Dâmboviţa | 0.143 | 0.308 | 181 | Gura Humorului | Suceava | 0.177 | 0.544 |
| 74 | Răcari | Dâmboviţa | 0.102 | 0.106 | 182 | Liteni | Suceava | 0.042 | 0.087 |
| 75 | Titu | Dâmboviţa | 0.083 | 0.213 | 183 | Milişăuţi | Suceava | 0.081 | 0.209 |
| 76 | Bechet | Dolj | 0.031 | 0.076 | 184 | Salcea | Suceava | 0.029 | 0.205 |
| 77 | Dăbuleni | Dolj | 0.052 | 0.236 | 185 | Siret | Suceava | 0.086 | 0.106 |
| 78 | Filiaşi | Dolj | 0.237 | 0.384 | 186 | Solca | Suceava | 0.000 | 0.053 |
| 79 | Segarcea | Dolj | 0.005 | 0.061 | 187 | Vicovu de Sus | Suceava | 0.182 | 0.338 |
| 80 | Bereşti | Galaţi | 0.005 | 0.061 | 188 | Videle | Teleorman | 0.076 | 0.186 |
| 81 | Târgu Bujor | Galaţi | 0.010 | 0.034 | 189 | Zimnicea | Teleorman | 0.151 | 0.144 |
| 82 | Bolintin-Vale | Giurgiu | 0.065 | 0.129 | 190 | Buziaş | Timiş | 0.005 | 0.049 |
| 83 | Mihăileşti | Giurgiu | 0.076 | 0.023 | 191 | Ciacova | Timiş | 0.005 | 0.000 |
| 84 | Bumbeşti-Jiu | Gorj | 0.029 | 0.118 | 192 | Deta | Timiş | 0.128 | 0.000 |
| 85 | Novaci | Gorj | 0.042 | 0.266 | 193 | Făget | Timiş | 0.047 | 0.023 |
| 86 | Rovinari | Gorj | 0.063 | 0.099 | 194 | Gătaia | Timiş | 0.055 | 0.038 |
| 87 | Târgu Cărbuneşti | Gorj | 0.026 | 0.118 | 195 | Jimbolia | Timiş | 0.115 | 0.072 |
| 88 | Ţicleni | Gorj | 0.083 | 0.038 | 196 | Recaş | Timiş | 0.026 | 0.133 |
| 89 | Tismana | Gorj | 0.021 | 0.046 | 197 | Sânnicolau Mare | Timiş | 0.115 | 0.122 |
| 90 | Turceni | Gorj | 0.000 | 0.030 | 198 | Babadag | Tulcea | 0.031 | 0.053 |
| 91 | Băile Tuşnad | Harghita | 0.000 | 0.042 | 199 | Isaccea | Tulcea | 0.034 | 0.046 |
| 92 | Bălan | Harghita | 0.005 | 0.049 | 200 | Măcin | Tulcea | 0.068 | 0.068 |
| 93 | Borsec | Harghita | 0.036 | 0.095 | 201 | Sulina | Tulcea | 0.000 | 0.008 |
| 94 | Cristuru Secuiesc | Harghita | 0.099 | 0.179 | 202 | Băbeni | Vâlcea | 0.216 | 0.152 |
| 95 | Vlăhiţa | Harghita | 0.036 | 0.141 | 203 | Băile Govora | Vâlcea | 0.000 | 0.209 |
| 96 | Aninoasa | Hunedoara | 0.055 | 0.202 | 204 | Băile Olăneşti | Vâlcea | 0.010 | 0.163 |
| 97 | Călan | Hunedoara | 0.070 | 0.163 | 205 | Bălceşti | Vâlcea | 0.068 | 0.103 |
| 98 | Geoagiu | Hunedoara | 0.057 | 0.023 | 206 | Berbeşti | Vâlcea | 0.034 | 0.110 |
| 99 | Haţeg | Hunedoara | 0.091 | 0.373 | 207 | Brezoi | Vâlcea | 0.135 | 0.338 |
| 100 | Petrila | Hunedoara | 0.091 | 0.232 | 208 | Călimăneşti | Vâlcea | 0.331 | 0.468 |
| 101 | Simeria | Hunedoara | 0.201 | 0.144 | 209 | Horezu | Vâlcea | 0.120 | 0.270 |
| 102 | Uricani | Hunedoara | 0.049 | 0.072 | 210 | Ocnele Mari | Vâlcea | 0.016 | 0.008 |
| 103 | Vulcan | Hunedoara | 0.185 | 0.586 | 211 | Murgeni | Vaslui | 0.026 | 0.065 |
| 104 | Amara | Ialomiţa | 0.070 | 0.061 | 212 | Negresti | Vaslui | 0.078 | 0.232 |
| 105 | Căzăneşti | Ialomiţa | 0.000 | 0.061 | 213 | Mărăşeşti | Vrancea | 0.029 | 0.224 |
| 106 | Fierbinţi-Târg | Ialomiţa | 0.042 | 0.087 | 214 | Odobeşti | Vrancea | 0.102 | 0.118 |
| 107 | Ţăndărei | Ialomiţa | 0.143 | 0.190 | 215 | Panciu | Vrancea | 0.201 | 0.106 |
| 108 | Hârlau | Iaşi | 0.156 | 0.198 | | | | | |

Thus, among the urban areas with high and very high values of the severity degree of road crashes, in 2008, we find the four towns surrounding the capital city (Bragadiru, Voluntari, Popeşti Leordeni and Pantelimon with a high and very high degree of severity, the city of Bragadiru with the highest value. In 2019 however, only the town of Voluntari maintained the highest road crash severity degree. The general trend in decreasing the severity degree proves the positive effects of the improvement of the general traffic conditions and the increase in the quality of the road infrastructure. Still, some urban areas remain prone to the high level of road crash severity and require rapid measures incidence reduction, among which, the most needed are the bypasses or highway sectors to reduce transit traffic (e.g. in the cities of Ilfov county). We can

therefore conclude that there is a close relationship between the severity degree of road crashes and the rank of cities. Thus, if in the case of rank 0 and 1 cities, the severity degree of road crashes is predominantly average, high, very high and exceptional, in the case of rank 2 and 3 cities, the very low and low crash severity degree is predominant (Table 8).

Table 8. General crash severity degree at the city level in Romania.

| No. | City rank | Year | Severity degree | | | | | | | | | | | | Total no. of cities |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Very low | | Low | | Medium | | High | | Very high | | Exceptional | | |
| | | | 0,000–0,200 | | 0,201–0,400 | | 0,401–0,600 | | 0,601–0,800 | | 0,801–1,000 | | > 1.000 | | |
| | | | no. | % | no. | % | no. | % | no. | % | no. | % | no. | % | |
| 1 | 0 | 2008 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 1 | 100.00 | 1 |
| 2 | 0 | 2019 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 0 | 0.00 | 1 | 100.00 | 1 |
| 3 | 1 | 2008 | 5 | 45.45 | 1 | 9.09 | 2 | 18.18 | 1 | 9.09 | 2 | 18.18 | 0 | 0.00 | 11 |
| 4 | 1 | 2019 | 2 | 18.18 | 3 | 27.27 | 4 | 36.36 | 0 | 0.00 | 2 | 18.18 | 0 | 0.00 | 11 |
| 5 | 2 | 2008 | 55 | 59.78 | 19 | 20.65 | 8 | 8.70 | 3 | 3.26 | 7 | 7.61 | 0 | 0.00 | 92 |
| 6 | 2 | 2019 | 60 | 65.22 | 19 | 20.65 | 8 | 8.70 | 3 | 3.26 | 2 | 2.17 | 0 | 0.00 | 92 |
| 7 | 3 | 2008 | 183 | 85.12 | 24 | 11.16 | 4 | 1.86 | 2 | 0.93 | 2 | 0.93 | 0 | 0.00 | 215 |
| 8 | 3 | 2019 | 159 | 73.95 | 45 | 20.93 | 10 | 4.65 | 0 | 0.00 | 1 | 0.47 | 0 | 0.00 | 215 |
| Total | | 2008 | 243 | 76.18 | 44 | 13.79 | 14 | 4.39 | 6 | 1.88 | 11 | 3.45 | 1 | 0.31 | 319 |
| | | 2019 | 221 | 69.28 | 67 | 21.00 | 22 | 6.90 | 3 | 0.94 | 5 | 1.57 | 1 | 0.31 | 319 |

This means that, if in the case of large urban centres the pace of urban development cannot keep up with the increase in the number of vehicles and road users and the existing road infrastructure is undersized, insufficient and unable to meet the traffic needs, in the case of medium-size and small cities, the degree of motorization is below the level of urban development and the traffic is still within the normal parameters (except for the transit traffic, which, in some cases, may become a contributing factor), there is a large number of urban centres recording a low and very low degree of severity of road crashes.

### 3.2. Urban road crashes by leading causes

The analysis on the degree of severity of road crashes by the dominant cause highlights an even more complex situation both from the temporal and spatial point of view. Hence, due to the large number of leading causes that were triggering factors crash occurrence in the analysed years, only the first five causes were further investigated in this study (as they caused the largest number of accidents): jaywalking, failure to yield right-of-way to vehicles, failure to yield right-of-way to pedestrians, inappropriate speed in adverse conditions and inattention when changing lanes.

*a). Jaywalking* represents the primary cause of road crashes in urban areas in Romania. With a total number of 4567 accidents in 2008 of which 72.02% in the cities, and a number of 2751 accidents in 2019 of which 65.50% in urban areas, this cause generates high crash severity values because pedestrians are directly involved and the end result is injuries or even deaths. The number of crashes caused by this factor is decreasing both in number (-1816 cases) and weight (39.76%) in the reference period, but it still remains among the top five dominant causes of road crashes at the city level, which proves the extent of its effects. The high incidence of this cause, both in 2008 and in 2019, is primarily determined by the low level of education of pedestrians as road users, the still very small sanctions that apply for pedestrian offences (most of the sanctions in Romania's road legislation are focused on the driver) and also the insufficiency of crossings with or without traffic lights, which discourage crossing the street through unauthorized places. Spatially, we note several cities with high severity level of road crashes related to this triggering factor (Fig. 1, a and b).

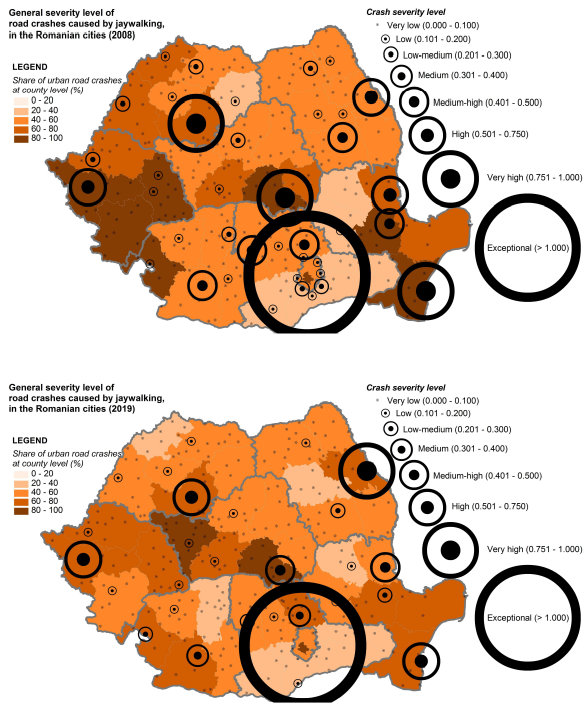


Fig. 1. General severity level of road crashes caused by jaywalking, in the Romanian cities (a. 2008; b. 2019).

If in 2008 the incidence of this cause was very high in cities such as Cluj-Napoca, Braşov and Constanţa, generating very high levels of crash severity, in 2019 it is observed that Iași is the only city that maintains the very high severity degree, while the values recorded in the other cities significantly decreased. Bucharest is an exception during the analysed period, registering the highest frequency of road crashes generated by the jaywalking.

The distribution of the number of car crashes at the county level, split by urban and rural areas, with jaywalking as the main cause, highlights the following relevant aspects: in 2008, high shares of urban road crashes were recorded in the counties of the west and south-west regions (Timiş, Hunedoara, Caraş-Severin, Mehedinţi), the south of Transylvania (Sibiu) as well as in the east and south-east areas of the country (Brăila, Constanţa); in 2019, the situation is improving at the national level, only two counties (Alba and Braşov) still recording high shares of crashes caused by jaywalking; the counties in the south of the country (Ialomiţa, Călăraş, Giurgiu, Teleorman) recorded the lowest shares of road crashes in the urban areas determined by jaywalking, both in 2008 and in 2019.

*b). Failure to yield right-of-way to vehicles* is the second most frequent cause of car crashes in urban areas. With a total number of 3378 accidents in 2008, of which 82.00% in urban areas, and a number of 3688 accidents in 2019 of which 75.81% in urban areas, this cause generates high road crash severity values because it directly involves drivers and the end result is injuries or even deaths.

The failure to yield right-of-way to vehicles still determines an increasing number (+26) of road crashes thus maintaining among the top five dominant causes of car crashes. The high incidence related to this cause, both in 2008 and in 2019, is primarily due to the very large number of vehicles in traffic, but also to the increasingly low training of drivers, who are frequently reckless or inattentive. To these, infrastructure-related contributing factors are to be considered, namely the low number of urban intersections with traffic lights, especially in the case of medium and small cities in the national hierarchy.

In 2008, the incidence of this cause was very high in urban centres such as Timişoara and Constanţa, generating very high degrees of road crash severity, while in 2019 several other cities recorded very high values of the severity index (Timişoara, Iaşi, Craiova, Constanţa) and high values of the severity index (Cluj-Napoca, Târgu Mureş, Bacău, Arad, Drobeta Tr. Severin, Braşov, Galaţi, Ploieşti). The city of Bucharest is also an exception in this case, registering the highest number of road crashes at the national level, caused by the failure to yield right-of-way to vehicles.

The spatial distribution of road crashes having as the main cause failure to yield right-of-way to vehicles in urban and rural areas at the county level, highlights the following relevant aspects: in 2008, high shares of urban road crashes were recorded in the counties in the west (Timiş, Arad, Bihor), the north-west (Sălaj, Maramureş), south of Transylvania (Alba, Sibiu, Braşov) as well as in the east and south-east of the country (Botoşani, Iasi, Vaslui, Brăila, Tulcea and Constanţa); in 2019 the situation improves at the national level, only 11 counties (Arad, Hunedoara, Alba, Sibiu, Braşov, Botoşani, Iaşi, Mehedinţi, Brăila, Tulcea and Constanţa) still recording high shares of road crashes; the counties in the south of the country (Ialomiţa, Călăraşi, Giurgiu) recorded the lowest shares of road crashes in urban areas, both in 2008 and in 2019.

From a spatial point of view, the urban centres with high degrees of severity determined by this dominant cause can be observed in Figure 2, a and b.

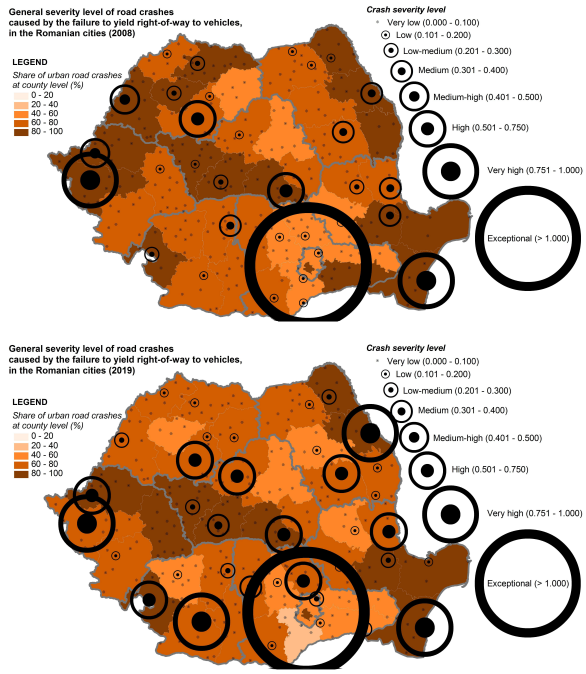


Fig. 2. General severity level of road crashes caused by the failure to yield right-of-way to vehicles, in the Romanian cities (a. 2008; b. 2019).

*c). Failure to yield right-of-way to pedestrians* represents the third most frequent cause of road crashes in urban areas. With a total number of 2678 accidents in 2008 of which 91.45% in urban areas and a number of 2863 accidents in 2019 of which 90.92% in urban areas, this cause generates high severity degree of road crashes because they directly involve drivers and pedestrians and the end result is injuries or even deaths.

This cause still determines an increasing number of road crashes in the reference period and still remains among the top five dominant causes of road crashes. The high incidence of this cause, both in 2008 and in 2019, is primarily determined by the very large number of vehicles in traffic, the increasingly low

training of drivers, to which we may add the poor infrastructure facilities, especially regarding intersections, especially in the case of medium and small cities in the national hierarchy. Spatially, a more detailed state of the urban areas that recorded high degrees of crash severity determined by this dominant cause can be observed in Figure 3, a and b.

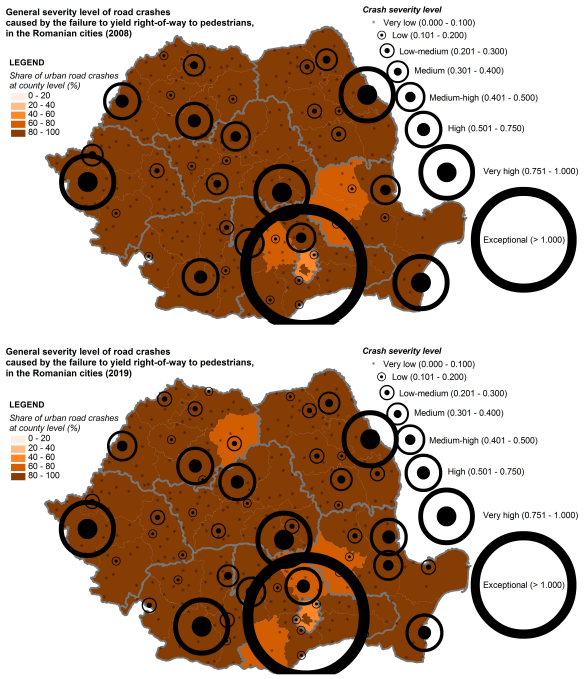


Fig. 3. General severity level of road crashes caused by the failure to yield right-of-way to pedestrians, in the Romanian cities (a. 2008; b. 2019).

In 2008, the incidence of this cause was highly recorded in the cities of Timişoara, Braşov, Iaşi and Constanţa, generating very high levels of road crash severity index; in 2019, it is observed that more urban areas recorded very high severity values (Timişoara, Iaşi, Craiova, Braşov) and others (Cluj-Napoca, Târgu Mureş, Galaţi, Ploieşti) recorded high values of crash severity index. Again, the city of Bucharest is an exception in this case, registering most of the cases of road crashes at the national level, generated by the failure to yield right-of-way to pedestrians.

The distribution of the number of accidents in urban and rural areas at the county level, with the main cause the failure to yield right-of-way to pedestrians, highlights the following relevant aspects: in 2008, a very high share of road crashes was registered in most counties in the country, primarily in urban areas, these values showing that this type of car crashes is specific to urban areas; in 2019, the situation remains approximately the same throughout the country, the absolute majority of traffic crashes caused by this cause occurring in urban areas.

This situation is explained by the great number of vehicles and pedestrians who share the same street infrastructure for mobility in the cities; also, pedestrian crossings without traffic lights are still very dangerous because of the irresponsibility of drivers who most of the time do not stop and fail to yield right-of-way to pedestrians.

*d). Inappropriate speed in adverse conditions* is the fourth most frequent cause of accidents in urban areas. With a total number of 2706 accidents in 2008, of which 44.53% in urban areas, and a number of 2463 accidents in 2019 of which 42.67% in urban areas, this cause generates high crash severity values because it directly involves drivers and the end result is injuries or even deaths.

Although the number of crashes shows a decreasing trend in the reference period (-12.78%) it still remains among the top five dominant causes of road crashes. The high incidence of this cause, both in 2008 and in 2019, is primarily determined by the very large number of vehicles in traffic, the increasingly low training of drivers, especially in the case of medium and small cities in the national hierarchy. Another cause is the state of the roadway, which is often not in the best condition (general road degradation, potholes, poor roadway maintenance, low visibility) lead to the occurrence of crashes in which case speed is not the dominant cause. From a spatial perspective, the urban areas with high degrees of severity determined by this dominant cause can be observed in Figure 4 a and b.

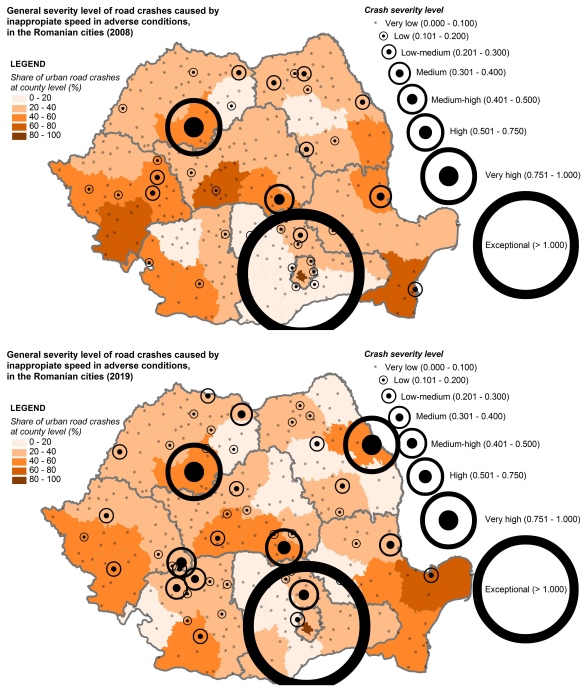


Fig. 4. General severity level of road crashes caused by inappropriate speed in adverse conditions, in the Romanian cities (a. 2008; b. 2019).

In 2008, the incidence of this cause was very high and generating very high levels of road crash severity in cities such as Cluj-Napoca and high in Braşov. In 2019, it is observed that several urban centres recorded very high severity values (Cluj-Napoca and Iaşi) and others (Braşov, Ploieşti) recorded high values of severity degree. The city of Bucharest is again

an exception in this case, registering the highest number of road crashes at the national level, caused by inappropriate speed in adverse conditions.

The distribution of the number of traffic crashes by urban-rural areas at the county level, highlights the following relevant aspects: this dominant cause has a lower incidence in urban areas than in extra-urban areas, due to speed limitations imposed by road legislation; a reduction in the share of traffic crashes in urban areas can be observed in 2019, compared to 2008; Tulcea county and the city of Bucharest recorded the highest shares of road crashes at the national level.

*e). Driver inattention when changing lanes* represents the fifth most frequent cause of road crashes in urban areas. This was the leading cause for 1344 road crashes in 2008, of which 77.43% in urban areas and for 232 road crashes in 2019, of which 95.69% in urban areas, at the national level. This cause generates high road crash severity values because it directly involves the drivers and the end results are injuries or even deaths. The magnitude of this triggering factor is decreasing during the reference period, expressed by the occurrence frequency (-77.50%) but still remains among the top five dominant causes of road crashes.

The high incidence of this cause in 2008 and the great reduction of over 77% in 2019 is primarily due to the very large number of vehicles in traffic, but also to the improvement of the road infrastructure. The maintenance of this leading cause in the top can be explained the numerous other distractions that reduce attention when driving (first of all, the use of mobile phones) and the insufficient attention of drivers when changing lanes, leading to minor or serious accidents with multiple implications and high degrees of severity. From a spatial point of view, the most affected urban areas by the high degrees of road crash severity determined by this dominant cause can be observed in Figure 5, a and b.

Thus, if in 2008 this was the leading cause for the very high occurrence of road crashes in Timişoara, Cluj-Napoca or Braşov, and high in the cities of Deva, Bacău, Galaţi and Constanţa, generating very high road crash severity degree, in 2019 it is observed that new urban cities recorded very high degree of road crash severity (Timişoara, Cluj-Napoca, Iaşi, Piteşti) and high degree of severity (Braşov, Galaţi). Again, Bucharest is an exception in this case, registering the most cases of road accidents at the national level, generated by driver inattention when changing lanes.

The distribution of the number of accidents in urban and rural areas at the county level highlights the following relevant aspects: in 2008, very high shares of urban road crashes determined by driver inattention when changing lanes were recorded in several counties in the country (Caraş-Severin, Sibiu, Braşov, Vaslui, Olt, Brăila, Constanţa), these values showing that this type of crashes is more specific to urban areas; in 2019, the situation generalized throughout the country, the absolute majority of crashes caused by this cause occurring in the cities. Exceptions to this rule are the counties of Bistrita-Năsăud, Sălaj, Caraş-Severin, Mehedinţi, Dâmboviţa, Teleorman, Brăila, Ialomiţa and Călăraşi, where the incidence values of this cause are the lowest in Romania.

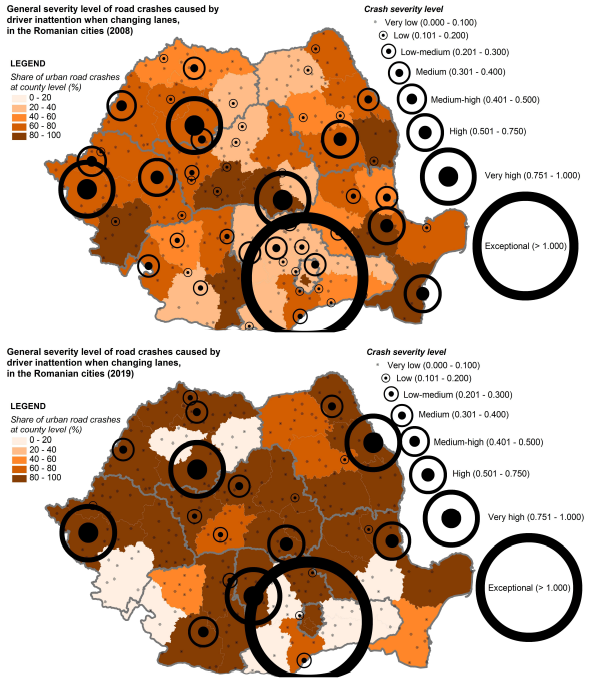


Fig. 5. General severity level of road crashes caused by driver inattention when changing lanes, in the Romanian cities (a. 2008; b. 2019).

The explanation for this situation may be that cities record a high motorization rate and due to the numerous intersections, traffic congestion, public transport and the existence of several traffic lanes in each direction drivers are forced to frequently change lanes; and their lack of adequate attention often leads to accidents. However, it is worth noting the over 77% decrease in the number of traffic crashes generated by this dominant factor between 2008 and 2019, which proves that measures have been taken and traffic conditions have greatly improved in many cities, especially in terms of road signalling and intelligent traffic lighting that significantly contribute to reducing the incidence of crashes caused by this factor.

### 3.3. City ranking by road crash severity level

Setting up a hierarchy of cities affected by traffic crashes of medium-high and very high severity degree is important because it helps prioritizing prospective strategic measures proposed for road safety based on factors, severity and location at the national level. We have selected the first top five leading causes of road crashes that influence the severity degree of their effects, thus creating a contextual state of facts at

the city level and specifically pinpointing the urban areas with their calculated traffic crash severity level in direct relation to the leading cause.

The relation of dependency between the road crash severity and the leading triggering factor becomes the starting information for drawing attention towards further systematic analyses of the additional circumstances in which the crash occurred at such severity level. Much more, we highlighted the dynamics in the severity degree for every city in the hierarchy, by calculating the variation of values between 2019 and 2008, to observe the decrease or increase tendencies. The five top leading causes in relation to the medium, high and very high severity levels of road crashes were previously identified. The rankings displayed in tables 9, 10, 11, 12 and 13 show the groups of cities recording the medium, high and the highest severity level of road crashes in 2008 and 2019. Only the values of the degree of severity in the following classes were considered: > 1.000 – exceptional degree of severity; 0.751 – 1.000 – very high degree of severity; 0.501 – 0.750 – high degree of severity; 0.401 – 0.500 – medium-high degree of severity.

The first ranked leading cause responsible for the high and highest severe road crashes at the city level in Romania is jaywalking. This finding is consistent with the results obtained by recent researches. This reflects the vulnerability of pedestrians as road users in urban areas.

In 2008, the most affected by this cause were 12 cities (most of them of rank 1) and Pitești (rank 2), half of which recorded high and very high severity level of road crashes. However, their number almost halved in 2019, which is a positive trend, overall. Still, Bucharest remains first ranked, while Iași moved up in the severity hierarchy, being the only city that recorded an increase in the severity of traffic crashes caused by jaywalking (Table 9).

Table 9. City ranking based on severity index values for road crashes caused by jaywalking.

| City | | Severity degree (2008) | City | | Severity degree (2019) | Trend |
|---|---|---|---|---|---|---|
| 1 | București | 9.989 | 1 | București | 4.497 | -5.491 |
| 2 | Constanța | 1.000 | 2 | Iași | 1.000 | 0.287 |
| 3 | Brașov | 0.884 | 3 | Cluj-Napoca | 0.716 | -0.136 |
| 4 | Cluj-Napoca | 0.852 | 4 | Constanța | 0.611 | -0.389 |
| 5 | Timișoara | 0.733 | 5 | Timișoara | 0.514 | -0.220 |
| 6 | Iași | 0.713 | 6 | Galați | 0.430 | -0.074 |
| 7 | Galați | 0.503 | 7 | Brașov | 0.403 | -0.481 |
| 8 | Bacău | 0.444 | | | | |
| 9 | Ploiești | 0.426 | | | | |
| 10 | Brăila | 0.426 | | | | |
| 11 | Pitești | 0.408 | | | | |
| 12 | Craiova | 0.403 | | | | |

The second leading cause responsible for medium, high and highest severe road crashes at the city level in Romania is failure to yield right-of-way to vehicles. This reflects the erratic behaviour of drivers in an increasingly congested urban traffic. In 2008, the most affected by this cause were only seven cities (all of them of rank 1), half of which recorded medium severity level of road crashes, except for Bucharest, which recorded exceptional values of crash severity. In this case, their number almost doubled in 2019, which is a negative trend, overall. Bucharest remained first ranked (although with a slight decrease in the severity degree), while Oradea moved down in the severity hierarchy; three of the 13 cities (Brașov, Constanța and Bucharest) recorded a slight decrease in the severity of traffic crashes caused by failure to yield right-of-way to vehicles (Table 10).

Table 10. City ranking based on severity index values for road crashes caused by the failure to yield right-of-way to vehicles.

| City | | Severity degree (2008) | City | | Severity degree (2019) | Trend |
|---|---|---|---|---|---|---|
| 1 | București | 6,176 | 1 | București | 5,702 | -0,474 |
| 2 | Constanța | 1,000 | 2 | Craiova | 1,000 | 0,822 |
| 3 | Timișoara | 0,818 | 3 | Constanța | 0,896 | -0,104 |
| 4 | Cluj-Napoca | 0,624 | 4 | Timișoara | 0,826 | 0,008 |
| 5 | Brașov | 0,578 | 5 | Iași | 0,795 | 0,469 |
| 6 | Oradea | 0,444 | 6 | Cluj-Napoca | 0,681 | 0,057 |
| 7 | Arad | 0,408 | 7 | Ploiești | 0,674 | 0,476 |
| | | | 8 | Bacău | 0,671 | 0,339 |
| | | | 9 | Arad | 0,650 | 0,242 |
| | | | 10 | Drobeta-Tr. Severin | 0,554 | 0,294 |
| | | | 11 | Târgu Mureș | 0,518 | 0,358 |
| | | | 12 | Brașov | 0,508 | -0,070 |
| | | | 13 | Galați | 0,505 | 0,117 |

The third leading cause responsible for medium, high and highest severe road crashes at the city level in Romania is failure to yield right-of-way to pedestrians. This reflects the erratic behaviour of both drivers and pedestrians in an increasingly congested urban traffic. In both reference years, there is an almost equal number of cities affected by this cause (most of them of rank 1) and Pitești (rank 2), almost half of which recorded medium severity level of road crashes, except for Bucharest, which recorded exceptional values of crash severity. In 2019, we note an increase in the severity degree of road crashes in these urban areas, which is a negative fact, overall. Bucharest remained first ranked (with a slight increase in the severity degree), while Oradea, Pitești, Constanța and Timișoara recorded slight decreases in the severity values (Table 11).

The fourth leading cause responsible for medium, high and highest severe road crashes at the city level in Romania is the inappropriate speed in adverse conditions. This reflects the tendency to over

speed in an increasingly congested urban traffic. If, in 2008, there were only three cities that recorded high and very high severity degree of road crashes, in 2019, we note a doubling in the number of cities, which is a negative fact, overall. Bucharest remained first ranked (with a slight increase in the severity degree), while Iași, Petroșani and Pitești, recorded substantial increases in the severity degree of crashes (Table 12).

Table 11. City ranking based on severity index values for road crashes caused by the failure to yield right-of-way to pedestrians.

| City | | Severity degree (2008) | City | | Severity degree (2019) | Trend |
|---|---|---|---|---|---|---|
| 1 | București | 5.145 | 1 | București | 5.187 | 0.042 |
| 2 | Iași | 1.000 | 2 | Iași | 1.000 | 0.000 |
| 3 | Timișoara | 0.886 | 3 | Craiova | 0.950 | 0.405 |
| 4 | Constanța | 0.858 | 4 | Timișoara | 0.810 | -0.076 |
| 5 | Brașov | 0.767 | 5 | Brașov | 0.807 | 0.039 |
| 6 | Cluj-Napoca | 0.610 | 6 | Cluj-Napoca | 0.741 | 0.132 |
| 7 | Oradea | 0.558 | 7 | Constanța | 0.595 | -0.263 |
| 8 | Craiova | 0.545 | 8 | Târgu Mureș | 0.576 | 0.085 |
| 9 | Ploiești | 0.499 | 9 | Ploiești | 0.526 | 0.028 |
| 10 | Târgu Mureș | 0.491 | 10 | Galați | 0.514 | 0.044 |
| 11 | Galați | 0.470 | 11 | Pitești | 0.458 | -0.012 |
| 12 | Pitești | 0.470 | 12 | Brăila | 0.445 | 0.246 |
| | | | 13 | Oradea | 0.430 | -0.128 |

Table 12. City ranking based on severity index values for road crashes caused by inappropriate speed in adverse conditions.

| City | | Severity degree (2008) | City | | Severity degree (2019) | Trend |
|---|---|---|---|---|---|---|
| 1 | București | 5.202 | 1 | București | 6.727 | 1.525 |
| 2 | Cluj-Napoca | 1.000 | 2 | Cluj-Napoca | 1.000 | 0.000 |
| 3 | Brașov | 0.433 | 3 | Iași | 0.803 | 0.557 |
| | | | 4 | Brașov | 0.519 | 0.086 |
| | | | 5 | Petroșani | 0.464 | 0.414 |
| | | | 6 | Ploiești | 0.426 | 0.266 |

Table 13. City ranking based on severity index values for road crashes caused by driver inattention when changing lanes.

| City | | Severity degree (2008) | City | | Severity degree (2019) | Trend |
|---|---|---|---|---|---|---|
| 1 | București | 15.367 | 1 | București | 5.857 | -9.510 |
| 2 | Cluj-Napoca | 1.000 | 2 | Cluj-Napoca | 1.000 | 0.000 |
| 3 | Brașov | 1.000 | 3 | Iași | 0.976 | 0.578 |
| 4 | Timișoara | 0.816 | 4 | Timișoara | 0.905 | 0.088 |
| 5 | Brăila | 0.694 | 5 | Pitești | 0.905 | 0.548 |
| 6 | Constanța | 0.663 | 6 | Galați | 0.738 | 0.381 |
| 7 | Deva | 0.551 | 7 | Brașov | 0.595 | -0.405 |
| 8 | Bacău | 0.520 | 8 | Craiova | 0.405 | 0.109 |
| 9 | Oradea | 0.480 | | | | |
| 10 | Arad | 0.408 | | | | |

## 4. CONCLUSIONS

Road safety in cities is relevant due to its impact on human safety, economic well-being, sustainable development, social equity, environmental concerns, legal compliance, and policy frameworks. By prioritizing road safety, cities can create safer, more sustainable, and liveable environments for their residents. The main aim of this study was to provide a thorough insight on the sustainability of all cities and towns of Romania in terms of safety of all participants in the road traffic. The effects of road crashes on the road users in urban areas were investigated, while highlighting the most affected cities by the increased level of road crash severity. Data on road crashes were extracted from the records provided by the General Directorate for Public Safety Police, Traffic Police Directorate in Romania. The primary leading causes were identified and ranked according to the number of crashes they determined and in relation to the severity of their effects. Based on the frequency of occurrence of road crashes, a top ten rank of causes was presented for each of the reference years to observe the contextual changes of road safety at the national level. A severity degree index was calculated to measure the magnitude of road crash effects on the driver, passengers and other traffic participants. Spatially, findings were presented at the local level, for all 319 cities in Romania. Results of calculations were presented for both of the reference years, 2008 and 2019. Considering that without knowledge of the magnitude of the problem and the risks of death and injury, the ability to implement context-specific and appropriate interventions is severely limited (WHO, 2018), we believe that was important to specifically point out the cities that are most affected by high and very high severity of traffic crashes. Since there is no one-size-fits-all approach to road crash severity and frequency, identifying the urban areas with these characteristics can aid in the modification of urban development plans, the regulatory acts pertaining to them, and strategic urban policies and activities. This study provides a thorough understanding of the existing situation, which is essential for enacting significant changes that will result in the development of more competitive, sustainable, and efficient cities. Decision-makers should make use of all the tools provided at the European and national level and create and implement customized measures for solving the deficiencies of road safety in accordance with their particular context. Considering the knowledge on the relation of dependency between road crash severity and the leading triggering factors, further studies should be conducted to identify the complementary circumstances in which crashes occur and have such severity level. This way, the prospective mobility management plans and actions would be directed towards solving infrastructure deficiencies and

enhancing active, green and shared urban mobility, tailor-made for each of the cities impacted socially and economically by this phenomenon.

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