

Original Article

The common road safety approaches: A scoping review and thematic analysis

Hamid Safarpour^a, Davoud Khorasani-Zavareh^{b,*}, Reza Mohammadi^c^a Department of Health in Emergencies and Disasters, School of Public Health and Safety, Shahid Beheshti University of Medical Sciences, Tehran, Iran^b Workplace Health Promotion Research Center, Shahid Beheshti University of Medical Sciences, Tehran, Iran^c Department of Neurobiology, Care Sciences and Society, H1, Division of Family Medicine and Primary Care, Huddinge, Sweden

ARTICLE INFO

Article history:

Received 7 August 2019

Received in revised form

20 January 2020

Accepted 12 February 2020

Available online 28 February 2020

Keywords:

Road safety

Vision zero

Road traffic injury

Road traffic accident

Approach

Safe system

ABSTRACT

Purpose: Comparison of effective road safety approaches with those of relatively similar countries can be used to identify possibilities for safety improvement. Since there is no clear and comprehensive study of countries' current and successful approaches to road safety in the world, the aim of this study was to identify common road safety approaches in the world.

Methods: This study was performed using scoping review and thematic analysis. The study followed the approach proposed by Arksey and O'Malley. In this study all articles were selected without time limit by searching in the following databases: Web of Science, PubMed, Scopus, ProQuest, and Embase. An initial search of 5612 papers was found and finally, 20 papers met the inclusion criteria and were analyzed.

Results: There were different road safety approaches in different countries around the world, which were classified in three themes: traditional approach, systemic approach, and vision zero. The traditional approach includes the sub-theme of the road-user approach, and the causal approach. The systemic approach also includes sub-themes of sustainable safety, safety system, and the United Nations plan for decade of action.

Conclusion: A systemic approach to road safety seems to be welcomed by most developed and developing countries, and a paradigm shift towards a safe system has taken place. Also, given the successful results of implementing vision zero in leading countries, most countries are trying to design and implement this approach. Finally, the choice and implementation of road safety approaches varies according to the principles, priorities and infrastructure of each country.

© 2020 Chinese Medical Association. Production and hosting by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Introduction

Road traffic injuries (RTIs) are one of the public health problems in which the community and decision makers continue to accept inevitably large-scale deaths and disabilities.¹ RTIs are one of the leading causes of death in the ages of 5–29 years, so that according to the World Health Organization's (WHO) 2018 report, 1.35 million people die each year from RTIs and 20–50 million are injured. These are the most important causes of death in low- and middle-income countries, and 93% of road traffic deaths occur in these countries. The financial consequences of RTIs are also significant. According to the WHO, RTIs account for 2%–7% of gross domestic product (GDP) in low- and middle-income countries.²

Because of the multifaceted nature of road traffic crashes (RTCs), experts around the world have involved to solve this problem for many years. There are many challenges in preventing RTIs. There are generally two different approaches to preventing RTIs: the traditional approach and the systemic approach. The traditional approach tends to focus on changing the behavior of road users and reducing human errors and holding users primarily responsible for the occurrence of RTCs.³ Rather than being seen as a public health problem, RTCs are often regarded as separate crashes due to human errors. The focus on human errors has made road safety practitioners more focused on road users.⁴ Unlike the traditional approach, the systemic approach considers the prevention of deaths from RTCs as a system in which both road designers and road users are responsible for. In this approach, the level of human tolerance to kinetic energy has been highly regarded, so that speeds in different areas should be considered in such a way as not to cause serious injury and death in a car collision.³ There are various road safety approaches to reduce the number of deaths and serious injuries from RTCs in different countries which have their own goals.

* Corresponding author.

E-mail address: davoud.khorasani@gmail.com (D. Khorasani-Zavareh).

Peer review under responsibility of Chinese Medical Association.

Since all approaches aim at preventing, reducing and improving management of fatal RTIs, thereby identifying different road safety approaches, their weaknesses and strengths can be applied as a model for implementing and deploying these approaches in other countries. Moreover, comparison of effective road safety approaches with those of relatively similar countries can also be used to identify possibilities for safety improvement. Since there is no clear and comprehensive study of countries' current and successful approaches to road safety in the world, the aim of this study was to identify common road safety approaches in the world.

Methods

This study was performed using scoping review and thematic analysis. First, using the scoping review, the road safety approaches in the world was reviewed. Then, using the thematic analysis, the results from the scoping review was classified and categorized. The purpose of the scoping review was to provide a method for mapping key concepts that encompass the field of research.⁵ Generally, scoping review was used for identification to demonstrate working definitions and conceptual boundaries of a topic or context. Therefore, scoping review is used when the body of texts is not yet fully explored or of a large, complex or heterogeneous nature that cannot be systematically reviewed.⁶ Unlike systematic review, scoping review provides an overview of the status of the research activity rather than evaluating its quality. Since the purpose of this study is to investigate the common road safety approaches, which is a new topic and concept, therefore, the scoping review method is suitable for this study. The study followed the approach proposed by Arksey et al.⁷ as well as the revised version of the Peters et al.⁶ This approach consists of five steps: identifying research question, identifying relevant studies, study selection, data charting, and collecting, summarizing and reporting the findings. In the next step, thematic analysis is used to analyze and categorize data.

Identifying the research questions

The objective of this scoping review was to identify the common road safety approaches in the world. A preliminary search for existing research and documents of the topic was conducted, and it was clear that there was no any comprehensive research on the common road safety approaches in the world. No study specifically designed to review the road safety approaches. Therefore, a scoping review of this topic will allow to know what the common road safety approaches in the world. The research question was as follows: what are the common road safety approaches in the world?

Identifying relevant studies

In this study all articles were selected without time limit by searching in the following databases Web of Science, PubMed, Scopus, ProQuest, and Embase. The last searching date was May 17, 2019. Bibliographic references of all major articles were investigated and reviews were assessed for other relevant articles. In addition, the Google search engine was used to search for documents and articles related to the subject. Search for articles was done individually and in combination using keywords such as road safety, traffic safety, road safety management, road traffic management, road strategy, and approach by using the Boolean operators “and/or”.

Study selection

All English-language studies conducted on common approaches to road safety worldwide were considered in this study. Relevant

articles were first collected and a list of abstracts was prepared after the search was completed. All duplicates were removed using Endnote ver. X6 software.

Charting the data

Required data was extracted using a pre-prepared checklist that included a variety of approaches, country, current approach, approach name, slogan, and key principles.

Collating, summarizing, and reporting the findings

Initially, using scoping review different codes and concepts were reviewed and extracted. Thematic content analysis was then used to analyze the data. The thematic content analysis steps include familiarizing with data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the report.⁸

Results

Papers related to common approaches to road safety in the world were included in the study. Accordingly, an initial search of 5612 articles was found and finally, using the PRISMA checklist, 20 articles met the inclusion criteria and were analyzed (Fig. 1).

Based on the results of the scoping review and a thematic analysis, road safety and strategies can be classified in three themes: traditional approach, systemic approach, and vision zero. The traditional approach includes the sub-theme of the road-user approach, and the causal approach. The systemic approach also includes sub-themes of sustainable safety, safety system, and the United Nations (UN) plan for decade of action (Table 1).

Traditional approach

The traditional approach tends to focus on changing the road users' behaviors and reducing human errors, with users being primarily responsible for the occurrence of RTCs, mainly through education, advertising and various campaigns.^{3, 9} Injuries resulted from RTCs are often considered as separate accidents due to human errors rather than as a public health problem. The focus on human errors has made road safety practitioners more focused on road users.^{4, 9} Traditional approach assumes that there is a limit to safety and there is an optimal level of deaths and serious injuries, determined by the point at which the costs of intervention exceed the benefits.⁹

Road-user approach

The road-user approach to road safety focuses on human errors as a major cause of RTCs and, therefore, the road users are responsible if a crash occurs. This view is shaped by findings claim that human errors accounts for 95% of RTCs.^{10, 11} In this approach, the main focus is on RTC prevention and hence measures are mainly performed to change the behavior of road users to adapt to the system such as regulation, monitoring of behavior, information and training so that the users behave properly and therefore, RTCs do not occur.^{11–14}

Causal approach

Causal theories of accidents claim that only an accurate knowledge of the actual factors that lead to accidents can help prevention. The two main trends in causal theories are deterministic events (sequence of events), and probabilistic (set of factors).¹⁵ In this approach, an accident may be caused by one or more events or factors. In this model, the accident is described as a chain of

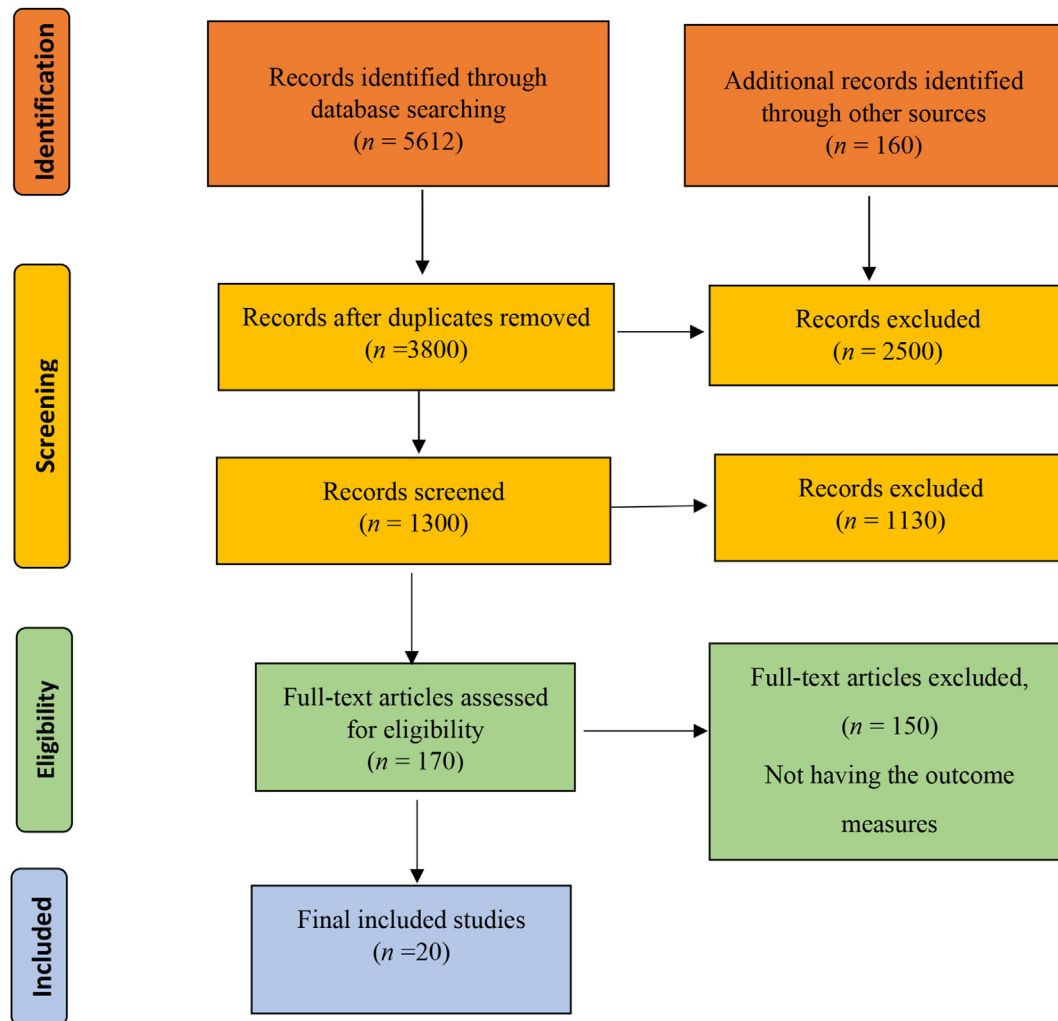


Fig. 1. PRISMA flow diagram for comparison of road safety approaches in according to the scoping review in the world.

conditions and events that lead to the injury. This approach states that accidents can be mitigated by reducing unsafe actions or conditions.¹⁶

Systemic approach

The first person who had a systemic approach to RTI prevention was Dr. William Haddon who introduced the Haddon matrix. This matrix is actually a combination of the factor that includes human factor, environment, and causative agent interacting with the three dimensions of the event, including pre-crash, crash, and post-crash.¹⁷ Another systemic approach was developed by Carol, who added a third dimension to the two Haddon dimensions, which was then the decision criteria of the interventions. According to this model, for any different interventions, its value criteria, including its cost, effectiveness, freedom, equity, and other identified criteria must be measured in order to make decision and effective interventions.¹⁸

Systemic approach focuses on the inherent weaknesses and traits of human beings and considers transport system designers to be responsible for promoting safety and preventing RTIs and stating that responsibility must be shared between system administrators and road users.³ In the systemic approach, the level of human tolerance to kinetic energy has been highly considered, so that

speeds in different areas must be sufficiently high to avoid serious injury and death in a car collision. Unlike the traditional approach, the systemic approach is top-down and at the level of strategy using political tools and has a long-term safety perspective.¹⁹ Based on the results, there are significant differences between traditional, systemic, and vision zero approaches (Table 2).

In the present study, using scoping review and thematic analysis, the sub-themes such as sustainable safety approach, safety system, and the UN plan for decade of action were introduced as systemic approaches to road safety.

Sustainable safety approach

The sustainable safety approach began in the Netherlands in the early 1990s. This approach confirms that humans are vulnerable to RTCs and are susceptible to errors. The purpose of sustainable safety is to prevent such errors as far as possible or reduce their consequences due to human limitations in traffic system design.²⁰ This strategy is based on five principles that are essential for a sustainable traffic system: (1) Functionality of roads: mono-functionality of roads as either through roads, distributor roads, or access roads in a hierarchical road network. (2) Homogeneity of mass and/or speed and direction: equality in speed, direction, and mass at moderate and high speeds. In places where traffic uses high speeds, different types of users and drivers driving in different

Table 1
Thematic analysis of road safety approaches according to the scoping review.

Themes	Description
Traditional approach	
Road-user approach	<ol style="list-style-type: none"> 1. Considered human errors as the major cause of road traffic crashes (RTCs). 2. Road-user has almost total legal responsibility for safety. 3. Major attention to RTC prevention. 4. Countermeasures are basically determined to change the behavior to adapt the road-user to the system. 5. 3Es: engineering, enforcement, and education.
Causal approach	<ol style="list-style-type: none"> 1. Road traffic crash can be prevented only by a precise knowledge of the real crash factors. 2. Two main trends: deterministic (sequence of events) and probabilistic (set of factors). 3. Enhancing human behavior (speed, alcohol, seat belts, and helmets) by legislation, enforcement, and campaigns. 4. Planning and designing to make safer infrastructure. 5. Safer vehicles through better crashworthiness, active vehicle safety, and vehicle inspections.
Systemic approach	
Sustainable safety	<ol style="list-style-type: none"> 1. Functionality of roads. 2. Homogeneity of mass and/or speed and direction. 3. Predictability of road course and road user behavior by a recognizable road design. 4. Forgivingness of the environment and of road users. 5. State awareness by the road user.
Safe system	<ol style="list-style-type: none"> 1. People make mistakes. 2. Human physical frailty. 3. A 'forgiving' road transport system. 4. Building a national road safety culture. 5. Data driven targets. 6. Corporate responsibility. 7. International collaboration. 8. 7Es: engineering, enforcement, education, economics, emergency response, enablement, and ergonomics.
The UN plan for decade of action	<ol style="list-style-type: none"> 1. Road safety management. 2. Infrastructure. 3. Safe vehicles. 4. Road user behavior. 5. Post-crash response.
Vision zero	<ol style="list-style-type: none"> 1. Three dimensions: ethics, responsibility, solutions. 2. Traffic deaths and serious injuries are acknowledged to be preventable. 3. Human life and health are prioritized within all aspects of transportation systems. 4. Acknowledgement that human errors are inevitable, and transportation systems should be forgiving. 5. Safety work should focus on systems-level changes above influencing individual behavior. 6. Speed is recognized and prioritized as the fundamental factor in road traffic crash severity.

UN: United Nations.

directions should be physically separated from each other to avoid collisions that can cause death or serious injury. (3) Predictability of road course and road user behaviour by a recognizable road design: road environment and road user behaviour that support road user expectations through consistency and continuity in road design. (4) Forgivingness of environment and road users: limiting injury through a forgiving road environment and predicting road user behavior. Roads should assist road users in the event of an error. (5) State awareness of road user: road users should be able to assess their capability to access and control driving tasks.^{20–22} Initially the sustainable safety system contained only the first three principles, but in 2005 the outlook for sustainable development was updated and two subsequent strategies were added.²¹ The first four are specifically related to road infrastructure.^{20,22}

Safe systematic approach

Safe system has evolved from the ideas that emerged in Sweden and the Netherlands in the mid-1990s and then after Australia in the 20th century from 1999 to 2002.²³ This approach represents a "paradigm shift" in road safety approaches. The shift from treating RTIs factors as rational to the underlying assumption that there are always inherent risks to RTIs is towards conceptualizing and pursuing the development and management of a road transport system that is inherently safe from human errors.²³ A key principle in the safe system approach is shifting responsibility from road users to road system designers to prevent RTIs.^{23,24} There are generally four key principles to a safe system: (1) People may make a mistake that can result in road injuries. (2) The human body has limited physical ability to tolerate the forces of RTC. (3) While individuals

have a responsibility to comply with traffic laws, there is also a shared responsibility with those responsible for the design, construction, management and use of roads and vehicles to prevent RTIs. (4) All parts of the system must be fused together to multiply their effects, and if one part fails, it will still be protected by the other parts of the system.^{20,24,25} The safety system approach typically considers key interactive pillars including safe roads, safe vehicles, safe speeds, and safe road users. The fifth pillar is the post-crash response introduced by the UN in 2010 but not yet reflected in many areas of the safe system.²⁰ Safe road: road is designed and maintained to reduce the risk of RTCs occurring and reduce the severity of injury in the crash event. Safe road prevents unintentional use by designing and encouraging safe behaviors by road users. Safe speed: speed limits are supplemented with road environments to manage RTC impact forces on human tolerance; and all road users comply with speed limits. Safe vehicles: the vehicles not only reduce the incidence rate of an RTCs and protect people, but also make driving easier and protect vulnerable users. Increasingly, these include vehicles that communicate with other roads and vehicles, while automated protective systems are used when the risk of a RTCs increases. Safe people: encourage people to have safe, sustainable and consistent behaviors through informed and trained road users. Licensing, training, road rules, enforcement and sanctions are all part of the safe system.²⁶

The UN plan for decade of action

Given the importance of road safety and increased political participation of countries and long-term action in national and international coordination, another program with a systemic

Table 2
Comparison of traditional, systematic, and vision zero approaches on road safety based on the scoping review.

Items	Approach		
	Traditional	Systematic	Vision zero
Philosophy	<ul style="list-style-type: none"> - Accidents are unavoidable - Mobility all the times contains a certain percentage of personal injuries. 	<ul style="list-style-type: none"> - People make mistakes and they are physically fragile/vulnerable in RTIs. - Varying quality and design of infrastructure and operating speeds provides inconsistent guidance to users about what is safe use behavior. 	<ul style="list-style-type: none"> - No one will be killed or serious injured in the road transport system. - People make errors, mistakes and misjudgments. - There are biomechanical tolerance limits. - The chain of events can be cut at many places.
Ethical imperative	Not clear.	Ethical aspects are often ignored.	It is never ethically acceptable that people to be killed or be injured seriously in the road transport system.
Direction	Bottom-up approach	Up-down approach	Up-down approach
Problem	Try to prevent all RTCs	Prevent crashes from resulting in fatal and serious casualties	Prevent crashes from resulting in fatal and serious casualties
Appropriate goal	Prevent road accident	Reduce fatalities and serious injuries	Eliminate/zero fatalities and serious injuries
Planning approaches	<ul style="list-style-type: none"> - Reactive to incidents - Incremental approach to reduce the problem 	<ul style="list-style-type: none"> - Proactively target and treat risk - Systematic approach to build a safe road system 	<ul style="list-style-type: none"> - Proactive planning - Systematic approach to build a safe road system - Strategic planning - Operative planning - Tactical planning
Causes of the problem	<ul style="list-style-type: none"> - Human errors - Non-compliant road users 	<ul style="list-style-type: none"> - System gaps - Failures in the system design is the cause of RTIs 	The system design as the main cause and system designers as responsible. (Road user, designers, administrators, etc.)
Focus on human characteristics	Excessive mechanical forces on humans	<ul style="list-style-type: none"> - Human body tolerance to high energy - Kinetic energy - Reduce mechanical forces to human tolerances 	<ul style="list-style-type: none"> - Human body tolerance to high energy - People are blind to kinetic energy - Reduce mechanical forces to human tolerances
Ultimately responsible	Individual road users	It places a shared responsibility across all elements of the system.	Shared responsibility amongst everyone, including those that design, build, operate and use the road system.
System method of work	Is composed of isolated interventions	Different elements of a safe system combine to produce a summary effect greater than the sum of the individual treatments-so that if one part of the system fails others parts provide protection.	People will sometimes make mistakes, so the road system and related policies should be designed to ensure those inevitable mistakes do not result in serious injuries or fatalities.
Cost of saving lives	Expensive	Cheap	Cheap

RTIs: road traffic injuries.

approach to preventing and reducing RTIs was announced: the UN plan for decade of action for road safety. In 2010, the UN general assembly adopted a declaration of the decade (2020–2011) calling it the plan for decade of action and required all membered states to implement preventive programs to reduce road traffic deaths and injuries. The program is based on the safe system approach and includes five pillars of action decade plan goals for road safety including road safety management, road and safe movement, safe vehicles, safe road users, and post-crash care.²⁷

Vision zero

The vision zero was first started in Sweden by Professor Claes Tingvall and approved by the parliament in October 1997.^{9,28} Vision zero is a public program that aims to achieve a system in which deaths or serious injuries resulting from RTCs reach zero.^{4,28,29} The vision zero represents a long-term goal and is based on the elements including ethics, responsibility, safety philosophy, and creating mechanism for change.^{30,31} This approach is based on an ethical imperative to reduce death and serious injury in the transportation system.^{9,24} Vision zero considers human beings as the highest value and the system must be designed so that a RTC does not cause death or serious injury.⁴ The vision zero is based on the principle that deaths and injuries caused by RTCs can be prevented. Another principle of the vision zero is that human errors are unavoidable and unpredictable, hence the system must be designed in a way that human errors are predicted and death or serious injury will not occur.^{4,31} Vision zero also emphasizes on changes in road safety responsibility. Vision zero defines the

responsibility view in such a way that system designers are always and ultimately responsible to design, to manage, and to provide use the road transport system and consequently responsible for the overall level of safety of the system.^{4,9,14,29} If road users are unable to comply with the rules, for example due to lack of knowledge, acceptance or ability, or occurrence of personal injury, system designers should take additional measures to prevent death or serious injury.^{24,29,31,32} The main focus of this outlook is on upgrading and modifying the transportation system, and if countries cannot change system safety such as road and users' safety, all focus should be on speed management. In this approach, speed management is very important and highly focused. These speeds are based on the human body's tolerance restriction against kinetic energy.^{3,11,33}

The results of the study illustrated that some of the leading countries in road safety follow different approaches with different goals, priorities and principles. In general, the best road safety approaches in the leading countries are shown in Table 3 along with their names and key principles.

Discussion

The traditional approach included a road-user approach and a causal approach to road safety. The systemic approach was also divided into three sub-themes: sustainable safety, safe system, and the UN plan for decade of action. In addition, the vision zero approach, despite similarities to the systemic approach, was classified as a separate approach. The results of the study demonstrate that there are important differences between the traditional and systemic approaches and the vision zero in road safety.

Sustainable safety

The sustainable safety approach is one of the systemic approaches that the Netherlands is leader in its implementation. The positive effects of the implementation of the sustainable safety in the Netherlands can be seen. In recent years the Netherlands has maintained a very well road safety record. The fatality rate has dropped from 811 deaths in 2006 to 613 in 2017.³⁴ The Netherlands recorded 31 fatalities per million inhabitants in 2017 that was well below the European Union (EU) average.³⁵ From the cost-benefit analysis, it can be concluded that the measures were cost effective as well. The benefits were about four times the cost and overall cost-effectiveness.²⁰

Safe system

The safe system approach has been implemented in some countries, such as Australia and to some extent in Germany. Although in Australia, national road safety has been reduced despite this approach, it has only been around 3.3% per year. As a result, it agreed on a new Australian road safety strategy: 2011–2020 that was more in line with Sweden's vision zero and Dutch sustainable safety approaches.³⁶ Based on this approach, both Australia and Germany have achieved some success in reducing fatal road traffic injuries^{2,37}, which could be due to a proper approach in road safety. In Australia as a step towards this long-term vision, a 10-year plan to reduce the annual number of deaths and serious injuries on Australian roads by at least 30% was presented. These goals are challenging because they are compared to a 23% reduction in road deaths achieved in the past decade.²⁶ In 2017, there were 1225 fatal road traffic injuries which had a decrease of approximately 14% from the 2011–2020 national road safety strategy.³⁸ Adopting and implementing a safe system approach requires strong organizational leadership and close collaboration between all key organizations involved. For example, reports show that in Victoria, implementing a safe system approach is usually accompanied by challenges that generally aren't technical and scientific. Instead, they are mainly political and social. While many governments are looking for safe system-based strategies, some land-based measures still depend on politicians to understand that they are acceptable to society and the public. Continuous efforts should be made to inform road users. However, success has been achieved by focusing on improving road network safety by examining speed limits and by specifically introducing improvements in modern vehicle safety features.³⁹

The UN plan for decade of action

The UN plan for decade of action for road safety is based on the safe system approach adopted by the UN in 2010. Many countries have adopted their goals and approaches to the program, and have announced a goal of reducing deaths by 2020. Analysis of the findings of various studies and sources shows that although some countries such as Sweden, Italy, Germany, Greece, and the United States have managed to achieve significant reductions in fatal RTIs, most countries have not succeeded in achieving the goals.^{2,27,37}

Vision zero

Vision zero is a long-term philosophy and guide to the road safety structure. Not only does this approach look systemic, it also takes into account the inherent weaknesses and traits of human beings and the ethics dimension. Thus, the vision zero goes beyond the systemic approach and the important difference is the ethical

and philosophical view of the value of human life.¹⁰ Countries like Sweden are at the forefront of the vision zero approach, followed by many countries such as Norway, Canada, the United States, the United Kingdom, and Poland which are inspired by this approach in road safety management. The experiences of these countries, especially Sweden, show that the vision zero approach is significantly effective in preventing road traffic injuries. For example, Sweden has reduced road traffic fatalities by more than 50% from 2007 to 2017.³⁷ Contrary to most statistics in which 90% of RTCs are the result of human errors, vision zero laws have placed RTIs planners responsible for RTIs prevention.^{9,11} However, rather than eliminating human errors or crashes, successful vision zero programs expect to address these problems through infrastructures that reduce RTCs by increasing the body's biological tolerance to external forces as a guiding mechanism.⁴⁰ The purpose of this approach is to minimize all potential accidental hazards whether caused by human errors or otherwise.⁴¹ Hazard reduction is achieved by separating traffic modalities at high speeds, managing the integrated traffic flow, and reducing collision angles at potential collision points.²⁸ The success of vision zero approach in Sweden has made it to be inspired in the United States for road safety.⁴¹ Some states also achieved remarkable successes following the vision zero, including a 43% reduction in fatal RTIs in Minnesota, a 48% reduction in Utah, and a 40% reduction in Washington state.^{42,43} The United States has also focused heavily on improving the principles and infrastructures of cycling based on the principles of vision zero.⁴⁴ Poland has also taken important steps to implement the vision zero. The most effective measures covers implementation and development of traffic safety programs at both regional and county levels, establishing the traffic safety observatory and two regional observatories, changes in driver training and examining procedures, implementation and improvement of a monitoring system (speed control and drivers' working hours control), standardizing bikers regulations, exhaustive construction of express highways and motorways, creating safe intersections, applying traffic calming measures, introducing traffic safety audits, upgrading the system of emergency rescue and post-crash response systems.⁴⁵ However, some measures in Poland have not yet gained the expected results. They are rarely, or unfortunately, have not been done.⁴⁵ In addition, the results of the previous studies show that governments do not charge a fee for introducing mindsets such as vision zero in road traffic safety program. The mindsets seem to have no cost. Implementing a safety plan is a way that requires resources and costs, especially if there is a limited time period. However, it should be made clear that the cost of implementing the vision zero is no higher than other road safety measures if done correctly.⁴⁶ Therefore, the basic principles of vision zero can be achieved in any country with any level of socio-economic development.^{4, 24}

Experiences in different countries showed that major advances in road safety can be achieved through comprehensive and concerted efforts and successes are likely to be achieved if road safety programs are well prepared and implemented.¹⁹ Worldwide, road safety approaches are developed, implemented, and evaluated based on different types of road-related deaths and injury estimates.⁴⁰ Road safety approaches are designed to select, guide and describe measures to mitigate these damages caused by RTCs.³⁶ Road safety approaches focus on road users, vehicles, roads and socio-economic factors.²⁵ Recently, there has been a gradual or steady improvement in road safety following the introduction of road safety approaches such as vision zero in Sweden and sustainable safety in the Netherlands.³⁶ The number of people killed in RTCs between 2000 and 2011 has fallen by almost 4.85%. There has also been a decrease in this period in the Netherlands and England.³⁶ Approaches vary widely in the way they are presented and such as road safety, transport or institutional contexts or for

Table 3

Global best practice countries in terms of road safety approaches, name/slogan, and key principles according to the scoping review.

Country	Current approach to road safety	Name of road safety/slogan	Key principles
Sweden	Vision zero	Safe traffic: vision zero on the move & "vision zero" from concept to action	<ul style="list-style-type: none"> - Traffic deaths and serious injuries are acknowledged to be preventable. - Human life and health are prioritized within all aspects of transportation systems. - Acknowledgement that human errors are inevitable, and transportation systems should be forgiving. - Safety work should focus on systems-level changes above influencing individual behavior.
Norway	Vision zero	Norwegian vision zero	<ul style="list-style-type: none"> - Speed is recognized and prioritized as the fundamental factor in crash severity. - An ethical stance. - Increased focus on the most serious RTIs, or their consequences. - Increased focus on monitoring the risk level in the road system, and, related to this, on the responsibility of authorities. - Emphasis on rationality and science as the basis for road safety policy.
Canada	System approach based on vision zero	Towards Zero: The Safest Roads in the World	<ul style="list-style-type: none"> - Ethics - Responsibility - Safety - Mechanisms for change
Netherland	System approach based on sustainable safety	Sustainable safety	<ul style="list-style-type: none"> - Functionality of road - Homogeneity of mass or speed and direction - Predictability of road course and road user behavior by recognizable road design - Forgivingness of environment and road users - State of awareness of road user
UK	System approach	Tomorrow's roads - safer for everyone& strategic framework for road safety	<ul style="list-style-type: none"> - Safer for children - Safer drivers - training and testing - Safer drivers - drink, drugs and drowsiness - Safer infrastructure - Safer speeds - Safer vehicles - Safer motorcycling - Safer pedestrians, cyclists and horse riders - Better enforcement - Promoting safer road use
US	System approach based on vision zero	Road safety strategies/strategic highway safety plans	<p>"Four E's"</p> <ul style="list-style-type: none"> - Engineering - Education - Enforcement - Emergency response
Australia	System approach based on safe system, vision zero and sustainable safety	National road safety strategy	<ul style="list-style-type: none"> - People make mistakes - Human physical frailty - A 'forgiving' road transport system - Building a national road safety culture - Data driven targets - Safe systems principles - Corporate responsibility - International collaboration
Poland	System approach based on vision zero	National road safety program	<ul style="list-style-type: none"> - System-based approach to road safety management, - Setting final and interim targets, - Road safety improvement based on "vision zero" and "Safe system" with strategic interventions comprising the basic pillars of safety: road safety management, safe road, safe vehicle, safe road users, post-crash response, - Focusing on the main road safety problems when identifying the priority interventions, - Integrated approach to the selection of specific measures based on the 3 E principle
Germany	Multiplicity approaches	National road safety program (risk: oriented approach)	<ul style="list-style-type: none"> - Formulation of national road safety strategy - Setting targets - Development of the road safety program - Monitoring of the road safety development in the country - Improvements in road infrastructure - Vehicle improvement - Improvement in road user education - Publicity campaigns - Enforcement of road traffic laws
Japan	System approach	The 10th traffic safety program white paper on traffic safety	<ul style="list-style-type: none"> - Maintenance of the road environment; - Dissemination and reinforcement of traffic safety messages; - Safe driving; - Vehicle safety; - Enforcement; - An improved rescue and emergency medical system; - Victim support, including an appropriate damage compensation system; - Research and development.

UK: United Kingdom, US: United States, RTI: road traffic injury.

implementation such as Sweden's vision zero.^{10,36} The vision zero scientific foundation shows that different road designs and vehicles, which improve human tolerance against external violence, can prevent 63% of deaths.⁹ A study done in Europe has shown that significant improvements have been made in the past decade in reducing the impact of road transport in terms of casualties. However, there is still a lot of work to be done to achieve vision zero on road safety by 2050. Also, despite efforts to coordinate between European countries, there are still significant differences in disaster management in the absence of a single structure, standards, data models and definitions, and there is no general agreement on the different stages of the process.⁴⁷

In general, there are different approaches to managing road safety in the world. Recently, the paradigm shift seems to have shifted to the safe system.^{25,48} This is a real paradigm shift, as it requires more than a purely political or administrative decision to simply switch to safe system. Building a safety system is a comprehensive, long-term exercise that requires broad support mobilization, as a safety system based on shared responsibility for road safety performance. Not just road users, but also all who involved in planning, building, maintaining, managing or using of road traffic need to endorse a responsibility for road safety performance, and act on it. Without strong, forward-looking leaders, nothing will change in road safety. At a political level, guiding a country or a city requires a change of political paradigm and public support.²⁵ In general, changing the paradigm of road safety issues in observing and responding to it requires a top leadership priority to make mental changes and guide stakeholders in advancing the road safety system. It also needs to create a sense of urgency to drive this change and raise awareness among all stakeholders that a safe system is the best approach to deliver improved road safety.²⁵ The real breakthrough in road safety management is a fundamental paradigm shift in how we look at road safety as well as in the strategies used to address it. This paradigm shifts from traditional road safety policies to an integrated perspective in which road traffic becomes a secure system. In general, the implementation and success of road safety approaches requires consideration of human rights and their safety. Accepting road safety as the right of all road users is only possible if all those associated with the road traffic system fulfill their obligations.¹

There are generally three types of approaches to road safety. The traditional approach, which includes a road-user and causal approach to road safety, focuses more on human errors and road users. Systemic approaches also include sustainable safety, the safe system, and the UN plan for decade of action. These approaches consider fatal RTI prevention as a system in which both road users and designer are responsible and each have different principles and goals in road safety. Another approach is the vision zero. Vision zero according to ethical philosophy and special attention to the value of human life is a more comprehensive approach than a systemic approach and a more comprehensive perspective on safety. Although each of these approaches has specific goals and principles, their ultimate goal is to reduce fatal RTCs. A systemic approach to road safety seems to be welcomed by most developed and developing countries, and a paradigm shift towards a safe system has taken place. Also, given the successful results of implementing vision zero in leading countries, most countries are trying to design and implement this approach. Finally, the choice and implementation of road safety prevention approaches varies according to the principles, priorities and infrastructure of each country. Proper modeling coupled with the principles of successful road safety practices can help to improve the safety and management of RTCs in different countries.

Funding

This study funded by Shahid Beheshti University of Medical Sciences, Tehran, Iran.

Ethical Statement

Not applicable.

Acknowledgments

We would like to thank all researchers who helped us in this study.

Declarations of Competing Interest

The authors declare no conflicts of interest.

References

- Mohan D. Traffic safety: rights and obligations. *Accid Anal Prev.* 2019;1: 159–163. <https://doi.org/10.1016/j.aap.2019.04.010>.
- World Health Organization. *Global Status Report on Road Safety 2018*. World Health Organization; 2018. https://www.who.int/violence_injury_prevention/road_safety_status/2018/en/.
- Khorasani-Zavareh D. System versus traditional approach in road traffic injury prevention. A call for action. *J Inj Violence Res.* 2011;3:61. <https://doi.org/10.5249/jivr.v3i2.128>.
- Tingvall C, Haworth N. *Vision Zero: An Ethical Approach to Safety and mobility. The 6th ITE International Conference Road Safety & Traffic Enforcement: Beyond 2000, Melbourne.* 1999.
- Armstrong R, Hall BJ, Doyle J, et al. "Scoping the scope" of a cochrane review. *J Public Health.* 2011;33:147–150. <https://doi.org/10.1093/pubmed/fdr015>.
- Peters MD, Godfrey CM, Khalil H, et al. Guidance for conducting systematic scoping reviews. *Int J Evid Base Healthc.* 2015;13:141–146. <https://doi.org/10.1097/XEB.0000000000000050>.
- Arksey H, O'Malley L. Scoping studies: towards a methodological framework. *Int J Soc Res Methodol.* 2005;8:19–32. <https://doi.org/10.1080/1364557032000119616>.
- Vaismoradi M, Turunen H, Bondas T. Content analysis and thematic analysis: implications for conducting a qualitative descriptive study. *Nurs Health Sci.* 2013;15:398–405. <https://doi.org/10.1111/nhs.12048>.
- Kristianssen AC, Andersson R, Belin MA, et al. Swedish Vision Zero policies for safety – a comparative policy content analysis. *Saf Sci.* 2018;103:260–269. <https://doi.org/10.1016/j.ssci.2017.11.005>.
- Larsson P, Dekker SWA, Tingvall C. The need for a systems theory approach to road safety. *Saf Sci.* 2010;48:1167–1174. <https://doi.org/10.1016/j.ssci.2009.10.006>.
- Peden M, Scurfield R, Sleet D, et al. *World Report on Road Traffic Injury Prevention*. World Health Organization Geneva; 2004. https://www.who.int/violence_injury_prevention/publications/road_traffic/world_report/en/.
- World Health Organization. *A 5-year Strategy for Road Traffic Injury Prevention*; 2001. http://whqlibdoc.who.int/hq/2001/WHO_NMH_VIP_01_03.pdf.
- Zein S, Navin F. Improving traffic safety: a new systems approach. *Transportation Res Rec J Transportation Res Board.* 2003;1830:1–9. <https://doi.org/10.3141/1830-01>.
- McIlroy RC, Plant KA, Hoque MS, et al. Who is responsible for global road safety? A cross-cultural comparison of Actor Maps. *Accid Anal Prev.* 2019;122: 8–18.
- Jamroz K. Review of road safety theories and models. *J Konbin.* 2008;1:89–108. <https://doi.org/10.2478/v10040-008-0012-z>.
- Kjellen UA, Albrechtsen E. *Prevention of Accidents and Unwanted Occurrences: Theory, Methods, and Tools in Safety Management*. CRC Press; 2017. <https://doi.org/10.1201/9781315120973>.
- Runyan CW. Using the Haddon matrix: introducing the third dimension. *Inj Prev.* 2015;21:126–130. <https://doi.org/10.1136/ip.4.4.302rep>.
- International Transport Forum. *Zero Road Deaths and Serious Injuries: Leading a Paradigm Shift to a Safe System*; 2016. <http://worldcat.org/isbn/9789282108055>.
- Jamroz K, Budzyński M, Romanowska A, et al. Experiences and challenges in fatality reduction on polish roads. *Sustainability.* 2019;11:959. <https://doi.org/10.3390/su11040959>.
- Weijermars W, Wegman F. Ten years of sustainable safety in The Netherlands: an assessment. *Transport Res Rec.* 2011;2213:1–8.
- Swedish National Road and Transport Research Institute. *Implementing the Safe System Approach to Road Safety: Some Examples of Infrastructure Related approaches. Road Safety on Four Continents: 16th International Conference*. Beijing, China. <http://worldcat.org/isbn/9789163729737>; 2013.

22. Woolley J, Stokes C, Turner B, et al. *Towards Safe System Infrastructure: A Compendium of Current Knowledge*. Sydney: Austroads; 2018.
23. Mooren L, Grzebieta R, Job RS. *Safe System—Comparisons of This Approach in Australia*. Melbourne, Victoria, Australia: Australasian College of Road Safety Conference; 2011.
24. Organization for Economic Cooperation and Development, International Transport Forum. Towards zero: ambitious road safety targets and the safe system Approach. *Source OECD Transport*. 2008;7:i245. <https://doi.org/10.1787/9789282101964-en>, 245.
25. Organization for Economic Cooperation and Development, International Transport Forum Zero Road Deaths and Serious Injuries: Leading a Paradigm Shift to a Safe System. <https://doi.org/10.1787/9789282108055-en>; 2016.
26. Australian Transport Council. *National Road Safety Strategy 2011–2020*; 2011: 112. <http://www.umcinc.com.au/uploads/Guard%20Rails/ROAD%20SAFETY%20STRATEGY%20FOR%202011%20-%202020.pdf>.
27. World Health Organization. *Global Plan for the Decade of Action for Road Safety, 2011–2020*. Geneva: World Health Organization; 2011. http://www.who.int/roadsafety/decade_of_action/plan/plan_english.pdf.
28. Johansson R. Vision Zero—Implementing a policy for traffic safety. *Saf Sci*. 2009;47:826–831. <https://doi.org/10.1016/j.ssci.2008.10.023>.
29. Belin MA, Tillgren P, Vedung E. Vision Zero—a road safety policy innovation. *Int J Inj Contr Saf Promot*. 2012;19(2):171–179. <https://doi.org/10.1080/17457300.2011.635213>.
30. Lindberg H. *How Dreams Can Become Reality Vision Zero 20 years..* AF: Maria Håkansson; 2017. https://www.afconsult.com/contentassets/8f0c19f4f7d24aa5bdbfd338128391ec/2017057-17_0194-rapport-nollvision-eng_lr.pdf.
31. Atkins D, Granhed M. *Vision Zero: Applying Road Safety to Avalanche safety*. *Int Snow Sci Work*. Alaska: Anchorage; 2012, 2012 <https://pdfs.semanticscholar.org/1018/41f6de0c7d92857d56a35b7f01e7405219f8.pdf>.
32. Fahlquist JN. Responsibility ascriptions and vision zero. *Accid Anal Prev*. 2006;38:1113–1118. <https://doi.org/10.1016/j.aap.2006.04.020>.
33. Khorasani-Zavareh D, Bigdeli M, Saadat S, et al. Kinetic energy management in road traffic injury prevention: a call for action. *J Inj Violence Res*. 2015;7:36–37. <https://doi.org/10.5249/jivr.v7i1.458>.
34. Statista Research Department. Number of road deaths in the Netherlands 2006–2018 [updated Jan 31, 2020] <https://www.statista.com/statistics/437942/number-of-road-deaths-in-netherlands/>.
35. European Commission. *Road safety statistics: what is behind the figures? 2019; 2018* [updated 4 April 2019] https://ec.europa.eu/commission/presscorner/api/files/document/print/en/memo_19_1990/MEMO_19_1990_EN.pdf.
36. Hughes B, Anund A, Falkmer T. System theory and safety models in Swedish, UK, Dutch and Australian road safety strategies. *Accid Anal Prev*. 2015;74: 271–278. <https://doi.org/10.1016/j.aap.2014.07.017>.
37. International Transport Forum. *Road Safety Annual Report*; 2018. https://www.itf-oecd.org/sites/default/files/docs/irtad-road-safety-annual-report-2018_2.pdf.
38. García de Soto B, Bumbacher A, Deublein M, et al. Predicting road traffic accidents using artificial neural network models. *Infrastructure Asset Manage*. 2018;5:132–144. <https://doi.org/10.1680/jinam.17.00028>.
39. Muir C, Johnston IR, Howard E. Evolution of a holistic systems approach to planning and managing road safety: the Victorian case study, 1970–2015. *Inj Prev*. 2018;24:i19–i24. <https://doi.org/10.1136/injuryprev-2017-042358>.
40. Johnston I. Beyond “best practice” road safety thinking and systems management—a case for culture change research. *Saf Sci*. 2010;48(9): 1175–1181. <https://doi.org/10.1016/j.ssci.2009.12.003>.
41. Cushing M, Hooshmand J, Pomares B, et al. Vision Zero in the United States versus Sweden: infrastructure improvement for cycling safety. *Am J Publ Health*. 2016;106:2178–2180. <https://doi.org/10.2105/AJPH.2016.303466>.
42. World Health Organization. *Global Status Report on Road Safety*; 2015. https://www.who.int/violence_injury_prevention/road_safety_status/2015/en/.
43. Vision Zero Philadelphia. *The Bicycle Coalition of Greater Philadelphia*; 2015. https://bicyclecoalition.org/wp-content/uploads/2014/01/VisionZero_Report_7.2_Web.pdf.
44. Zahabi SAH, Strauss J, Manaugh K, et al. Estimating potential effect of speed limits, built environment, and other factors on severity of pedestrian and cyclist injuries in crashes. *Transport Res Rec*. 2011;2247:81–90. <https://doi.org/10.3141/2247-10>.
45. Jamroz K, Michalski L, Żukowska J. Polish experience of implementing vision zero. *Curr Trauma Rep*. 2017;3:111–117. <https://doi.org/10.1007/s40719-017-0086-y>.
46. Sigbörsson H, Jónsson R, Einarsson S, et al. *Vision Zero and Traffic Safety*. Icelandic Road Administration; 2013. [http://www.vegagerdin.is/vefur2.nsf/8d461983982f539900256935003eac25/ea0d585acd3bf9e00257bc0003de468/\\$FILE/Nullsyn_fIsl_samantekt_ensk.pdf](http://www.vegagerdin.is/vefur2.nsf/8d461983982f539900256935003eac25/ea0d585acd3bf9e00257bc0003de468/$FILE/Nullsyn_fIsl_samantekt_ensk.pdf).
47. Steenbruggen J, Nijkamp P. Traffic Incident Management in Europe—Guide for Best Practices. In: *The 8th conference on geo-information for disaster management*. Best Pract; 2012:193–216.
48. Whitelegg J, Haq G. *Vision Zero: Adopting a Target of Zero for Road Traffic Fatalities and Serious Injuries*. The Stockholm Environment Institute (SEI); 2006. https://www.researchgate.net/profile/Gary-Haq/publication/263969088_Vision_Zero_Adopting_a_Target_of_Zero_for_Road_Traffic_Fatalities_and_Serious_Injuries/links/00b4953c7785d5548c000000/Vision-Zero-Adopting-a-Target-of-Zero-for-Road-Traffic-Fatalities-and-Serious-Injuries.pdf.