ROAD TRAFFIC INJURIES: CAUSES AND PREVENTION TECHNIQUES

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ABSTRACT: Road traffic injuries remain a major public health problem. Injuries result from the interconnection of human behavior, vehicle technology, and environmental factors. Key causes include inadequate road infrastructure, speed, chaotic and/or distracted driving, poor norms and standards, and poor enforcement of traffic laws. The most vulnerable road users are pedestrians, cyclists, and motorcyclists; they face increased risks, especially in low- and middle-income regions. Effective prevention requires a multidisciplinary approach that combines technological improvements, clear legislation, and public education. This paper highlights current trends, examines primary determinants of road traffic injuries, and proposes comprehensive strategies to mitigate their impact.

KEY WORDS: road traffic, injury, prevention, safety systems.

1. INTRODUCTION

Road traffic injuries remain a leading public-health and development challenge, with around 1.19 million deaths each year, and are the top cause of death among citizens up to 29 years old. More than half of fatalities are pedestrians, cyclists, and motorcyclists, and 90–92% of deaths occur in low- and middle-income countries [1]. This burden persists despite modest global progress and imposes high macroeconomic costs, typically up to 3% of GDP in many countries [2].

Modern practice in improving road safety is guided by the Safe System/Vision Zero paradigm, which accepts human fallibility and builds redundant layers of protection across safer roads, speeds, vehicles, users, and post-crash care [3]. The literature emphasizes that achieving results requires implementation fidelity, which involves shifting design standards, assuming the institutional roles, and accountability, not simply rebranding existing programs [4]. Where Safe System principles are completely operationalized, especially around speed management and VRU-first design, fatal and serious injuries fall substantially [5].

Excess speed remains the most powerful, system-wide determinant because it governs crash energy and injury severity [2]. There is now substantial empirical support for the decision to limit the speed regime city-wide to 30 km/h. Analyses across European cities report 23% fewer crashes, 37% fewer deaths, and 38% fewer injuries after adoption, particularly when speed limitation is combined with self-enforcing street design [6]. Experimental studies [7,8] also show that lowering the speed limit from 50 to 30 km/h reduces injury severity. The sustained implementation of automated speed control serves as a validated complement. Speed cameras have been shown to reduce crashes and casualties [8]. Those gains vanish when enforcement is suspended, stressing the role of credible deterrence [9].

Occupant and user protection measures continue to deliver large benefits. Seat belts, first introduced in 1968, reduce the risk of fatal injury by 45–60% depending on vehicle type [10]. It was shown in [11] that the

correct use of children restraint/booster mitigates injury risk by 45–70%. Motorcycle helmets reduce the risk of fatal injury by 40% and severe head injury by 70%, while bicycle helmets noticeably reduce the risk of head injury [12].

Implementing blood alcohol concentration (BAC) limits at 0.05 g/dL, combined with strict enforcement, leads to significant reductions in alcohol-related crashes, as demonstrated in [13,14].

Recent advancements in vehicle technology have introduced additional complexities. The EU General Safety Regulation (GSR2) requires the implementation of Intelligent Speed Assistance (ISA), Autonomous Emergency Braking (AEB), Emergency Lane-Keeping, Driver Distraction warnings, and other safety systems in new vehicles. So, a regulatory baseline for active safety is being established [15,16]. Empirical evidence demonstrates that AEB can reduce car-to-car rear-end collisions by 50% and car-to-pedestrian collisions by 30%. ISA can lower population-level risk as more people use it. Scenario modeling indicates that risk could decline further as ISA becomes more widely adopted [16,17].

The growth of micromobility (e-scooters and e-bikes) brings risks and safety opportunities. In actual papers [18,19], it is suggested that while risk per trip may improve as systems mature, severe injuries are rising, particularly where riders mix with high-speed motor traffic.

This paper addresses road traffic injuries and introduces a comprehensive classification scheme intended to serve as an effective tool for technicians and stakeholders addressing the rise in road safety concerns.

2. CLASSIFICATION OF ROAD TRAFFIC INJURIES

Road traffic injuries are the consequences of road accidents. Road accidents are unforeseen events on public roads that involve one or more vehicles, pedestrians, or cyclists. In some cases, and depending on the region, they can also affect domestic or wild animals.

Understanding the definition and scope of road traffic accidents is essential for identifying their causes and implementing effective solutions to improve road safety and reduce road fatalities.

There are numerous criteria for classifying traffic injuries and/or accident causes. This section presents the most representative classification criteria.

A. Injury Severity. For this classification, we consider the KABCO (Crash Outcome Data Evaluation System) [20] and the AIS (Abbreviated Injury Scale) [21] systems, and propose a scale with five Severities:

A-1 Fatal injury resulting in death at the scene or within 30 days of the crash.

A-2 Incapacitating injury consists of severe cuts, fractures, unconsciousness, or injuries requiring assistance from the scene.

A-3 Non-incapacitating injury is a visible injury, such as a bruise or minor cut, that does not affect the capacity of the person to perform tasks.

A-4 Possible injury consists of pain produced by an invisible injury.

A-5 No injury, but property damage to the vehicle or the surroundings.

B. Contributing Factors. The broad factor-based categories we define here are the following:

B-1 Time-related factors, including time of day, rush hour, and seasonal variations.

B-2 Environmental factors
such as weather, lighting, and road surface conditions.

B-3 Traffic management factors, among which are speed limits, signs, traffic volume, and work zones, are identified as the most influential category.

B-4 Road user behavior characterized by speed, fatigue, distraction, and late reaction because of illness or the influence of drugs or alcohol.

C. Affected Road users. This classification applies to traffic participants and does not consider the humans whose property is affected.

C-1 Pedestrians are people who cross the street or walk on the pavement.

C-2 Cyclists are exposed to accidents due to their weak protection.
C-3 Motorcyclists are extremely exposed due to speed and instability.
C-4 Vehicle occupants are the best protected; thus, there are numerous victims.

D. Injury type. In accidents, different body parts can be affected. One possible classification is:
D-1 Head/brain injury occurs during sudden impacts or violent movements of the head.
D-2 Chest injury can lead to several serious problems, such as fractures and breathing difficulties.
D-3 Arms and legs are among the most frequent injuries in road accidents.
D-4 The spine is an extremely vulnerable part of the body during road accidents.
D-5 Internal organs are the main affected parts of the victims' bodies.

E. Crash Type Classification
E-1 vehicle-to-pedestrian crashes happen to pedestrians crossing and walking along a road.
E-2 Accidents involving a single vehicle can damage that vehicle.
E-2.1 Run-off-road,
E-2.2 Roll-over,
E-2.3 Fixed-object impacts,
E-2.4 Animals.
E-3 Vehicle-to-vehicle collisions are the must commun road accidents worldwide.
E-4 Multi-vehicle pileups are a chain of crashes/accidents, and happen especially on highways.

A comprehensive discussion on road traffic accidents is given below.

A. Injury Severity.
A-1 Fatal injury
A fatal road traffic accident is defined as a collision involving a vehicle that results in the death of its occupants or people outside the vehicle. It is often caused by violent collisions involving vehicles, pedestrians, or cyclists. These accidents are usually due to speeding, inattentive driving, driving under the influence of alcohol or drugs, fatigue, or poor road conditions. The force of the impact can cause serious head, chest, or other vital organ injuries, making survival unlikely. Emergency response time, seatbelt use, and vehicle safety features have a decisive influence on the outcome of the accident. Fatal road traffic accidents also have profound emotional and economic consequences for families and communities, highlighting the importance of responsible driving, improved infrastructure, and strict adherence to traffic laws by all road users. Reducing these tragedies requires collective awareness, more responsible behavior, and continued investment in road safety.

A-2 Incapacitating injury
A disabling injury following a road traffic accident refers to a serious injury sustained in a traffic accident that permanently or temporarily limits a victim's ability to perform normal daily activities. These injuries can involve severe damage to the brain, spinal cord, or limbs, potentially resulting in paralysis, loss of mobility, or cognitive impairment. Common causes include high-speed collisions, failure to wear a seatbelt, and driving under the influence of drugs. Victims may require long-term medical care, rehabilitation, and assistive devices, placing an emotional and financial burden on families. Disabling injuries underscore the critical importance of road safety awareness, improved vehicle design, and strict adherence to traffic laws to reduce the severity of these consequences.
These include serious cuts, fractures, loss of consciousness, or injuries requiring the intervention of firefighters or emergency services at the scene of the accident to provide first aid and transport victims to the nearest medical facility.
These disabling injuries can include internal fractures with bleeding or limb fractures, such as leg fractures, if the vehicle's hood has rolled up and crushed passengers' feet. Rib fractures can also occur when they come into violent contact with the steering wheel, if the airbags fail to deploy. Head trauma, usually resulting in a severe fracture, is also possible.
It is important to distinguish between the two main types of disability: permanent and temporary. Permanent disability resulting

from a road traffic accident refers to a lasting and irreversible loss of physical or mental abilities, leading to a reduction in independence, work capacity, and daily functional abilities, despite treatment and rehabilitation. It can also negatively impact a country's economy if no national measures are taken to reduce the number of victims in such serious accidents.

Temporary disability following a road traffic accident refers to a short-term loss of physical or functional capacity that limits normal activities. It can include fractures, soft tissue injuries, or pain requiring rest, treatment, and rehabilitation until recovery

A-3 Non-incapacitating injury

A non-incapacitating injury is a visible injury sustained in a road accident that does not limit a person's ability to carry out normal activities. These injuries are generally minor and include bruises, small cuts, abrasions, or mild swelling. Although they may cause discomfort or temporary pain, they do not result in long-term physical impairment or require extensive medical treatment. People with non- incapacitating injuries are usually able to continue working, walking, and performing daily tasks without assistance.

For example, a driver involved in a low-speed collision may suffer a bruise on the arm from the seatbelt or a minor cut on the hand from broken glass. While the injury is visible and may require basic first aid, it does not prevent the individual from driving, working, or managing routine responsibilities. Although less severe and non-incapacitating, injuries should still be properly treated to prevent infection or complications and ensure full recovery.

A-4 Possible injury

A possible injury in a road accident may involve pain caused by an invisible injury, meaning damage that is not immediately visible through external wounds. These injuries often affect soft tissues, nerves, or internal organs and may include whiplash, muscle strain, internal bruising, or mild traumatic brain injury. Victims might feel discomfort, stiffness, headaches, or dizziness hours or even days after the accident. Because there are no obvious signs, such injuries are sometimes underestimated or ignored, leading to delayed treatment and prolonged recovery. Invisible injuries can still interfere with daily activities, work performance, and emotional well-being. Medical evaluation is essential after any road accident, even when injuries seem minor. Early diagnosis helps prevent complications and ensures proper care. Awareness of invisible injuries emphasizes the importance of cautious driving and prompt medical attention following accidents. Some signs and symptoms can be short-lived, such as irritability, nausea and vomiting, sleep disturbance, and sensitivity to light or sound.

Some examples:

- Ringing in the ears
- Headache or feeling of head pressure
- Slurred speech / Fatigue
- Personality change
- Sleep disturbance

A-5 No injury

Road accidents that cause no physical injury but result in property damage still require attention and proper handling. In such cases, vehicles, roadside structures, fences, traffic signs, or nearby property may be damaged. Drivers are usually required to stop, assess the situation, and exchange information such as insurance and contact details. Authorities may need to be notified, especially if public property is affected. Insurance claims are commonly filed to cover repair costs. Although no one is hurt, these accidents can still cause traffic delays, financial loss, and emotional stress. Proper documentation, photographs of the damage, and cooperation between parties help resolve the situation efficiently. Preventive measures such as cautious driving and adherence to traffic rules can reduce the occurrence of property-damage-only accidents.

B. Contributing Factors.

B-1 Time-related factors

Time-related factors, including time of day, rush hour, and seasonal variations, play a significant role in the occurrence and severity of road accidents. The time of day influences visibility and driver alertness; accidents are

more common at night due to reduced lighting and fatigue. Rush hour periods, typically in the morning and evening, increase the risk of accidents due to heavy traffic, congestion, and driver stress, which can lead to sudden braking and collisions. Seasonal variations also affect road safety. Winter brings slippery roads, fog, and reduced daylight, while summer may see increased accidents due to higher travel volumes and speeding. Rainy seasons can reduce traction and visibility, increasing the likelihood of crashes. Understanding these time-related factors helps authorities plan safety measures and encourages drivers to adjust their behavior, improving overall road safety

B-1.1 Time of day

Road accidents most often occur during rush hours, especially in the early morning (7–9 AM) and evening (4–7 PM) when traffic volume is high. Accidents are also common late at night, due to poor visibility, fatigue, and impaired driving. Reduced alertness and congestion significantly increase crash risk during these periods

Figure 1. Challenge of driving at night [22]

B-1.2 Rush hour

Rush hour plays a major role in road accidents due to increased traffic density and driver stress. During morning and evening peak hours, roads become congested as people commute to and from work or school. This congestion leads to frequent stopping, sudden lane changes, and reduced reaction time, increasing the likelihood of collisions. Drivers may feel rushed or impatient, which can result in aggressive driving behaviors such as speeding, tailgating, or ignoring traffic signals. Pedestrian and cyclist activity is also higher during rush hours, further increasing the risk of accidents. Limited road space combined with high vehicle volume creates complex traffic situations that demand constant attention. Effective traffic management, flexible work hours, and public transport use can help reduce rush-hour accidents and improve overall road safety

B-1.3 Seasonal variations

Seasonal variations significantly influence road accident patterns. During winter, fog, rain, snow, and icy roads reduce visibility and traction, increasing the risk of crashes. Monsoon or rainy seasons lead to slippery surfaces and reduced braking control. In summer, higher travel volumes, speeding, and driver fatigue raise accident rates. Seasonal weather conditions directly affect road safety and driving behavior.

B-2 Environmental factors

Environmental factors such as weather, lighting, and road surface conditions play a crucial role in the occurrence of road accidents. These environmental challenges demand greater driver awareness, proper vehicle maintenance, and improved road infrastructure to minimize accident risks and enhance overall road safety

B-2.1 The influence of the weather

Weather plays a major role in road accidents, and its impact varies with a country's climate and geography. Adverse weather conditions such as rain, fog, snow, or strong winds reduce visibility for drivers, increasing the risk of collisions. In cold-climate countries such as Canada, Norway, or Russia, snow, ice, and freezing temperatures reduce tire grip and visibility, leading to skidding and longer braking distances. In tropical countries like India and Thailand, heavy rainfall and monsoon conditions lead to flooded roads, poor visibility, and slippery surfaces, increasing crash risk. Desert regions experience dust storms and extreme heat, which can impair visibility and vehicle performance. In temperate countries, fog, rain, and seasonal storms are common contributors. Each country faces unique weather-related challenges, making

region-specific road safety measures, driver training, and infrastructure essential to reduce weather-related accidents

B-2.2 Lighting

Lighting plays a crucial role in road safety and accident prevention. Poor lighting conditions, especially at night or on poorly illuminated roads, reduce visibility and make it difficult for drivers to see pedestrians, obstacles, road signs, or other vehicles in time. Glare from headlights or insufficient street lighting can also cause visual discomfort and delayed reactions. Proper road lighting and well-maintained vehicle headlights significantly reduce accident risks**.**

B-2.3 Road surface conditions

Road surface conditions play a crucial role in road accidents, as they directly affect vehicle control and braking effectiveness. This is particularly dangerous at high speeds. Wet, icy, or muddy surfaces reduce tire grip, increasing the risk of skidding and loss of control. Uneven roads, potholes, gravel, or oil spills can cause sudden swerves or damage the vehicle. Poor road conditions significantly increase the risk of accidents, especially for motorcyclists, whose vehicles require greater stability.

B-3 Traffic management factors

Traffic management factors are among the most influential contributors to road accidents because they directly shape driver behavior and traffic flow. Speed limits regulate vehicle movement; when ignored or poorly enforced, higher speeds reduce reaction time and increase crash severity. Traffic signs and signals provide essential guidance; missing, unclear, or ignored signs often lead to confusion and collisions. Traffic volume, especially during peak hours, increases congestion, sudden braking, and driver stress, thereby raising the risk of accidents. Work zones introduce lane changes, narrowed roads, and unexpected obstacles, which demand heightened attention. When traffic management systems are inadequate or poorly maintained, drivers face unpredictable conditions. Effective planning, clear signage, strict enforcement, and proper work-zone management significantly reduce accidents and improve overall road safety

B-3.1 Speed limits on roads

Speed limits play a crucial role in reducing road accidents by controlling vehicle speed and reducing crash severity.

Thus, the consequences for occupants in a road accident. When drivers exceed speed limits, reaction time decreases and stopping distance increases considerably, making collisions more likely. Higher speeds also result in more severe injuries and fatalities. Properly enforced speed limits significantly improve road safety in cities as well as in rural regions of a given country.

B-3.2 Traffic signs and signals

Traffic signs and signals are placed on the road to help avoid accidents by guiding drivers, regulating traffic flow, and warning about potential hazards. They create a predictable environment in which all road users—drivers, cyclists, and pedestrians—know what to expect, reducing confusion and preventing dangerous situations. Clear, visible signs also support safer decision-making, especially at complex intersections, in high-speed areas, or in poor weather conditions.

Non-respect of traffic signs and signals is a major cause of road accidents because these controls are designed to regulate traffic flow and prevent conflicts between road users. Ignoring stop signs, red lights, speed-limit signs, or pedestrian crossings leads to confusion and unexpected vehicle movements. Drivers who fail to obey signals often enter intersections at the wrong time, causing side-impact or head-on collisions. Disregarding warning signs can lead to accidents at sharp curves, construction zones, or hazardous road sections. Pedestrians and cyclists are especially vulnerable when drivers ignore signals meant to protect them. Poor awareness, impatience, distraction, or lack of enforcement contribute to this behavior. Strict adherence to traffic signs and signals, along with proper education and enforcement, is essential to reduce accidents and ensure safe, orderly road use

B-3.3 Traffic volume

Traffic volume plays a significant role in road accidents because higher numbers of vehicles increase the chances of conflict between drivers. In heavy traffic, drivers must be extremely careful, as congestion leads to frequent braking, lane changes, and reduced reaction time. Even small mistakes can quickly result in collisions when roads are busy.

B-3.4 Work zones

Work zones significantly increase the risk of road accidents due to sudden changes in traffic patterns and road conditions. Lane closures, narrowed roads, uneven surfaces, and construction equipment require drivers to slow down and stay alert in the whole work zone. Poor signage or driver inattention in work zones can lead to collisions, especially rear-end crashes. Reduced speed limits and clear warnings are essential to improve safety in these areas. Furthermore, workers on the site are also in danger if drivers do not pay attention.

Figure 2. Roadworks on the motorway [23]

C. Affected road users

Affected road users refer to the classification of people involved in road traffic and, consequently, in road accidents, based on their role as traffic participants, without considering damage to property. It focuses on pedestrians, cyclists, motorcyclists, and vehicle occupants, highlighting how different road users face varying levels of risk and injury depending on their exposure, protection, and interaction with traffic conditions

C-1 Pedestrians involved in a road accident

Pedestrians are considered vulnerable road users. They can be defined as people who walk on pavements or cross roads for daily or temporary travel. They face serious dangers on the roads due to their lack of physical protection. Major risks include speeding vehicles, poor visibility at night or by the end of the day, distracted drivers due to their phone or something else, unsafe crossings, and failure to respect pedestrian right-of-way, often leading to severe injuries or fatalities.

C-2 Cyclists as vulnerable road users

Cyclists are highly vulnerable road users because they lack physical protection and share space with faster, heavier vehicles. They face risks from collisions, poor road surfaces, limited visibility, and drivers failing to respect cycling lanes or safe passing distances. Therefore, cyclists are required to wear a helmet to protect themselves in the event of a fall or impact with the ground or other vehicles.

C-3 Motorcyclists and road challenges.

Motorcyclists are always at risk on the road because they lack the physical protection cars provide. They are less visible to other drivers, more affected by road surface defects, and highly exposed to weather conditions. Even minor collisions can result in severe injuries due to direct impact, high speeds, and limited stability. They therefore need some protection. They can be better protected through strict speed enforcement, dedicated motorcycle lanes, high-visibility gear, quality helmets, safer road surfaces, and increased driver awareness training.

For motorcyclists, injury severity is often assessed using the Head Injury Criterion (HIC), which measures the likelihood of head trauma during impact. High HIC values indicate severe head acceleration, commonly resulting from direct collisions or falls. Helmets significantly reduce HIC levels and the risk of fatal head injuries

Motorcyclist safety on the roads can be improved through lower speed limits, dedicated motorcycle lanes, better road maintenance, high-visibility protective gear, quality helmets, and increased awareness campaigns. Strict enforcement of traffic laws and safer road design also contribute significantly to reducing the risk of accidents

and the severity of injuries. The construction of motorcycle guardrails aims to prevent motorcyclists from being cut by poles during an accident.

C-3.3 Vehicle occupants in road accidents

Vehicle occupants are affected by road accidents through sudden deceleration, direct impact, or vehicle intrusion. Common injuries include head, chest, and limb trauma. Injury severity depends on crash speed, seatbelt use, airbag deployment, and vehicle safety design.
Internal measures to protect vehicle occupants during road accidents focus on reducing injury severity inside the vehicle. These include seat belts, airbags, head restraints, and energy-absorbing interiors that limit occupant movement during impact. Crumple zones help absorb collision forces, while reinforced passenger compartments prevent intrusion [24]. Advanced systems such as electronic stability control and automatic emergency braking also reduce crash severity and protect occupants before and during an accident.

D. Injury type.

D-1 Head and brain injuries

Brain injuries in road accidents are among the most serious outcomes, often caused by sudden impact or violent movement of the head. These injuries range from mild concussions to severe traumatic brain injuries. Consequences may include memory loss, difficulty concentrating, speech problems, emotional changes, or long-term disability. In severe cases, brain injuries can affect independence and quality of life.

Figure 3. Head impact injury [25]

After a road accident, immediate medical attention is essential, even if symptoms seem mild. Warning signs such as headaches, dizziness, confusion, or nausea should never be ignored. Rest, medical monitoring, and rehabilitation therapies are often required for recovery. Wearing seatbelts, using helmets, and following traffic laws significantly reduce the risk of brain injuries. Early diagnosis and proper care improve recovery outcomes and help prevent long-term complications.

D-2 Chest injuries from road accidents

Chest injuries from road accidents can lead to several serious problems that affect movement and breathing.
Victims often experience shoulder, arm, and chest pain due to muscle strain, fractured ribs, or internal bruising. Chest pain that worsens with movement or deep breathing may indicate possible damage to the lungs or ribs. Difficulty breathing is a critical symptom and may result from lung injury, collapsed lung, or internal bleeding. Visible bruises on the chest are common signs of impact from seatbelts or steering wheels. Immediate medical evaluation is essential, as chest injuries can worsen quickly if untreated. Early diagnosis and proper care help prevent complications and support recovery.

D-3 Arms and legs injuries

Arms and legs are frequently injured in road accidents because they are the most vulnerable parts of the body upon impact. The consequences can include fractures, ligament tears, deep wounds, nerve damage, crush injuries, and even permanent disabilities. These injuries often require surgery, rehabilitation, and a lengthy recovery period, affecting mobility and quality of life, both personal and professional.
These leg injuries can lead to an inability to walk and force the victim to move around with a cane, or even in a wheelchair for people with reduced mobility.

D-4 The spine

The spine is an extremely vulnerable part of the body during road accidents
The spine is extremely vulnerable in road accidents because it absorbs the sudden forces of impacts, rollovers, or abrupt decelerations. These violent shocks can cause vertebral

fractures, herniated discs, or spinal cord injuries. The consequences can range from chronic pain and reduced mobility to partial or complete paralysis. Even seemingly minor accidents can lead to hidden spinal cord injuries requiring urgent evaluation and lengthy rehabilitation. The victim may then find themselves needing to use a cane or even a wheelchair to get around.

D-5 Internal organs

Internal organs are the first to be affected by severe head, chest, or pelvic trauma, as these areas contain vital structures that are poorly protected against significant impact forces. These impacts can cause cerebral edema, pulmonary contusions, cardiac or hepatic lacerations, and internal bleeding due to ruptured blood vessels. Pelvic fractures can damage the bladder, major arteries, and even the kidneys. These injuries often pose a life-threatening risk to the victim and require rapid diagnosis and immediate surgical or intensive care to prevent potentially fatal complications.

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E. Accident Type Classification.

The accident type classification groups road traffic accidents into structured categories based on impact configuration, number of vehicles involved, and primary collision mechanism. This framework helps investigators analyze trends, identify contributing factors, and design targeted safety interventions. A clear classification also promotes standardized reporting, injury prediction, and the development of effective prevention strategies in different road environments**.**

E-1 Vehicle-pedestrian collisions

Vehicle-pedestrian collisions occur when a vehicle strikes a pedestrian. They are among the most serious accidents because pedestrians are unprotected. These incidents often happen at intersections, crosswalks (marked or unmarked), on sidewalks, in parking lots, or when pedestrians cross the road illegally or unexpectedly. Frequent contributing factors include driver inattention for various reasons, excessive speed, poor visibility, and pedestrian misjudgment of the vehicle's distance or speed. Weather conditions, such as snow, fog, or rain, can also worsen accidents. Because the human body absorbs the full force of the impact, injuries are usually severe: fractures, head trauma, and potentially fatal internal injuries. This is why preventative measures, such as traffic calming, adequate lighting, and safe crossing infrastructure, are essential.

E-2 Single-Vehicle Crashes

Single-vehicle crashes involve only one motor vehicle and typically result from loss of control, distraction, speeding, mechanical failure, or adverse environmental conditions. These incidents can cause significant harm to both the vehicle and its occupants because there is no second party to absorb part of the impact. Major sub-types include run-off-road crashes, rollovers, collisions with fixed objects such as trees or poles, and crashes caused by sudden evasive maneuvers to avoid animals or obstacles. Improving road design, maintaining vehicles properly, and reducing risky driving behaviors are key to preventing these events

E-2.1 Run-off-road crashes

A vehicle runs off the road when it unintentionally leaves the roadway due to a loss of steering control caused by a slippery or uneven surface, a sudden evasive maneuver to avoid an obstacle, or impaired driver function (fatigue, drowsiness, etc.). These events often result in collisions with fixed objects such as trees, poles, or barriers, increasing the risk of serious injury. Poor

visibility, excessive speed, and inadequate road maintenance can also contribute to loss of control. Improving roadside design, installing guardrails, and promoting safer driving practices help reduce the frequency and severity of these accidents when they are unavoidable.

E-2.2 Rollover crashes

A rollover accident occurs when a vehicle flips onto its side or roof. This risk is particularly high for tall vehicles with a high center of gravity, such as SUVs, vans, trucks, and buses. These accidents can be triggered by sudden steering movements while traveling at high speeds or when taking a corner too fast. Impacts with a curb or the road surface, or during a sudden evasive maneuver, can also occur. Once a rollover has begun, occupants are at high risk of serious injury from roof intrusion, ejection, or violent internal impacts against the vehicle's body. Proper tire control, precise load balancing, and stability control systems significantly reduce the risk of a rollover. Load balancing in trucks is therefore essential to prevent the load from shifting while driving and unbalancing the vehicle in curves, which can cause a rollover.

E-2.3 Fixed-object impacts

Collisions with stationary objects occur when a moving vehicle strikes stationary structures such as roadside trees, poles, walls, road signs, or road safety guardrails. These accidents are often serious because the object absorbs only a small portion of the kinetic energy, causing the vehicle to slow down abruptly, also known as deceleration. They are frequently caused by driver inattention, speeding, fatigue, loss of control in curves, or poor weather conditions that reduce tire grip. Obstacles located too close to the roadway can also increase the risk of accidents. Improving overall road design, installing guardrails in accident-prone areas, and promoting safer driving can significantly reduce the likelihood and severity of these collisions.

E-2.4 Animal collisions

Animal collisions occur when a vehicle strikes a wild or domestic animal that suddenly crosses the road, creating a hazard for drivers and passengers. These accidents often occur in rural or wooded areas, especially at dawn or dusk, when animal activity increases, and visibility decreases. Large animals, such as deer, cattle, or wild boar, can cause significant property damage and serious injuries to occupants due to the force of the impact. Driver distraction, excessive speed, and inadequate lighting further increase the risk, as reaction time is often too slow. Solutions primarily involve installing warning signs indicating the potential presence of animals and erecting fences or barriers to prevent wildlife from crossing the road. Encouraging drivers to reduce their speed in high-risk areas is an effective measure to decrease the number of these incidents or mitigate their severity.

E-3. Vehicle-to-Vehicle Collisions

Vehicle collisions, involving contact between two motor vehicles, are one of the most common types of accidents. They include rear-end collisions, often caused by failure to maintain a safe following distance or sudden braking; head-on collisions, usually serious due to the combined impact speed; side (T-) collisions, common at intersections when a driver fails to yield or runs a red light; and side-impact collisions, which typically occur during lane changes or merging. These accidents are more likely in heavy traffic, at busy intersections, or when drivers are distracted, speeding, or misjudging safe following distances. Environmental factors such as poor visibility, wet road surfaces, and inadequate signage can further increase the risk. Effective measures to address this include maintaining sufficient safety distances, improving the design of traffic-light intersections, and promoting attentive and defensive driving.

E-4 Multi-Vehicle Pileups

Multi-vehicle collisions are chain-reaction accidents involving three or more vehicles, usually triggered by an initial collision that is unavoidable for subsequent drivers. These

events are particularly common on high-speed roads where vehicles travel very close together and have little time to react. Poor visibility (fog, smoke, heavy rain, or windblown snow) significantly increases the risk of misjudging distances or failing to see stopped vehicles. After the initial impact, subsequent vehicles may collide due to inertia, emergency braking, or a lack of escape routes.

Multi-vehicle collisions often result in serious injuries, major road closures, and complex emergency response situations due to the number of vehicles and people involved.

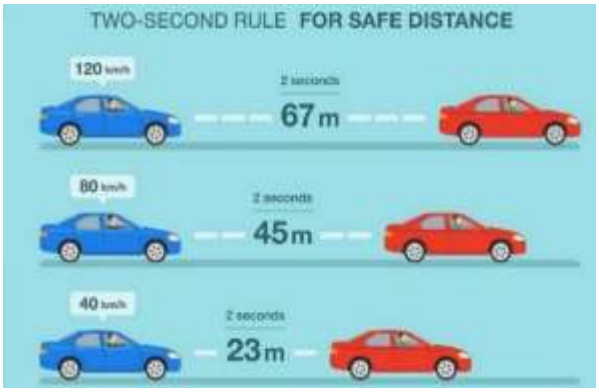

Figure 3. The safe distance between two vehicles driving in the same direction [26]

Maintaining a safe following distance is essential to avoid pile-ups, especially on highways at high speeds or in low visibility. The principle is simple: distance = reaction time + braking distance (Figure 3). Without sufficient distance, the slightest driver error can instantly cause a pile-up, as the reaction time is too short to brake or avoid the vehicle in front. This is why it is imperative to maintain a safe following distance on the road

3. CONCLUSION

To draw a relevant conclusion regarding the severity of injuries from road traffic accidents, it is essential to establish a link between the main determining factors, the road users most at risk, and the most serious types of accidents.

The severity of injuries resulting from road traffic accidents is influenced by a combination of factors: impact speed, collision configuration, vehicle mass, protective systems, and environmental conditions. Vulnerable road users, such as pedestrians, cyclists, and motorcyclists, suffer the most serious consequences because they lack structural protection. High-energy accidents, including head-on collisions, side collisions, rollovers, and pileups, consistently result in the most serious injuries due to rapid deceleration forces and complex impact dynamics. Aggravating factors such as distraction, excessive speed, poor visibility, and inadequate infrastructure further amplify the severity of injuries.

Ultimately, understanding how these elements interact is essential for designing safer roads, improving vehicle standards, guiding emergency responses, and reducing the human and economic burden of road accidents worldwide.

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